Associer arbres et cultures
When Trees and Crops Get Together

10e Congrès nord-américain d'agroforesterie, Québec, 2007
Opportunités économiques et bénéfices environnementaux de l'agroforesterie
Economic Opportunities and Environmental Benefits from Agroforestry
The 10th North American Agroforestry Conference, Québec City, 2007

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Actes du Congrès / Conference Proceedings

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The 10th North American Agroforestry Conference

Québec / Québec City, Canada
10-13 juin 2007 / June 10-13, 2007

Alain Olivier et Suzanne Campeau, Éd. / Eds

Canada

AFTA

Groupe interdisciplinaire de recherche en agroforesterie (GIRAF)

UNIVERSITÉ LAVAL

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ALAIN OLIVIER & SUZANNE CAMPEAU ÉD. / EDS

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AVANT-PROPOS

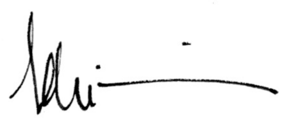
Il y a dix-huit ans, se tenait à Guelph, en Ontario, le 1er congrès nord-américain d'agroforesterie. L'objectif du Congrès était de donner aux personnes travaillant dans le domaine de l'agroforesterie tempérée en Amérique du Nord un forum leur permettant d'interagir et d'échanger des idées. À ce moment-là, comme le soulignaient les organisateurs, il n'existait tout simplement aucune tribune pour interagir avec les autres intervenants du domaine de l'agroforesterie sur les questions qui concernaient spécifiquement sa pratique en Amérique de Nord.

Le contexte a changé, et la valeur des arbres et des arbustes en territoire agricole, de même que celle des cultures dans les parcelles forestières, est aujourd'hui largement reconnue. De plus en plus de gens impliqués en agriculture, en foresterie et en aménagement du territoire voient l'agroforesterie comme un système durable d'utilisation des terres pouvant procurer des bénéfices variés aux exploitants agricoles, aux propriétaires de forêts privées et à la société en général.

En fait, il est maintenant bien connu que l'agroforesterie s'inscrit dans une perspective de développement durable alliant préservation de l'environnement et développement social et économique. Les techniques agroforestières contribuent à la conservation des sols et à la protection des cours d'eau, augmentent la biodiversité en milieu agricole et participent à la lutte contre les changements climatiques grâce à la séquestration de carbone. De plus, les productions agroforestières contribuent à diversifier les économies régionales, tout en valorisant les ressources et en créant de l'emploi dans des zones rurales qui en ont bien besoin à un moment où elles sont confrontées à d'importants changements au plan culturel, social, économique et environnemental, notamment en raison des difficultés rencontrées dans les secteurs agricole et forestier.

Au cours des deux dernières décennies, de nombreux efforts ont été investis dans des activités de recherche visant à accroître nos connaissances sur les fondements scientifiques des techniques agroforestières. Les bandes riveraines arborées, les haies brise-vent, les systèmes sylvopastoraux, les cultures intercalaires et les cultures sous couvert forestier ont bénéficié de ces nouvelles connaissances et ceux et celles qui pratiquent l'agroforesterie peuvent maintenant compter sur des sources d'information diversifiées concernant ces techniques.

Néanmoins, l'adoption à grande échelle des techniques agroforestières par les exploitants agricoles et les propriétaires de forêts privées est loin d'être acquise. En plus de fournir de l'information sur les bénéfices environnementaux et les opportunités économiques que peut offrir l'agroforesterie, le présent Congrès vise donc à encourager le développement et l'utilisation de pratiques de gestion durables du territoire rural axées sur l'intégration d'arbres au paysage, en stimulant l'échange d'expériences diverses reliées à l'adoption des techniques agroforestières, Durant les dernières années, on a pu observer un accroissement considérable de l'intérêt manifesté envers l'agroforesterie par les exploitants agricoles, les propriétaires de forêts privées et tous ceux et celles qui interviennent dans les domaines de l'agriculture, de la foresterie et de l'environnement en Amérique du Nord. De nombreux projets de développement et de transfert technologique sont actuellement menés dans toutes les régions du Canada et des États-Unis. En permettant l'échange de l'expertise accumulée dans le cadre de ces projets, ainsi que dans des projets similaires réalisés en Europe, en Australie et dans les zones tempérées de l'Amérique du Sud, le 10e congrès nord-américain d'agroforesterie qui se tient à Québec en 2007 offre une occasion privilégiée d'avoir une perspective renouvelée sur le rôle que peut jouer l'agroforesterie et sur les moyens de s'assurer qu'elle puisse atteindre les objectifs qu'on veut lui confier.



Alain Olivier

Président du Comité organisateur

FOREWORD

Eighteen years ago, the First North American Agroforestry Conference was held in Guelph, Ontario. The objective of the Conference was "to provide a forum within which people working in temperate North American agroforestry systems could interact and exchange ideas". At that time, as emphasized by the organizers, "there was simply no in-place format to interact with others working in agroforestry, dealing with the situation and problems here in North America".

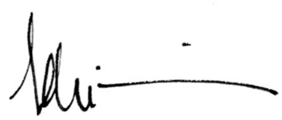
The context has changed, and the value of trees and shrubs in the agricultural landscape, as well as the value of crops in forest stands, are now highly recognized. More and more people involved in agriculture, forestry and land management see agroforestry as a sustainable land use system that can provide various benefits to the farmers, the private forest landowners and the society in general.

In fact, it is now well known that agroforestry can play a significant role in sustainable development by linking environmental preservation with social and economic development. Agroforestry techniques contribute to soil conservation and watercourse protection, increase biodiversity within the agricultural environment and help fight climate change through carbon sequestration. Furthermore, agroforestry products help to diversify regional economies while adding value to our resources and creating jobs in rural areas that really need them in a context where they are experiencing troublesome shifts in their cultural, social, economic and environmental systems due to the important changes encountered in the agriculture and forestry sectors.

During the last two decades, a lot of efforts have been invested in research activities aimed at increasing our knowledge of the scientific basis of agroforestry techniques. Riparian buffers with trees, windbreaks and shelterbelts, silvopastoral systems, intercropping systems, and forest farming systems have benefited from this increased knowledge and agroforestry practitioners can now rely on various sources of relevant information about these techniques.

Nevertheless, the adoption of agroforestry techniques by farmers and private forest landowners is still an area of concern. Thus, in addition to providing information on the environmental benefits as well as the economic opportunities of agroforestry, this present conference, through the exchange of experiences in the adoption of agroforestry techniques, aims at stimulating the development and the use of sustainable rural land management practices through the integration of trees into the landscape.

In the last years, an unbelievable increase in interest in agroforestry has been observed among farmers, private forest landowners and those who work in agriculture, forestry and the environment in North America. Various development projects are being conducted in all parts of Canada and the United States at this very moment. Thanks to the exchange of expertise developed in these projects and in similar projects conducted in Europe, Australia and temperate areas of South America, the Tenth North American Agroforestry Conference that is held in Québec in 2007 provides a fabulous opportunity to gain a renewed perspective on the role that agroforestry can play and on the means to ensure it attain the objectives set for it.



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SECTION 1

Haies brise-vent

Windbreaks and Shelterbelts

KEYNOTE SPEAKER

AN OVERVIEW OF SHELTERBELTS IN MODERN AGRICULTURE – UTILISATION DES BRISE-VENT DANS L'AGRICULTURE MODERNE

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Abstract: Shelterbelts are linear features of agro-ecosystems comprised of trees and/or shrubs that form part of an agriculture production system. This includes trees and/or shrubs planted or retained as a barrier to reduce wind speed and to protect crops, livestock, buildings, work areas and roads from wind and snow as well as enhance biodiversity. Shelterbelts can be located around farmsteads, adjacent to roadsides, on the boundaries or within fields or around livestock facilities. A well designed windbreak system can serve multiple purposes but usually includes both environmental and economic benefits. This paper reviews the role and benefits of planted and natural shelterbelts in modern agriculture production systems.

Key Words: Windbreak, biodiversity, erosion control, particulate capture, IPM.

Résumé : Les brise-vent sont des éléments linéaires d'un agroécosystème, composés d'arbres et/ou d'arbustes qui forment une partie d'un système de production agricole. Ils comprennent les arbres et/ou arbustes plantés ou conservés en guise de barrière pour réduire la vitesse du vent et protéger les cultures, le bétail, les édifices, les aires de travail et les routes du vent et de la neige, ainsi que pour améliorer la biodiversité. Les brise-vent peuvent être placés près des fermes, des routes, des limites des champs ou dans les champs ou près des installations destinées au bétail. Un système de brise-vent bien conçu peut avoir plusieurs utilités, mais comprend normalement des avantages environnementaux et économiques. Ce document étudie le rôle et les avantages des brise-vent plantés et naturels dans les systèmes de production agricole modernes.

Mots-clés : Brise-vent, biodiversité, contrôle de l'érosion.

INTRODUCTION

The agricultural production areas of Canada contribute significantly to world food production. This has not come without ecological costs. The fragmentation of the agro-ecosystem and habitat destruction associated with the clearing and cultivation of land for monoculture production have contributed to a loss of diversity. Over the past 50 years agriculture practices have intensified significantly. It has been reported by Sheehan et al. (1987) that over 60 percent of the pre-settlement wetlands and adjacent field boundaries have disappeared in the prairie provinces of Manitoba, Saskatchewan and Alberta. This has led to a decline in natural areas and associated habitats. Habitat loss and fragmentation are frequently identified as major causes of biodiversity loss (Spellerberg 1995). These losses can potentially alter ecological processes such as

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pollination, decomposition, nutrient cycling, seed dispersal and predation (Harrison and Braun 1999).

Shelterbelts and hedgerows are linear features of agro-ecosystems comprised of trees and/or shrubs that form part of an agriculture production system. This includes trees and/or shrubs planted or retained as a barrier to reduce wind speed and to protect crops, livestock, buildings, work areas and roads from wind and snow as well as enhance biodiversity. Shelterbelts can be located around farmsteads, adjacent to roadsides, on the boundaries or within fields or around livestock facilities. A well designed shelterbelt system serves multiple purposes but it usually includes both environmental benefits and economic benefits.

Drought and climatic severity have significantly contributed to land degradation in Canada. Historically tree shelterbelts have been used in a number of ways to reduce the vulnerability of agriculture land to climate induced land degradation. Over the years, shelterbelts have been primarily established to control the wind and in turn reduce evaporation, increase moisture conservation and reduce soil movement (Schroeder 1988). Although wind speed reduction is still a primary reason for shelterbelt planting, new technologies such as conservation tillage and extended cropping have provided alternative solutions to land degradation problems and reduced the need for shelterbelts for wind erosion control. However the importance of ecological benefits provided by shelterbelts are becoming widely recognized by land owners and managers. This paper reviews the multiple benefits associated with shelterbelts.

SHELTERBELT BENEFITS

Wind reduction

Many shelterbelt and hedgerow benefits accrue from the impact on windspeed. As the wind approaches the shelterbelt, some wind moves through the shelterbelt by the force of the wind. However, the resistance by the trees creates back pressure which causes some of the wind to be forced over the shelterbelt. The horizontal windspeed for a short distance upwind of the shelterbelt is less because of this back pressure. The air going through the shelterbelt moves more slowly and becomes turbulent because of the interference by the trees. The pressure in this «quiet zone» is less than that of the air moving over the shelterbelt so that the higher wind above the shelterbelt is gradually drawn back toward the ground. Shelterbelts give very good protection in the «quiet zone» which is normally a leeward distance extending as far as six to eight times the height of the shelterbelt. Scale models have been used to show that this is true regardless of the shelterbelt's height (Woodruff and Zingg 1952). Beyond the "quiet zone" there is a zone in which the windspeed gradually recovers to its unsheltered value. This distance, which McNaughton (1988) calls the «wake zone», can extend as far as 20h. In this zone, turbulence is less than in the «quiet zone» but horizontal windspeed is greater.

The porosity of the shelterbelt has an effect on the extent of the «quiet zone» and the «wake zone» and so does the angle at which the wind hits the shelterbelt. More dense shelterbelts are more resistant to the wind and reduce the windspeed more but the protected zone is less. The zone of protection for a shelterbelt is greatest when the wind is perpendicular.

Soil erosion

Field shelterbelts have been planted on the prairies since the early 1900's to protect the soil from wind erosion. However, it was not until later, that this protective function was well understood. Bagnold (1943) showed that the amount of soil movement due to wind erosion was approximately related to the cube of the wind velocity. Chepil (1945) found that there was a threshold windspeed which was required to initiate the movement of soil and that bouncing soil particles dislodged further particles so that there was an avalanching effect. Hagen (1976) used this relationship to show the reduction of wind erosion by shelterbelts and concluded that shelterbelt effects could extend as far as 30h. However, in the development of the Wind Erosion Equation (Woodruff and Siddoway 1965), this relationship was simplified so that shelterbelt protection of soil was assumed to be complete to a distance of 10h and that no shelterbelt effect extended beyond 10h. Shelterbelts can also trap significant amounts of soil blown from adjacent fields. Soil cesium was found to be much higher near a Saskatchewan shelterbelt than in the middle of the field (PFRA Shelterbelt Centre 1987).

By trapping snow, well-placed shelterbelts can direct spring meltwater into catchments or other areas where it does not present an erosion risk. Snowmelt in forest plantations is less because of the shading by the trees so that peak flows in streams may be reduced (Kort et al. 1998). Good snow cover in forested areas insulates the underlying soil and, since this soil generally has increased soil permeability, meltwater infiltration into the soil is often better (Kort et al. 1998). By reducing overland flow, erosion is reduced. This also true for summer storm events. Agronomists have long advocated the planting of shrubs along land contours in rolling countryside (van Eimern et al. 1964). When they form a physical barrier, they physically trap sediment from sheet erosion above the tree row and, over time can form terraces which further reduce erosion.

The snow trapped by shelterbelts on slopes can result in water erosion if it melts quickly in the spring or if the soil below it is wet and frozen. Each condition results in an increase of overland flow with an increase in water erosion if the soil is not adequately protected by grass or crop residue.

Microclimate and crop growth

The reduction of windspeed and the increase in turbulence near a shelterbelt has several effects on microclimate, thereby affecting the growth of plants in the protected zone. Especially in the «quiet zone», temperature and humidity are increased during the day while nighttime temperature is often a little less (Rosenberg 1976). The temperature increase, in the sheltered area, on a day of calm winds (less than 5 m/s) can be as much as 4^{o}C (Rosenberg 1974).

The improved microclimate in the sheltered zone improves crop growth rate and its Water Use Efficiency (Rosenberg 1974). Higher daytime temperature increases the rate of photosynthesis while lower nighttime temperature reduces the amount of loss caused by respiration. High humidity means that plants can open their stomata more in sheltered areas and use water more efficiently. According to Grace (1988), there is no evidence that the total water use by sheltered crops is less than used by unsheltered crops since plants open their stomata more and leaf surface areas are greater in sheltered areas. The increased turbulence in the «quiet zone» also transfers water vapour away from the crop canopy more efficiently than under conditions of laminar flow as would be experienced under open field conditions.

In addition, high windspeed causes direct damage to plants by causing leaves to rub against each other and to tear in the wind so that photosynthates must be used for the repair of wounds while damaged leaves lose water unnecessarily (Grace 1988). In high wind conditions, photosynthates are also needed to create structural strength in the plant. These effects cause the plant=s photosynthetic resources to be diverted away from growth.

Crops that depend on insects for pollination receive an additional benefit from wind protection since insects are more effective under protected conditions and warmer temperatures (Norton 1988). Crops such as sensitive fruits also have better quality in shelter because there is less bruising and less dehydration.

The differential effects of shelter on crops results in some crops being much more sensitive to the protection provided by shelterbelts than other crops (Kort 1988). Drought-adapted field crops such as cereal grains are not as responsive to shelter as leafy vegetable crops or fruiting crops, especially those that depend on insect pollination. Kort and Brandle (1991) incorporated these differences into an economic model, AWBECON@, in which crop yield benefits were translated into Net Present Value (NPV) over the life of a shelterbelt.

Effects on water

In winter, shelterbelts control the movement of snow. Field shelterbelts can provide extra moisture for the following year's crops. Most obviously, trapped snow may provide soil moisture when it melts in the spring. This is not necessarily the case though, since trapped snow above a wet, frozen soil will result in much of the water running off rather than infiltrating the soil (PFRA Shelterbelt Centre 1990). Snow meltwater that did infiltrate the soil in another Saskatchewan study was found to cause local groundwater "mounding" proving that snow trapping represents a significant source of groundwater recharge (PFRA Tree Nursery 1986).

When snow is allowed to move freely across open fields, much of the moisture is lost to the atmosphere through sublimation (Gurevich 1952; Tabler 1975; PFRA Shelterbelt Centre 1992). In a Saskatchewan study, the amount of snow on a landscape that was well protected by shelterbelts was 29% greater than the amount on nearby land that had no shelterbelts (PFRA Shelterbelt Centre 1989). The cause and mechanics of the reduction of snow erosion by shelterbelts is similar to that of soil erosion reduction. Prevention of snow erosion prevents significant loss of moisture.

Shelterbelts can effectively trap snow for harvesting water. Jairell and Schmidt (1990) showed that a well-placed snow fence would trap over five times as much snow in a pasture dugout in Wyoming as a dugout without a snow fence. By trapping snow where it is needed, shelterbelts can provide extra water for cattle or domestic uses, for groundwater recharge or for replenishing water supplies in natural riparian areas.

It was established in the earlier section on "crop growth", that shelterbelts do not significantly reduce the amount of water transpired by crops. However, shelterbelt trees generally use more water in the summer than the same area of crop so that groundwater can be diminished and crop yields in the root zone of the trees are less.

When shelterbelts are used to protect open water bodies such as streams and dugouts, the amount of water used by the trees can be offset by the reduced evaporation from the open water body. Despite the fact that turbulence and air temperature are greater in sheltered areas, Rosenberg (1974) showed that water vapour pressure is also higher and evaporation is decreased by more than 50% in well-sheltered sites. This has implications for the management of riparian zones in which it is important to maintain water levels.

Benefits of shelterbelts for biodiversity and integrated pest management

Biodiversity, including plants (de Blois et al. 2002), songbirds (Jobin et al. 2001; Mah 2003), insects (Ouin and Burel 2002), is protected and in most cases enhanced by agroforestry practices. The agroforestry system's characteristics (age, species, connectivity, location, etc) are expected to be well-linked with many aspects of biodiversity. For example, birds nest, perch and feed on specific tree or shrub species.

Numerous studies from a diversity of agricultural systems have demonstrated the link between shelterbelts, hedgerows or riparian buffers with greater biodiversity (Varchola and Dunn 2001). Research studies have also found that floral composition (Jobin et al. 2001), spatial arrangement (Croxton et al. 2002) and number of linear elements (Dover et al. 2000) affect species-specific abundance and diversity within these features as well as the broader agricultural landscape. Connectivity of shelterbelt elements with natural habitats (eg. woodlands) provides corridors for the movement of species among habitat fragments (Croxton et al. 2002).

Shelterbelts and hedgerows have been proven important habitats from which beneficial insect species move onto surrounding cropland providing full or partial control of pest species (Baute et al. 2002). In general, there are a greater number of arthropod species inhabiting field margins as compared to the cultivated fields (Lewis 1969; Doane 1981). This difference was attributed to a greater availability of microhabitats in the field margin, making them important in the source-sink dynamics of arthropod populations inhabiting the agro-ecosystem (Fry 1994). Since field boundary habitats represent an interface between farm practices and the ecosystem, it is desirable that the agriculture industry develop practices that enhance, rather than replace, these natural processes (Leaver 1994).

Studies have demonstrated that fields with a high diversity of plants tend to also have a higher diversity of parasitoids and predators because (1) pollen and nectar from weeds serve as supplementary food sources and (2) they are often host plants for alternative prey (Altieri 1994). So it is understood that conservation of biodiversity (i.e. especially natural enemies) through habitat management, plant structure, and diversity can positively impact on our ability to manage the pest species. Management strategies for control of insect pests have broadened into the concept of ecological pest management and are no longer focused only on the pest species complex (Pimentel et al. 1992). Field boundary areas including shelterbelts and hedgerows harbour many arthropods, including insects, spiders and mites, which affect crop yields and soil health because they include both pest and beneficial species (Powell 1986). Sustainable management strategies, crop loss prevention and maintenance of soil health are central to our capacity to maintain the biological productivity of agricultural systems.

French and Elliot (1999) observed that natural treed habitats surrounding wheat fields served as permanent habitats for predatory ground beetles, many of which moved into the wheat and fed on economic pests of wheat. Baute et al. (2002) identified specific insect pests of field crops in Ontario that also use shelterbelts at field margins as part of their life history strategy. *Lygus* plant bug species (Hemiptera: Miridae) overwinter as adults in shelterbelts and then re-invade adjacent agricultural crops (eg. strawberries, alfalfa and canola) in the spring (Broadbent et al. 2002) and it is suspected that beneficial parasitoids of *Lygus* also build up populations in these field margin habitats.

On the Canadian prairies, wildlife habitat has decreased because of farming activities. Field and farmyard shelterbelts provide significant benefits for wildlife, mainly for birds because of requirements for nesting habitat, food sources, and protection in both summer and winter that are readily provided by shelterbelts (Mah 2003). Abandoned farmstead shelterbelts often retain an array of fruiting species, coniferous trees and deciduous trees to create a complex habitat in which many different species can thrive.

Particulate capture

For intensive livestock operations, shelterbelts can be effective windbreaks and visual screens. Theobold and Milburn (2002) suggested that the planting of trees around farm buildings may be an effective and low-cost method to recapture gaseous ammonia near the farm and reduce long-range atmospheric transport. Asman (2005) discussed the present knowledge on the potential that shelterbelts have to remove ammonia, gaseous pesticides and odour compounds, and particles of different sizes (e.g. pesticide sprays, odour compounds attached to particles etc.) originating from agricultural activities. Asman (2005) concluded that entrapment by the shelterbelt increases with:

- The height of the shelterbelt;
- Stability of the atmosphere;
- Wind speed (for particles);
- Particle size (for particles with diameter > 1×10^{-7} m).

And that entrapment by the shelterbelt decreases with:

- Source height;
- Distance from the source to the shelterbelt (point source) or length of the field upwind of the shelterbelt (area source);

- Optical porosity of the shelterbelt. The smaller the porosity the larger fraction of the air flow approaching the shelterbelt will be forced to go through the shelterbelt;

- Typical length of the vegetation elements (leaves, needles) in the shelterbelt. Coniferous trees that have small needles entrap more efficiently than deciduous trees that have larger leaves;

- Wind speed (for gases);

- Surface resistance and molecular mass (gases).

A thorough review of odour reduction benefits of shelterbelts was completed by Tyndall and Colletti (2000). Odours from such operations are considered a problem because they cause mental and physical health concerns for humans and animals, economic results for real estate values, tourism and recreation activities, and stress relationships within communities. They reported that most odour complaints resulted from hog operations and land application of the effluent. In hog operations the liquid manure decomposes anaerobically, resulting in increased odour-related problems. They cited a study that intense and persistent odours travel as aerosols and concluded that shelterbelts can reduce the spread of odours mainly by causing their dilution in the atmosphere or by intercepting or causing the deposition of the particles. Increased dilution effects would be mainly due to the increased turbulence leeward of the shelterbelts and lower windspeed over storage lagoons would reduce the rate at which the aerosols entered the airstream.

Windspeed reductions leeward of shelterbelts were predicted by modeling to increase deposition of aerosols of up to 56%. Conifers were suggested as a possibly effective way of physically intercepting aerosols on their leaf surfaces and it was pointed out that, for evergreen conifers, the benefits would continue year-round. However, in western Canada, odours in winter are not considered as serious as in summertime. Tyndall and Colletti (2000) also suggested that some volatile organic compounds could be directly adsorbed on the leaf surface or metabolized on entering the leaves through the stomata. Whether these effects are enough to reduce odours to a satisfactory level was not established since aerosol reduction has not been accurately quantified.

Vegetative barriers such as shelterbelts has been shown to be effective at mitigating droplet spray drift in several studies and reviews (Hewitt 2001; Ucar and Hall 2001; Richardson et al. 2002) by modifying wind fields and intercepting spray. The documented magnitude of the spray drift deposit reduction in these studies ranged from 50 to greater than 95 percent, dependent on a number of variables that include distance from the source, vegetation height, foliage type, porosity and orientation relative to wind direction and wind speed (Parkin et al. 2003). The parameters that govern effective mitigation by the vegetation have not been well defined, but are thought to revolve around target size, droplet size spectrum, vegetation porosity, collection efficiency and shelterbelt height (Davis et al. 1994; Hewitt 2001).

Farmyard protection

Shelterbelts for the protection of farmyards are important for farm families. In the winter, their functions are to control snow and to protect the farm buildings from cold winds. In the summer they protect against hot, dry winds. This gives the farm family a sense of home as the shelterbelt provides a yard in which they can relax outdoors or grow a garden.

In a study done at Indian Head, Saskatchewan (Moyer 1990), it was found that a good shelterbelt could reduce the use of home-heating fuel by as much as 25%. Moyer showed that heat loss from insulated test trailers proceeded by infiltration (physical movement of air from the inside to the outside) and through conduction (transmission of heat through walls, windows and roof). Wind protection reduced the heat loss through infiltration but not through conduction. The rate of conduction was controlled by the insulative value of the surface involved. For well-sealed, modern buildings, the infiltrative heat loss would be relatively less and the savings in heat cost would be expected to decrease accordingly.

Shelterbelts for carbon sequestration

Plants, through photosynthesis, convert carbon dioxide into oxygen by fixing the carbon into sugars and then into organic molecules such as cellulose. It is therefore quite easy to know the amount of carbon dioxide removed from the atmosphere by measuring the amount of carbon existing in the trees. By knowing the growth rate of different shelterbelt species under different climatic and soil conditions, the Shelterbelt Centre has been able to calculate the amount of carbon dioxide removed from the atmosphere by the shelterbelt program (Kort and Turnock 1999; Kort and Turnock 2001). Results from research by Kort and Turnock, (1999; 2001) were used to calculate that the trees sent out under the existing shelterbelt program (assuming 5.3 million trees and shrubs per year) since 1990 would sequester 1.7 Mt (CO_2 equivalent) aboveground, in the first Kyoto verification period (2008-2012). Although this would not play a large role in meeting Canada's Kyoto commitments, it is important to recognize the environmental role the shelterbelts play in this capacity.

CONCLUSION

Cultivation of arable land in Canada has resulted in much-altered ecosystems in all regions of the country. On the prairies for example, only small remnants of native short-grass prairie remain and field boundary habitats, such as shelterbelts, provide corridors between these remnant natural areas. While the impacts of shelterbelts on erosion control and crop productivity have been well researched, the ecological and environmental benefits of shelterbelts in promoting sustainable agriculture and ecological diversity in intensely cropped agricultural landscapes in Canada are not as well documented. It is likely, however, that that these features offer a diversified habitat and influence the microclimate. Properly designed planted shelterbelts and/or retention of natural hedgerows can provide a valuable interface between farm practices and natural ecosystems and have significant potential to increase biodiversity by creating and/or maintaining habitat for a wide diversity of organisms as well as support other ecological functions that improve air quality, protect land and water.

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A PROTOCOL FOR SHELTERBELT ASSESSMENT RELATED TO ITS FUNCTION

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Abstract: Shelterbelts throughout Canada have many different structures and designs. Since the multiple benefits of shelterbelts depend on their structural characteristics, a protocol was created for measuring the characteristics of a shelterbelt which are related to environmental benefits. From 2003 to 2006, the protocol was developed, tested and refined in numerous shelterbelts in Saskatchewan, Ontario, New Brunswick and Prince Edward Island. Measurements included the height, diameter and density of individual trees and shrubs as well as measures of overall shelterbelt height, width, length and porosity. These measures were considered to be independent variables that would permit the estimation of shelterbelt benefits for wind reduction, carbon sequestration, and water and nutrient uptake by the shelterbelt. Herbaceous vegetation was also sampled as an indicator of biodiversity. The data collected allowed general conclusions to be made about the impact of shelterbelt structure. The protocol is relatively simple to use and should be a useful tool for shelterbelt assessment. This information collected under the study will result in the development of shelterbelt categories useful in modeling shelterbelt environmental benefits.

Résumé : Les brise-vent dans l'ensemble du Canada ont beaucoup de différentes structures et conceptions. Puisque les avantages multiples des brise-vent dépendent de leurs caractéristiques structurales, un protocole a été créé pour mesurer les caractéristiques d'un brise-vent qui sont liées aux avantages environnementaux. De 2003 à 2006, le protocole a été développé, examiné et raffiné dans de nombreux brise-vent en Saskatchewan, Ontario, au Nouveau-Brunswick et l'île du Prince Édouard. Les mesures ont inclus la taille, le diamètre et la densité de différents arbres et arbustes aussi bien que des mesures de taille, de largeur, de longueur et de porosité globales du brise-vent. Ces mesures ont été considérées comme variables indépendantes qui permettraient l'évaluation des avantages des brise-vent pour la réduction de vent, la séquestration de carbone, et la prise de l'eau et d'éléments nutritifs par les brise-vent. La végétation herbacée a été également prélevée comme indicateur de biodiversité. Les données ont rassemblé des conclusions générales permises à faire au sujet de l'impact de la structure des brise-vent. Le protocole est relativement simple à employer et devrait être utile pour l'évaluation des brise-vent. Cette information rassemblée sous l'étude aura comme conséquence le développement des catégories des brise-vent utiles en modelant les avantages environnementaux des brise-vent.

INTRODUCTION

The development of a shelterbelt assessment protocol was undertaken to evaluate shelterbelt structure and design in relation to the environmental protection benefits that the shelterbelt was expected to perform. Shelterbelts and other agroforestry practices provide multiple environmental functions on the agricultural landscape, including conservation of biodiversity and protection of

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air, water and soil. They are considered to be Beneficial Management Practices (BMPs), which are supported through various environmental programs such as the Government of Canada's Greencover program. They reduce wind, trap snow, provide habitat, prevent erosion and serve as field boundaries as well as performing other functions. Although many trees and shrubs are planted, natural shelterbelts also perform the same environmental functions and so were also of interest in this project. These natural shelterbelts may be remnants of cleared forests or naturally regenerated on uncultivated strips.

Design recommendations for planted shelterbelts are based on knowledge of tree and shrub characteristics but, in Canada, the final structure of mature shelterbelts has not been generally assessed in relation to their designs or the functions that they were designed to perform, so an assessment of shelterbelt condition can provide important information for design improvement. The ability to evaluate shelterbelt characteristics and structure also provides us with the ability to collect data that could be used in agroforestry modeling (Bank et al. 2007).

The need to have a standard protocol for hedgerow assessment in the United Kingdom was recognized and resulted in the development of the Hedgerow Evaluation and Grading System in 1992 (Clements and Tofts 1992), followed by a hedgerow survey in Wales (Rich et al. 2000) and a standard hedgerow survey manual for the UK in 2002 (Bickmore 2002). In the UK, the impetus for this was the concern for the conservation of biodiversity and the recognition that hedgerows represented important habitat for biodiversity at many levels – plants, insects, birds, mammals and other organisms (Bickmore 2002). Other vegetation surveys have also been reported in which similar sampling strategies have been used (Winward 2000).

Biomass in shelterbelts affects the greenhouse gas (GHG) balance as woody tissue is almost 50% carbon by weight (Kort and Turnock 1999). Shelterbelt value as a carbon sink can be determined for prairie shelterbelts because the rate of growth of most prairie tree species and their dependence on region, site and climatic factors are known (Kort and Turnock 1999; 2000; Schroeder 2002). Growth rates for many species are also known in other regions of Canada. For tree species, the most usual and simplest measurements are diameter at breast height (DBH) and height. Equations for biomass usually depend on these two factors (Kort and Turnock 1999). Shrubs also contain significant amounts of biomass but shrub height and crown diameter are more practical indicators of biomass since DBH cannot be measured where there are many stems (Kort and Turnock 1999). Other functions such as nutrient uptake and wind reduction also depend on growth rates so that height, DBH and, for shrubs, crown width, are important measures of shelterbelt function.

As a windbreak, a shelterbelt's function depends on its porosity (Borrelli et al. 1989). This affects its ability to reduce wind erosion (Skidmore and Hagen 1977), trap particulates (Tyndall and Colletti 2000), trap snow (Scholten 1988) and provide shelter for crops (Kort 1988).

Shelterbelt width and species composition affect the degree to which it can provide habitat for plants (de Blois et al. 2002), songbirds (Jobin et al. 2001; Mah 2002), insects (Ouin and Burel 2002) and mammals. Shelterbelt width is an important factor in herbaceous biodiversity since native forest understory plants were not found in single-row shelterbelts (de Blois et al. 2002). Forest interior bird species also require wider shelterbelts (Jobin et al. 2001) and greater width and plant species diversity should increase the abundance of natural pollinators (Javorek, 2007, pers. comm.). Birds nest, perch and feed on specific tree or shrub species (Mah 2002).

Direct measurements of herbaceous biodiversity in the shelterbelts were considered to be important because Duelli and Obrist (1998) found that plant diversity is a good indicator of biodiversity since it was well-correlated with diversity of fauna and other organisms. Compared to sampling for the diversity of fauna, measurement of herbaceous species diversity is easy and cost-effective.

Agroforestry buffers can also reduce water erosion by trapping sediment, especially when protecting riparian sites (Dosskey 2001). Properly designed agroforestry systems can reduce streambank erosion or gully formation.

The sampling protocol developed thus sought to take into account those features of shelterbelts that influence the benefits that they have on the landscape.

METHODOLOGY

The procedure for shelterbelt assessment was developed to be, at once, relatively simple and fast to perform, while being comprehensive and thorough. The main components of the protocol are:

1) Basic hedgerow information. This includes contact information for the landowner or land manager, date of the assessment, site identification number, shelterbelt age, and the orientation and main function of the shelterbelt. For planted shelterbelts, age can be determined through planting records or by asking the landowner. For natural shelterbelts, age can be determined by extracting cores at breast height from the stems of dominant trees and counting their rings on-site, if possible, or storing them and determining them later.

2) Three 30 m long sub-samples of the shelterbelt, designated A, B and C, are selected so that sub-samples A and C are near the ends of the shelterbelt, and sub-sample B is near the middle. The exact location of each sub-sample is chosen randomly, except if it corresponds with a large gap in the shelterbelt. Temporary flags are placed in the ground to mark each end of each sub-sample and the GPS coordinates of all sub-samples are stored.

3) The shelterbelt width is measured for each sub-sample.

4) The tree and shrub spacing and density is determined in each sub-sample and the heights and diameters of individual trees and shrubs are measured including up to ten individuals of each species in each sub-sample.

5) For shelterbelts that have fallen woody debris, the woody debris is inventoried by measuring the diameter of logs and branches that intersect with transects that are perpendicular to the shelterbelts.

6) Herbaceous vegetation is assessed, both in terms of total number of species and species dominance. For species number, a walk-through is done for each entire sub-sample. For dominance, percent cover ratings are estimated for species occurring within Daubenmire 0.1 m^2 quadrats. A metal frame of 0.5 m X 0.2 m is thrown down randomly three times on each edge of the hedgerow and three times in the middle.

7) Digital photos are taken perpendicular to each sub-sample for later porosity assessment and upwards through the canopy for an estimate of canopy cover.

8) Two composite soil samples, one for 0-30 cm depth and one for 30-60 cm depth are collected in each sub-sample for later analysis of soil texture salinity and acidity.

9) The slope of the terrain is measured parallel and perpendicular to the shelterbelt.

The survey protocol was used in 2006 in four regions of Canada – Saskatchewan, southern Ontario, New Brunswick's Acadian Peninsula and Prince Edward Island. Surveyors worked in pairs and developed efficient division of labour after a little experience. There was little equipment required for the measurements. A laser hypsometer (Haglof Inc. Sweden) was used to measure the length and width of each sub-sample, to measure tree heights, and to determine the slopes. A hand-held GPS unit was used to determine the location of each shelterbelt and the three sub-samples within each shelterbelt. A calliper was used to determine stem diameters. A Daubenmire frame of 20 cm X 50 cm was made by bending light rebar so that it had three sides only and was open at one end. This could be thrown for random herbaceous sampling. A JMC Backsaver soil sampler (Clements Associates Inc. Newton, IA) was used to collect soil samples. A 5-megapixel digital camera was used to take pictures of the shelterbelts and a 2.44 m surveyor's rod was used to provide a scale in each picture. All data were collected on paper in the field and were entered into a single database in the office.

The following three tables (Table 1, Table 2 and Table 3) show the datasheets that were used in the field for data collection. Completed data were entered into a database for further analysis and summary. A user manual was developed which explained the terms in more detail.

A visual porosity scale was devised as shown on the left side of Fig. 1. The scale was constructed from a variety of photos that were converted into black-and-white images and for which the exact ratio of black to white pixels was determined by computer analysis. The porosity photos for each sub-sample in each shelterbelt were attached to the appropriate database records so that rapid porosity assessment and direct data entry into the database could be done for the bottom third, middle third and upper third of each shelterbelt sub-sample.

The assessment protocol was improved and modified over three years from 2004 to 2006. In 2004, 45 shelterbelts were assessed in Saskatchewan and, in 2005, 48 Saskatchewan shelterbelts were assessed. In 2006, assessments were done on 45 shelterbelts in New Brunswick, 46 shelterbelts in southern Ontario and 40 shelterbelts on Prince Edward Island. The amount of time required for the field evaluation of each shelterbelt ranged from one hour for single row, single species shelterbelts to over two hours for diverse, wide, natural shelterbelts.

Table 1: Datasheet for basic site and shelterbelt/hedgerow data.

1.Basic

101 Comments:

102 Date ______ 103 ID# ______ 104 Sampler ______

105 Landowner or contact name ______

106 Landowner or contact phone ______

107 Landowner or contact address ______

Location

108 GPS Coordinates ______

108 Local coordinates (i.e legal land discription) ______

109 Vegetation type* ______

110 Agroforestry type** ______ 111 Orientation ______

112 Age ______

(use more than one if needed)

Agroforestry Dimensions

113 Length (m) ______

114 Area (m^2) ______

115 Configuration*** ______

Sample	116 Width (m)	117 Width over crops (m)	118 Snags (Dominant or CoDominant)	119 Fallen dead (downwood) (>4 cm)
A				
B				
C				

120 Gaps		
Sample	Length	Width

* Veg type options

NW - Natural woody
PW - Planted woody

** Agroforestry type options

AC - Alley crop
CF - Crop (field)
FB - Field boundary
FY - Farmyard
IC - Intercrop
LBN-livestock -Barns
LO-livestock -Outdoors
LW-Lane way
PF - Pasture (field)
RB - Riparian buffer
RS - Roadside

** Configuration options

AA - Area agroforestry
IR - In rows
LB - Linear buffer

Table 2: Datasheet for tree measurement.

2. Trees Datasheet

Sample the trees in their rows from North to South or West to East, row one being North or West.
For trees not in rows, like natural shelterbelts, count trees over 10 cm diameter for each species

201 Sample		202 length (30m)				202 length (30m)				202 length (30m)				202 length (30m)		
203 Row (if applic.)																
204 Species																
205 Crown width of row (m)																
206 Trees per sample																
	207 Diameter (cm)	208 Height (m)	209 Age (yrs) (if different from planting age) In natural shelterbelts, core 2 dominant trees per species	210 % live crown	207 Diameter (cm)	208 Height (m)	209 Age (yrs) (if different from planting age) In natural shelterbelts, core 2 dominant trees per species	210 % live crown	207 Diameter (cm)	208 Height (m)	209 Age (yrs) (if different from planting age) In natural shelterbelts, core 2 dominant trees per species	210 % live crown	207 Diameter (cm)	208 Height (m)	209 Age (yrs) (if different from planting age) In natural shelterbelts, core 2 dominant trees per species	210 % live crown
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
211 parallel slope:																
212 perpendicular slope:																
	213 Comments:				213 Comments:				213 Comments:				213 Comments:			

Table 3: Datasheet for herbaceous groundcover survey.

3. Herbaceous plants datasheet (Because there can be multiple layers of foliage, the total can be greater than 100%.)

* Includes woody groundcover up to 1.3 m in height and includes vines

Species names can be common names on datasheet but need to be converted to Latin names

Quadrat

301. Sample___________	1	2	3	4	5	6	7	8	9
302.Location(N,S,E,W or M)									
303. Cover Category	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover
304. Bare Ground									
305. Litter									
306. Species:									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
Other species from sample walk-through									

RESULTS AND DISCUSSION

The protocol was tested and used for shelterbelt assessment in four different regions of Canada and minor modifications were made. In total 224 shelterbelts were assessed. These shelterbelts were categorized into eight shelterbelt types (Table 4).

The use of the protocol for herbaceous biodiversity showed some interesting relationships and trends. The diversity of the herbaceous plants growing in the shelterbelts was greater in the natural shelterbelts than in the planted ones and this was mostly attributable to a greater incidence of native herbaceous species in the natural shelterbelts (Fig. 2 and Fig. 3). This was consistently seen in all regions. Equal numbers of non-native species were found in both types of shelterbelts and there was no difference in the quadrats along the edges of the shelterbelts, those that adjoined the cultivated fields. Instead, the differences were mainly in the quadrats in the interiors of the shelterbelts. Similar results were found in Quebec shelterbelts south of Montreal by Boutin et al. (2002). Although Fig. 2 and Fig. 3 show species number on a per quadrat basis, de Blois et al (2002) found, in Quebec, that greater shelterbelt width increased the number of species found.

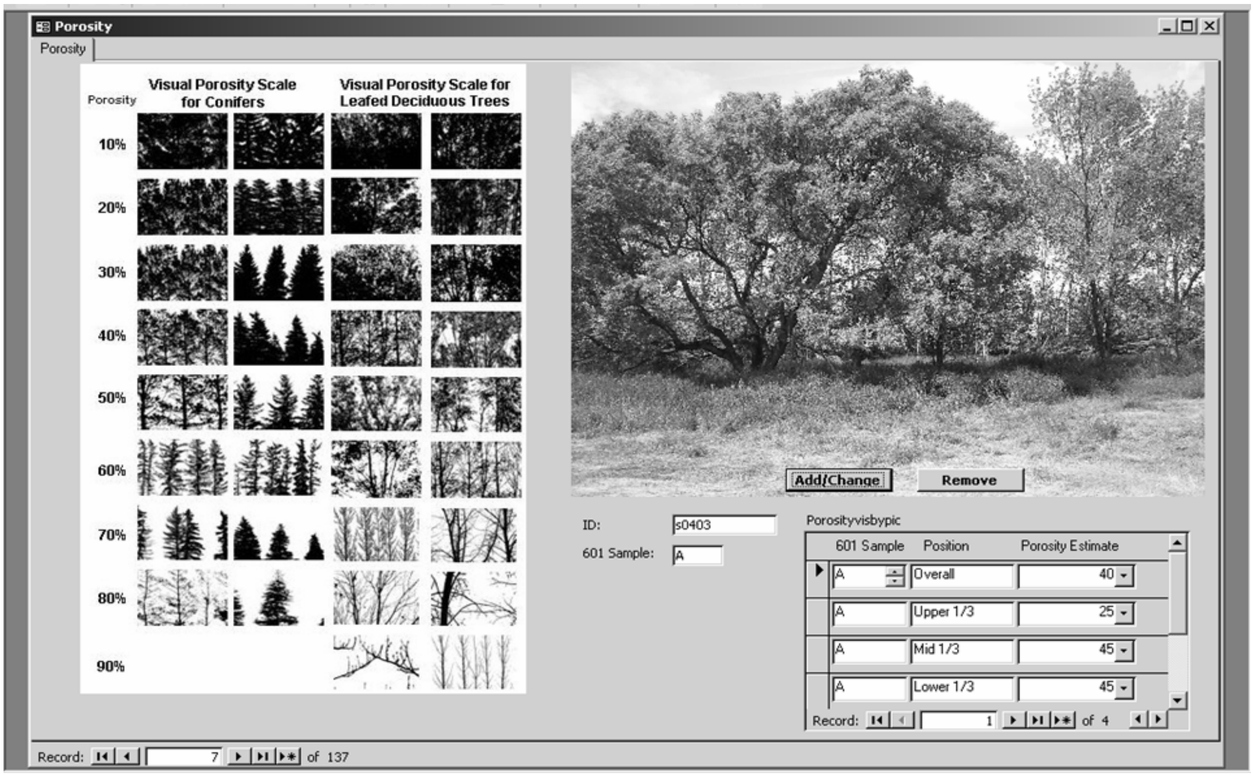

Fig. 1: Database procedure for assessment of shelterbelt visual porosity.

Shelterbelt widths were also greater for the natural shelterbelts in all regions (Fig. 4). Saskatchewan shelterbelts were wider than in the other regions, perhaps reflecting the number of multi-row farmyard shelterbelts that were included in the survey. For field shelterbelts, this was also likely because of the predominance of wider deciduous tree and shrub species compared to planted shelterbelts in the other regions, which were mainly composed of narrow conifers such eastern white cedar. In New Brunswick, the shelterbelts were narrow and short (Fig. 5), whether they were natural or planted shelterbelts. This was likely because the shelterbelts sampled were in the blueberry-growing area of the Acadian Peninsula where the soil was acidic and shallow. In these shelterbelts, no soil samples could be collected at the 30-60 cm depth..

The average height of the shelterbelts that were sampled was greatest in Ontario, especially for the natural shelterbelts which were composed of tall deciduous species like sugar maple (*Acer saccharum*).

Table 4. Datasheet for inventorying woody debris.

Woody Debris

For those shelterbelts that have dead woody debris, this should be inventoried as it can provide habitat for many species and may represent an important carbon reservoir. Create a transect line perpendicular to the shelterbelt at each end of each sub-sample (A, B and C) and measure the diameter (cm) of each dead log that intersect the line.

Sub-sample	A		B		C	
Transect	1	2	1	2	1	2
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Table 5: Number of shelterbelts/hedgerows surveyed by type in four regions.

	Agroforestry Type								
Region	Conifer	Conifer Decid.	Conifer Decid. Shrub	Conifer Shrub	Decid.	Decid. Shrub	Natural	Shrub	Total
NB	17	9					19		45
ON	29	4	1	2	2	1	7		46
SK	1	6	19		16	33	9	9	93
PEI	7	7	5	1	1	1	18		40
Total	54	26	25	3	19	35	53	9	224

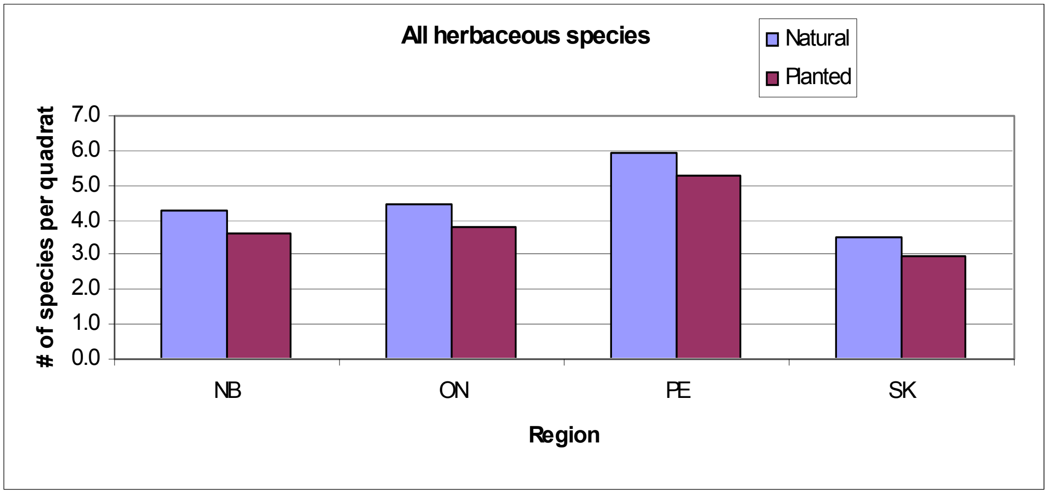

Fig. 2: Average number of herbaceous species found in 0.1 m^2 quadrats in four regions.[1]

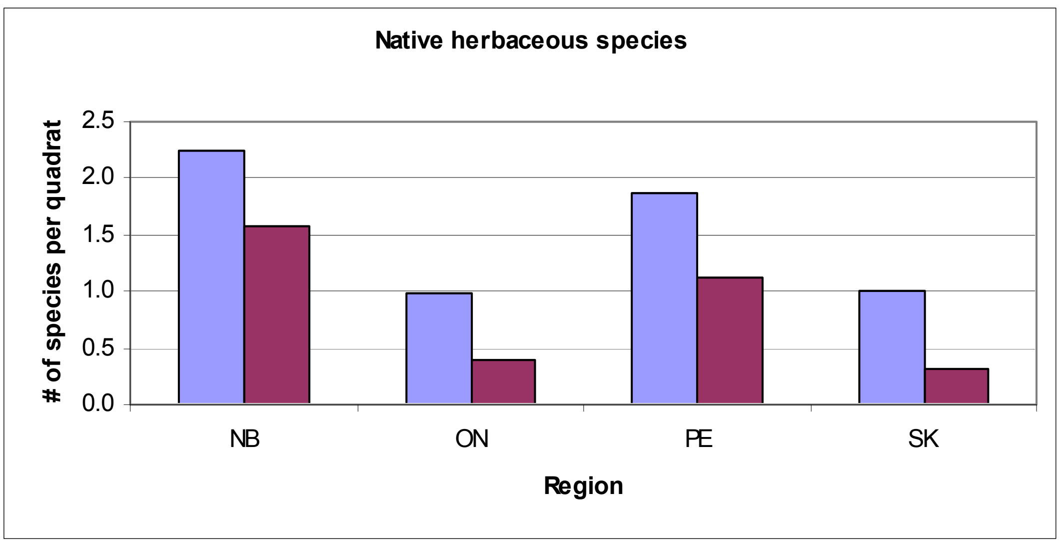

Fig. 3: Average number of native herbaceous species found in 0.1 m^2 quadrats in four regions.[1]

[1] This figure is in colour in the electronic version of the Proceedings (CD)

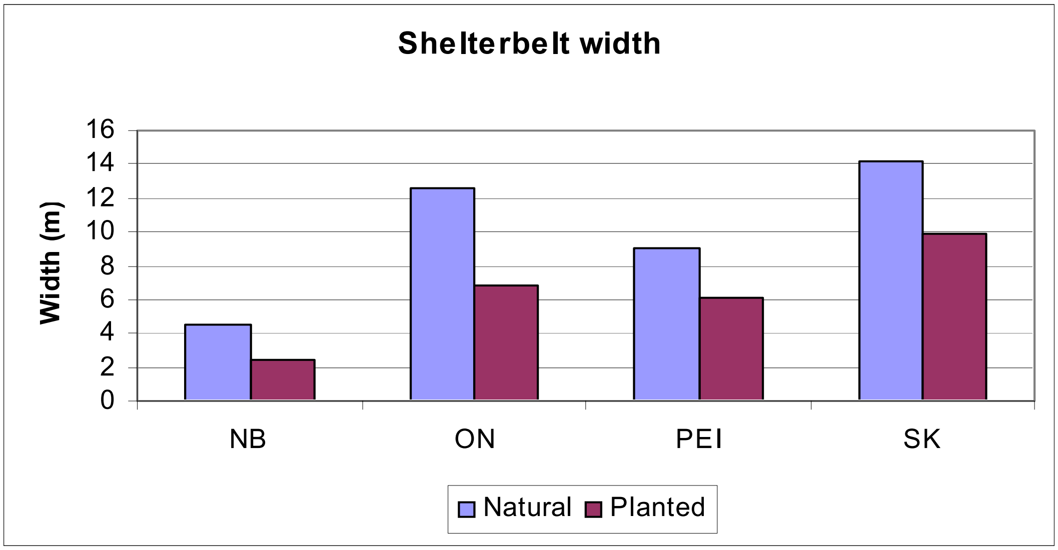

Fig. 4: Widths of representative shelterbelts/hedgerows in four regions of Canada.[1]

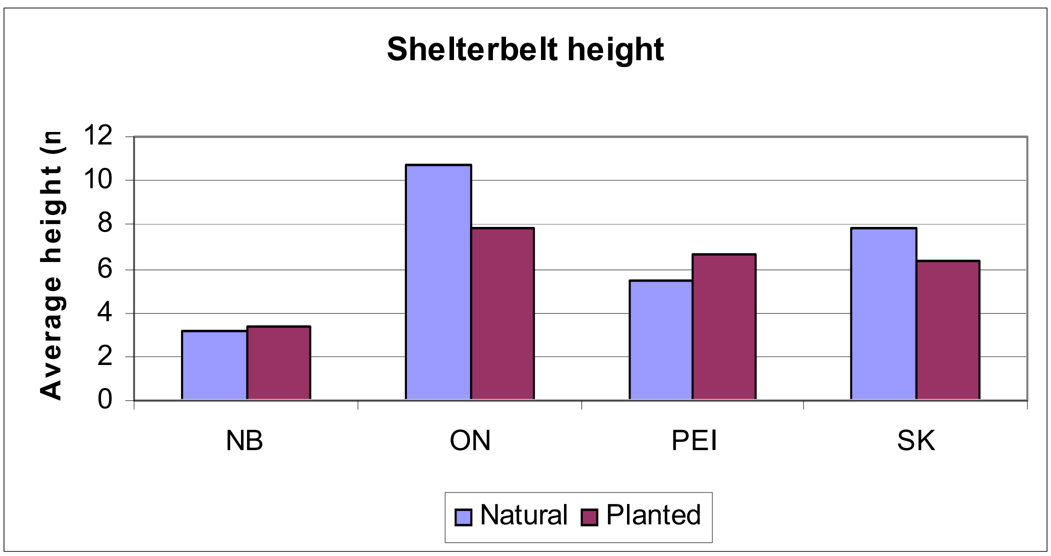

Fig. 5: Heights of representative shelterbelts/hedgerows in four regions of Canada.[1]

Porosity analysis of the lower, middle and upper thirds of the canopy showed that there were regional porosity differences in the shelterbelts sampled (Fig. 6). The Ontario and Prince Edward Island shelterbelts, which consisted mainly of conifers, were quite dense in the lower and middle canopies, while the mostly deciduous Saskatchewan shelterbelts had a somewhat greater porosity. The greatest porosity was found in the very narrow conifer shelterbelts sampled on the Acadian peninsula in New Brunswick.

[1] This figure is in colour in the electronic version of the Proceedings (CD)

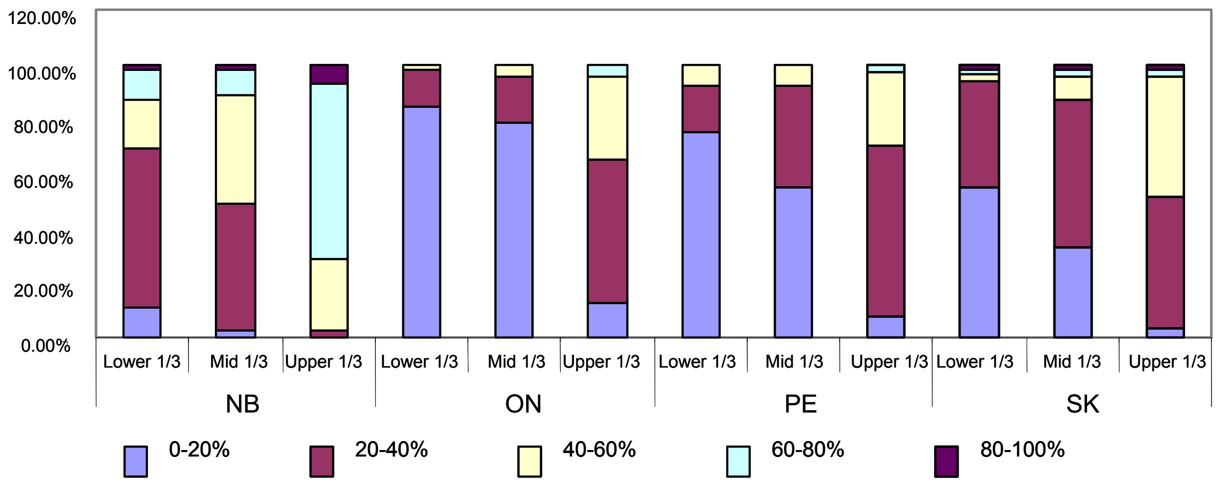

Fig. 6: Average porosities of shelterbelts in four Canadian regions.[1]

CONCLUSIONS

This protocol presents a way to standardize assessment of agroforestry buffers and it was successfully used in a variety of Canadian shelterbelts. Like the Hedgerow Evaluation and Grading System (Clements and Tofts 1992) and the subsequent hedgerow survey technique, (Bickmore 2002) in the UK, it consisted of ground-based sampling of shelterbelt dimensions, species composition and herbaceous biodiversity associated with the shelterbelts. In addition to these measurements porosity was assessed and individual tree measurements were used to calculate shelterbelt woody biomass so that other shelterbelt benefits could also be estimated. The data collected were considered to be those that were best related to the environmental functions that shelterbelts are known to perform.

We did not attempt, as yet, to assess other parameters that give shelterbelts value due to their position on the landscape, although these are significant and an important part of shelterbelt design. For example, the value of a shelterbelt as a snow trap for protecting a road or highway, as a corridor for the movement of wildlife or as a way of reducing home-heating requirements all depend on the shelterbelt being positioned correctly. Since all the shelterbelts were identified by location through GPS coordinates, these analyses can be done retroactively when criteria and measurement parameters have been agreed upon. Of interest will be such parameters as shelterbelt orientation, proximity to the area or object to be sheltered and proximity and connectivity to natural features such as native woodlands or riparian areas.

Since the sites have been recorded by GPS, these shelterbelts can serve as permanent sample plots to be reanalyzed in the future so that changes in their structure, such as biomass accumulation or increase or decrease of porosity can be estimated.

[1] This figure is in colour in the electronic version of the Proceedings (CD)

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SHELTERBELTS ON ONTARIO HOG FARMS: AN EXAMPLE OF AN INDUSTRY PARTNERSHIP TO PROMOTE ADOPTION OF AGROFORESTRY PRACTICES

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Abstract: Shelterbelts around hog barns provide multiple benefits to hog producers, neighbours, and the environment by reducing wind speed, controlling odour and dust, lowering barn heating costs, providing wildlife habitat, and beautifying the landscape. Ontario's Conservation Authorities offer agroforestry services to private landowners including tree planting, technical advice, and design services. In 2005, Conservation Ontario entered into a partnership with Ontario Pork to deliver a two-year project demonstrating the benefits of shelterbelts around hog barns. This is part of a larger project on shelterbelt establishment for hog barn odour control and improved aesthetics in Eastern Canada, administered by the Canadian Pork Council. Funding is provided by Agriculture and Agri-Food Canada's Greencover Canada Technical Assistance Program. Twelve demonstration sites have been established across the province to demonstrate shelterbelt design around barns and the use of black plastic mulch for weed control. The project has generated widespread interest in barn shelterbelts from all sectors of the livestock industry. The development of relationships between Ontario's hog producers and foresters at Conservation Authorities has been one of the goals of the project. As part of this industry partnership, training workshops on barn shelterbelt design are provided to forestry technicians. Ontario Pork staff provides information on barn ventilation systems to give foresters an understanding of barn ventilation needs, which is important in determining proper shelterbelt location and species selection. Training and extension material has also been developed for farmers and extension staff.

INTRODUCTION

Shelterbelts around hog barns provide many benefits to hog producers, neighbours and the environment, including odour and dust control, lowered barn heating costs, and aesthetic improvements to the farmstead. Ontario's Conservation Authorities (CAs) offer agroforestry services to private landowners including tree planting, technical advice and design services. In 2005, Conservation Ontario entered into a partnership with Ontario Pork to deliver a two-year project demonstrating the benefits of shelterbelts around hog barns. Anne Loeffler of the Grand River Conservation Authority acted as a provincial coordinator. This was part of a larger project on shelterbelt establishment for hog barn odour control and improved aesthetics in Eastern Canada, administered by the Canadian Pork Council. Funding was provided by Agriculture and Agri-Food Canada's Greencover Technical Assistance Program. Quebec and Atlantic Region programs were coordinated in partnership with the Federation des producteurs de porcs du Quebec and the Atlantic Swine Research Partnership Inc. respectively.

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In Ontario, an industry partnership between conservation authorities and the livestock industry was expected to be useful in addressing the following traditional obstacles to shelterbelt establishment:

- CA forestry extension staff generally is not familiar with barn ventilation requirements and therefore lacked an appreciation of the potential effect of a poorly placed shelterbelt on barn temperatures and animal comfort.

- While CA staff is experienced in tree planting and maintenance, there was a need for training on shelterbelt design and function.

- Many hog producers have not made use of the services of the Conservation Authorities in the past as many producers are fearful of any perceived Government involvement in their daily operations.

- There is a lack of awareness within the hog industry of the potential odour control benefits of establishing shelterbelts adjacent to barns.

- There is a general lack of awareness of the many benefits of planting shelterbelts around farm buildings.

Thus a partnership between the Ontario hog industry and conservation authorities to promote shelterbelt establishment around hog farms was born. The project consisted of three major components:

- Establishment of demonstration sites on hog farms across the province;

- Training workshops for forestry extension staff and consultants;

- Development of extension material for farmers and extension staff.

DEMONSTRATION SITES

In total, 27 demonstration sites were established across eastern Canada. The twelve Ontario sites were distributed across those areas of the province that produce significant numbers of hogs. The sites were established in 2005 and 2006. Eight sites were established on black plastic mulch. While black plastic mulch has been widely used in the Prairie Provinces and Quebec, it had not previously been used in Ontario for tree shelterbelts. Therefore the use of this technique attracted significant attention from farmers and media. The Prairie Farm Rehabilitation Administration, a branch of Agriculture and Agri-Food Canada from Indian Head, Saskatchewan provided two mulch layers for the eastern and western parts of the province to promote the use of the plastic mulch technique for improved weed control and soil moisture retention.

The actual site preparation and mulch-laying on the demonstration sites was an important learning experience for the CA staff and farmers involved, and have fostered an interest in using this technique on other farm sites being established through regular CA tree planting programs. The biggest lesson learned it that the sites need to be extremely well prepared (well cultivated, disced or rototilled to a depth of at least 20 cm) to allow the mulch to be laid. Since the appropriate level of tillage is not possible on some sites, the use of black plastic mulch cannot be recommended for all situations.

In the course of developing tree planting plans and choosing demonstration sites, there was opportunity for CA staff to develop new relationships with local hog producers and farm leaders. These sites also provided the training ground for the practical components of the workshops held for extension staff.

TRAINING WORKSHOPS

A series of four training workshops were organized in eastern and western Ontario to train CA staff, Ministry of Natural Resources Stewardship Coordinators and consultants in shelterbelt function, design, establishment and maintenance. About 25 individuals participated in Ontario. Similar workshops were held in Quebec and the Atlantic Region, thereby providing specialized shelterbelt training to over 100 individuals.

The workshop instructor was Andre Vezina of Institut de technologie agroalimentaire of La Pocatiere, Quebec. Sam Bradshaw, environmental specialist from Ontario Pork, attended workshops within Ontario to provide the “hog producer context”, particularly in relation to barn ventilation needs. This excellent training opportunity led to new contacts between the CAs and Ontario Pork as well as local hog producers. The workshops included practical field components to provide hands-on experience in shelterbelt design, soil preparation and mulch laying, planting trees into mulch, and pruning of hardwoods. Participants from across eastern Canada also were invited to La Pocatiere, for tours of established shelterbelts. This workshop focused on the use of multiple tree and shrub species within shelterbelts, and allowed staff to observe the tremendous growth that has been achieved on plastic mulch on Quebec sites.

EXTENSION MATERIALS

In conjunction with the training workshops, Andre Vezina developed a series of extension materials for use of extension staff and farmers. Specifically, the following material was developed to support the project:

- A farmer guide entitled “Farmstead Shelterbelts: Planning, planting and maintenance”;
- Detailed lecture notes for the use of workshop participants on shelterbelt function, design, establishment and maintenance;
- A series of PowerPoint presentations to accompany the lecture notes;
- A booklet on the use of tree and shrub species in shelterbelts entitled “Selection and arrangement of plants in shelterbelts and buffer strips”;

- A spreadsheet to calculate the cost of shelterbelt implementation;
- Another spreadsheet to determine shelterbelt profitability and the timeframe for economic return on investment;
- A CD-ROM containing all lecture notes, PowerPoint presentations, species booklet, and spreadsheets;
- A website which includes most of the above material, as well as photos and planting plans for all demonstration sites established through this project. The website is available in English and French language at www.wbvecan.ca.

The guidebook has been widely distributed by Ontario Pork, who mailed the farmer guidebook to every hog producer in the province. It is also being distributed through the Ontario Soil and Crop Improvement Association in Greencover Program information packages. The lecture notes and CD-ROMS were distributed to workshop participants, consultants, and government agencies as requested.

OUTCOMES

This industry partnership has been very successful is raising the profile of shelterbelts within the livestock industry in Ontario, particularly for the purpose of odour control. Media coverage of the project has generally been very positive. By establishing shelterbelts, hog farmers were shown to be cognizant and caring of barn odour concerns and their neighbours. This was a positive portrayal of the hog industry in the press. For Ontario's conservation authorities, the shelterbelt project provided new opportunities to work in a pro-active manner with livestock producers. New communication avenues were established between the local CAs and the hog industry, resulting in better understanding between the groups and opening the door for collaboration on future projects. For example, this partnership has spawned a new project to start this year promoting riparian buffers and awareness of surface water quality issues. The new project is a partnership between Trout Unlimited, Ontario Pork and Conservation Ontario.

Twelve demonstration sites have been established throughout Ontario to showcase shelterbelt design and establishment techniques. These trees will eventually benefit the farmers by controlling odour, reducing wind speeds, controlling snow, reducing barn heating costs, beautifying the landscape and hopefully leading to better relationships with the surrounding community. The use of black plastic mulch for tree establishment is being demonstrated for the first time across the province.

The training workshops have now provided specialized shelterbelt information to CA forestry staff and raised the level of technical expertise available across the province. The excellent extension materials developed to support the workshops will be another lasting legacy of this project.

A third year of funding has been approved to allow the development of further extension material, provide more training workshops, and permit CA staff to collect data on tree survival and growth on the demonstration sites.

ACKNOWLEDGEMENTS

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THE USE AND FUTURE OF WINDBREAKS IN THE WHEATBELT REGION OF WESTERN AUSTRALIA

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Abstract: Tree windbreaks have been widely planted across the Western Australian wheatbelt. Recent research has confirmed that windbreaks provide substantial benefits in reducing wind erosion and crop damage in exceptionally dry and windy years. However, crop or pasture yield near the trees is reduced due to competition for water in most years. Competition losses can be reduced by severing lateral tree roots.

Despite this information, the widespread adoption of minimum tillage practices often combined with reduced stocking rates, or even de-stocking, has contributed to a decline in the use of tree windbreaks in recent years. Farmers are now more able than ever to maintain anchored plant residues on areas of erodible soil. Consequently, their limited conservation budgets are going to areas other than windbreaks.

In future, the development of commercial agroforestry systems for the medium and low rainfall areas of the wheatbelt will improve the economic attractiveness of planting trees. If current declining rainfall trends continue, and climate change increases the inter-annual variability of rainfall, then farmers may again perceive the that the protection benefits of windbreaks outweigh the competition costs.

Key Words: Wind erosion, shelter, tree/crop competition, no-till, climate change.

INTRODUCTION

Dryland agriculture in Western Australia (WA) is predominately practiced in the region known as the wheatbelt. In 1998, wind erosion in the wheatbelt was estimated to affect 10,000 ha annually, at a cost of AUS $21 million /year (MacGregor and Pilgrim 1998). Historically tree windbreaks have been used widely across the wheatbelt; primarily to protect soils from wind erosion. While research has confirmed that windbreaks provide substantial benefits in reducing wind erosion and crop damage in exceptionally dry and windy years, the number of windbreaks planted for wind erosion control *per se* has declined in recent years.

This paper describes the findings of recent research into the value of tree windbreaks in the WA wheatbelt, suggests a number of reasons for the decline in planting windbreaks and makes the case for continued farmer interest and Government support for planting windbreaks.

WINDBREAK RESEARCH IN THE WHEATBELT

Recent WA research has shown that there are two broad zones of crop response in the lee of windbreaks. The competition zone, where competition, principally for water, between the trees and crops or pasture results in reduced agricultural productivity and a sheltered zone where agricultural productivity is unchanged or increased (Sudmeyer et al. 2002). The competition zone is largely confined to the area occupied by tree roots and extends 3-4 times the height of the trees (H) while the sheltered zone extends up to 20 H.

The magnitude of yield changes within these zones depends on crop type, the degree of shelter provided by the windbreak and edaphic and climatic conditions (Fig. 1; Sudmeyer et al. 2002). Windbreaks provide most benefit in drier areas or years, particularly when crops are subject to wind damage and sand blasting. In these years, increased grain yield in the sheltered zone exceeds competition losses and net yields in windbreak systems are greater than from unsheltered crops. In dry years, when unsheltered crops are not subjected to severe sandblasting damage, increased yield in the sheltered zone offsets reduced yield in the competition zone, so net yields in windbreak systems are similar to unsheltered crops. But in years with average or above average rainfall and no wind damage, yield in the sheltered zone is largely unchanged and yield losses in the competition zone result in a net reduction in yield.

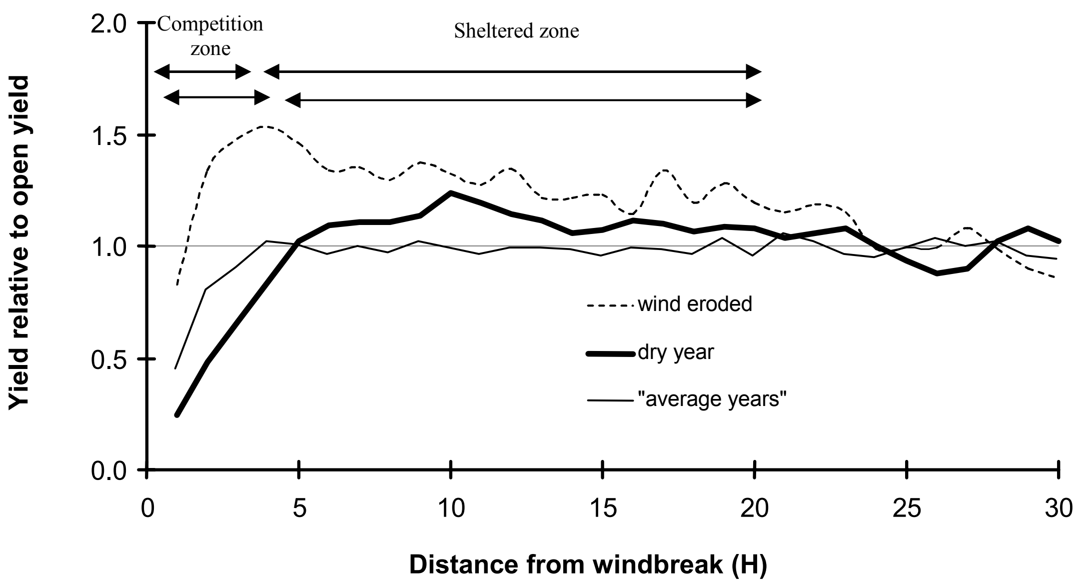

Fig. 1: Crop yield in the lee of windbreaks expressed as a percentage of yield outside the sheltered zone, at various distances from windbreaks expressed as multiples of tree height (H). Data from 64 field years in Western Australia (after Sudmeyer et al. 2002).

Agricultural production in the competition zone can be significantly increased in many situations by severing lateral tree roots (Sudmeyer and Flugge 2005). Economic analysis using these data and typical tree growth rates and establishment costs for the south coast of WA showed that over the 35 year life of a pine windbreak it takes 2-4 severe wind damage events before all of the costs of windbreak establishment and competition are recovered (Jones and Sudmeyer 2002). When windbreak trees are also harvested for commercial products, the returns from the trees can offset competition losses (Jones and Sudmeyer 2002).

Given that microclimate changes in the sheltered zone do not significantly increase agricultural production in most years, windbreaks should be regarded as a form of insurance. A lack of specific wind erosion risk data means land managers have to make a subjective evaluation of windbreaks based on their recollection of wind erosion damage on their farm. This evaluation is now being made at a time when agronomic advances have given farmers unprecedented means other than planting windbreaks to manage wind erosion risk.

WHY ARE FEWER WINDBREAKS BEING PLANTED?

Wind erosion in WA has been mitigated by several agronomic innovations combined with economic and policy drivers that have allowed farmers to reduce soil disturbance and maintain more anchored plant residues.

The greatest agronomic change mitigating wind erosion has been the rapid adoption of no tillage (no-till) cropping systems. Eighty six percent of farmers planting crops used no-till in 2003 (D'Emden and Llewellyn 2005). Increasing use of no-till farming has been accompanied by a marked reduction in the size of the Australian sheep flock due to declining returns from wool production (ABS 2003; ABS 2007).

Better farming practices, reduced stocking rates, clear guidelines detailing the amount of anchored stubble, or pasture required to prevent wind erosion and governmental assistance to de-stock in times of drought have all given farmers more confidence than ever before in their ability to maintain anchored plant residues on areas of erodible soil and so manage wind erosion risk without using windbreaks.

While good agronomic and grazing practices minimize the risk of wind erosion, it is not always possible to maintain an adequate cover of annual vegetation, particularly in dry years or where rainfall is variable. Wind erosion continues to occur in these years though it could be argued that it is on a smaller scale than occurred prior to the 1980's. Despite such events, it seems that the perceived costs of windbreaks now outweigh their benefits for many farmers, consequently limited conservation budgets are being spend in areas other than windbreaks.

WHAT IS THE FUTURE FOR WINDBREAKS IN THE WHEATBELT?

Despite the current decline in the use of windbreaks they still have a place on wheatbelt farms and their use may increase in future, although windbreak systems will take novel forms and be designed to achieve multiple outcomes rather than just providing shelter.

Without significant new developments in weed management it seems likely that increased cultivation, and all of the wind erosion risks it entails, may again be a feature of cropping systems in WA. Sixty three percent of farmers using no-till report some herbicide resistance on their farms, with 45% planning to reduce the area of no-till to deal with weed control issues (D'Emden and Llewellyn 2005).

Climate change also has the potential to greatly increase the risk for wind erosion in WA. Over the last 25 years average rainfall in the southwest of WA has declined by 10-15% (IOCI 2002). Climate models predict that rainfall in the southwest will continue to decline, by as much as 20% by 2030 and even further in subsequent years, with summer and autumn temperatures increasing by up to 2^{o}C over the same period (Pittock 2003). Reduced rainfall (particularly opening rains), and consequently reduced crop and pasture cover, increased temperature, climate variability and a shift to grazing enterprises in some areas will all act to reduce farmers ability to maintain adequate vegetative cover on soils susceptible to wind erosion, i.e. wind erosion risk will increase.

While climate change and herbicide resistance may work to offset gains in mitigating erosion risk, it is the development of new industries based on utilizing woody biomass that will make the establishment of windbreak systems more financially attractive to farmers. Changing government policy regarding energy generation and CO_2 emissions, may also have a profound effect on the economics of such systems.

The coming decades will see wheatbelt farmers having to deal with a number of new challenges and opportunities which will produce many innovations and adaptations. Among these will be an expansion in windbreaks incorporated into alley farming systems for their risk management, and income diversification benefits.

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ANALYSE ÉCONOMIQUE DE SIX MODÈLES DE HAIES BRISE-VENT UTILISÉS POUR LA PROTECTION DES BÂTIMENTS D'ÉLEVAGE PORCIN DANS L'EST DU CANADA

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Résumé : L'implantation de haies brise-vent autour des bâtiments d'élevage porcins constitue une mesure de plus en plus répandue dans l'est du Canada pour réduire les problématiques d'odeurs et de cohabitation. Les haies brise-vent peuvent aussi diminuer les coûts de chauffage et de déneigement et procurer un revenu d'appoint au producteur par la vente de bois. Cependant, l'implantation et l'entretien des haies entraînent des coûts pour le producteur, dont les revenus sont aussi réduits à cause de la perte d'espace cultivable. Les marges (bénéfices moins les coûts) et le délai de recouvrement ont été calculés pour six modèles de haies composées de 1 à 3 rangées d'arbres ou d'arbustes dans le cadre d'un projet initié par le Syndicat des producteurs de porcs de la Mauricie.

Les haies brise-vent autour des bâtiments d'élevage porcin constituent un investissement dont les bénéfices économiques sont palpables dans les 10 à 20 années suivant leur implantation. Les modèles incluant une rangée d'arbres à feuilles persistantes présentent les marges actualisées les plus fortes (entre 35 000 $ et 40 000 $ après 40 ans). La réduction des coûts de chauffage et de déneigement constituent les principales sources de revenus, alors que l'entretien constitue la principale source de dépenses. La haie constituée de trois rangées (peupliers hybrides, épinettes et feuillus nobles) est la haie qui présente la marge actualisée la plus élevée, mais elle exige un plus grand investissement de la part du producteur.

Mots-clés : Haies brise-vent, rentabilité, bâtiments d'élevage

INTRODUCTION

L'implantation de haies brise-vent autour des bâtiments d'élevage porcin constitue une mesure de plus en plus répandue dans l'Est du Canada pour réduire les problèmes d'odeurs et de cohabitation. De plus, les haies brise-vent peuvent diminuer les coûts de chauffage et de déneigement et procurer un revenu d'appoint au producteur par la vente de bois ou de petits fruits. Des haies bien conçues peuvent également embellir les paysages tout en contribuant à la biodiversité et à l'effort de réduction des gaz à effet de serre. Cependant, l'implantation et l'entretien des haies entraînent des coûts pour le producteur, dont les revenus sont aussi réduits à cause de la perte d'espace cultivable.

Dans Olivier, A. et S. Campeau, éd. 2007. *Associer arbres et cultures*. Actes du 10e Congrès nord-américain d'agroforesterie, Québec, Canada, 10-13 juin 2007.

Ce feuillet technique est destiné aux conseillers agricoles qui planifient l'installation de haies brise-vent autour des bâtiments d'élevage porcin. Il a comme objectif de vérifier, pour six modèles de haies brise-vent, si le bilan net est positif pour le producteur agricole et, si tel est le cas, quel est le délai de récupération.

MÉTHODE

Description des modèles de haies

Les six modèles de haies à l'étude constituent des modèles recommandés au Québec. Ils comptent de une à trois rangées d'arbres ou d'arbustes, dont la hauteur varie entre 30 et 60 cm au moment de leur plantation. Les haies, dont la longueur est de 700 m, sont implantées sur un paillis de plastique noir, technique largement répandue au Québec. Cependant, pour un des modèles retenus, les coûts et les revenus ont été calculés en utilisant des arbres de plus grande taille (hauteur de 1,5 à 2 m), un paillis de copeaux et un système d'irrigation.

Description de la ferme porcine à protéger

La ferme porcine à protéger est une ferme type naisseur-finisseur qui comprend 150 truies produisant annuellement 2 924 porcs, un inventaire moyen de 915 porcs à l'engraissement, une porcherie maternité de 766,5 m² et une porcherie d'engraissement de 945 m² (Géagri 1999). La ventilation des bâtiments est mécanique. Un chemin de ferme de 300 m de long permet d'accéder aux bâtiments d'élevage. Les coûts de chauffage sont fixés à 10 000 $/an.

Principes et critères économiques retenus

Le modèle détermine la marge actualisée entre, d'une part, les économies et les revenus qu'engendre au fil des ans la haie et, d'autre part, ses coûts d'implantation et d'entretien. Pour l'évaluation de ces paramètres, le modèle incorpore un taux d'inflation basé sur l'indice des prix à la consommation, un coût d'opportunité pour le loyer de l'argent et un taux d'actualisation afin de ramener la marge en dollars constants pour une année de référence. Ces taux sont basés sur l'analyse des données (1995-2005) de la Banque du Canada.

Réduction des coûts de chauffage des bâtiments

Une haie bien localisée peut entraîner des réductions significatives des coûts de chauffage (Vézina 2006). Ces économies de chauffage varient en fonction de la hauteur de la haie, donc de l'âge de celle-ci. Les pourcentages de réduction retenus sont de 0 % pour les haies âgées de 0 à 10 ans, de 2,5 % pour les haies de 10 à 20 ans et de 10 % pour les haies de 20 à 40 ans. Ces pourcentages s'appliquent dans le cas où l'on compte au moins une rangée d'arbres à feuilles persistantes. Pour les haies constituées uniquement de feuillus, la réduction équivaut à 40 % des pourcentages proposés. Une réduction supplémentaire s'applique pour tenir compte de la croissance en hauteur plus rapide des peupliers. Ces réductions ne s'appliquent que pour des bâtiments à ventilation mécanique. Dans le cas des bâtiments à ventilation naturelle, on conseille d'installer les haies à une distance correspondant à 8 fois leur hauteur à maturité pour éviter de nuire à la bonne circulation de l'air. À cette distance, les haies n'auront pas d'impact sur les réductions de coûts de chauffage.

Réduction des coûts de déneigement

Une haie bien localisée peut également entraîner des réductions des coûts d'opérations du déneigement (G. Beauregard, MAPAQ, août 2006, communication personnelle). Les économies liées aux opérations du déneigement vont aussi varier en fonction de la hauteur de la haie, donc de l'âge de celle-ci. Les pourcentages de réduction retenus sont de 0 % pour les haies âgées de 0 à 5 ans, de 10 % pour les haies de 5 à 10 ans et de 20 % pour les haies de 10 à 40 ans. Ces pourcentages s'appliquent dans le cas où l'on compte au moins une rangée d'arbres à feuilles persistantes ou une rangée d'arbustes.

Revenus en bois

Les volumes de bois récoltables ont été calculés à partir de tables de cubage (Honer et al. 1983) et de mesures effectuées dans des haies brise-vent de la Mauricie. Les prix du bois sont ceux du marché en juin 2006 dans cette région. Le bois récolté est destiné majoritairement au sciage sauf pour le bois du houppier qui est vendu comme bois de chauffage. Les revenus nets ont été calculés en multipliant les volumes de bois par le prix de celui-ci et par un facteur de 0,35 pour tenir compte des frais d'exploitation. Des revenus en bois sont obtenus après 20 ans avec les modèles intégrant le peuplier hybride et au bout de 40 ans avec ceux intégrant les feuillus nobles.

Revenus en petits fruits

L'implantation d'arbustes fruitiers dans les haies peut offrir des revenus supplémentaires aux producteurs. Le revenu total en fruits est obtenu par le produit du rendement et du prix au marché pour le sureau blanc, qui sont respectivement de 1,25 kg/plant et de 800 $/tonne. Ce rendement est conservateur car il a été mesuré en haies brise-vent avec des plants n'ayant possiblement pas encore atteint leur plein potentiel de production (Lebel et DeRoy 2007). Les revenus nets ont été calculés en multipliant le revenu total par un facteur de 0,2 pour tenir compte des frais de récolte et de mise en marché.

Coûts des pertes d'espace cultivable

Les coûts liés aux pertes d'espace cultivable augmentent avec l'accroissement en largeur de la haie au fil des ans. Les pertes de revenus ont été établies en se basant sur une rotation type 'maïs-maïs-soya' (G. Beauregard, MAPAQ, août 2006, communication personnelle). Les pertes ont été calculées pour une surface obtenue en multipliant la largeur de la haie par sa longueur et par un facteur de 0,5. Ce facteur est introduit dans l'équation car on suppose que la haie se trouve en terrain cultivé que sur la moitié de sa longueur.

Coûts d'implantation et d'entretien

Les coûts d'implantation des six modèles tiennent en compte la planification, la préparation du sol, la pose du paillis de plastique (1,2 m de largeur), la plantation des végétaux et la subvention pour l'implantation (70 %) octroyée par le programme Prime-vert (Vézina 2006). Pour la haie constituée d'arbres de plus fortes dimensions, les coûts ont été calculés à partir de données de Néri (2004). Les coûts d'entretien comprennent les coûts de remplacement l'année suivant la plantation, le fauchage, la taille de formation et l'élagage.

RÉSULTATS ET DISCUSSION

Les marges cumulatives actualisées après 5, 10, 20 et 40 ans, pour les six modèles retenus, sont présentées au tableau 1. Les marges cumulatives après 40 ans se situent entre 35 000 $ et 40 000 $ pour l'ensemble des haies, sauf pour la haie de feuillus nobles et d'arbustes fruitiers (25 913 $) et la haie utilisant des arbres de fort calibre (10 715 $). Dans le cas d'une haie non subventionnée, la marge cumulative actualisée après 40 ans est peu affectée puisqu'elle est réduite d'environ 3 000 $ (-7%). À court terme, l'impact est plus important, comme en témoignent les marges cumulatives après cinq ans, qui sont respectivement de -4 206 $ et de -7 412 $ pour la haie avec et sans subvention.

Une seule rangée d'arbres à feuilles persistantes confère une marge cumulative légèrement inférieure à celle des haies de 2 ou 3 rangées comptant aussi des feuillus nobles ou des peupliers récoltables. Cependant, l'entretien, la récolte et la transformation du bois des haies comptant deux et trois rangées génèrent plus d'activités économiques. De plus, il est beaucoup plus facile d'assurer une pérennité de la protection avec les modèles utilisant 2 ou 3 rangées plutôt qu'une seule. Finalement, la contribution à la biodiversité et à la séquestration de carbone est généralement supérieure dans le cas de haies comptant plus de végétaux.

Le délai de récupération, pour tous les modèles, se situe entre 10 et 20 ans, sauf pour le modèle préconisant la plantation d'arbres de fort calibre, où elle se situe à 36 ans, à cause des coûts d'implantation plus élevés.

Les modèles constitués d'une seule rangée, incluant des arbres à feuilles persistantes, sont ceux dont la période de recouvrement est la plus courte, principalement à cause des coûts d'entretien qui sont moindres. Si on ne tient pas compte de la subvention pour l'implantation, le nombre d'années pour le recouvrement passe de 16 à 19 ans pour le modèle à trois rangées.

Deux modèles ont été analysés en détail pour déterminer la répartition des revenus et des coûts, soit la haie comptant une rangée de peupliers hybrides et d'épinettes, et celle comptant trois rangées (une de peupliers, une d'arbres à feuilles persistantes et l'autre de feuillus nobles et d'arbustes fruitiers). Pour le modèle à une rangée de peupliers hybrides et d'épinettes en alternance, les revenus liés aux économies de chauffage sont le plus importants (56 %), suivis de ceux liés aux économies de déneigement (39 %) et de ceux liés à la récolte du bois (5 %; Fig. 1). Pour le modèle à trois rangées, les revenus liés à la réduction des coûts de chauffage (48 %) et des coûts de déneigement (35 %) demeurent importants mais les revenus liés à la récolte du bois sont plus imposants (15 %). Les revenus liés à la production de petits fruits sont plutôt faibles (2 %).

Tableau 1 : Marges cumulatives actualisées sur différentes périodes pour six modèles de haies.

Nombre de rangées	Espèces d'arbres	Marge cumulative actualisée après 5 ans ($)	Marge cumulative actualisée après 10 ans ($)	Marge cumulative actualisée après 20 ans ($)	Marge cumulative actualisée après 40 ans ($)	Délai de récupération (ans)
1	Épinettes, pins ou thuyas	-1 885	-677	6 873	35 756	11
1	Peupliers hybrides et épinettes	-2 351	-811	9 809	38 692	11
1	Feuillus nobles et arbustes fruitiers	-2 633	-1 920	3 884	25 913	14
2	Peupliers hybrides / Épinettes, pins ou thuyas	-2 992	-1 688	9 408	38 291	13
2	Feuillus nobles / Épinettes, pins ou thuyas	-3 239	-2 945	3 658	37 459	15
3	Peupliers hybrides / Épinettes, pins ou thuyas / Feuillus nobles et arbustes fruitiers	-4 206	-3 340	7 172	40 107	15
3	Peupliers hybrides / Épinettes, pins ou thuyas / Feuillus nobles et arbustes fruitiers (sans subvention)	-7 412	-6 545	3 967	36 902	19
3	Peupliers hybrides / Épinettes, pins ou thuyas / Feuillus nobles et arbustes fruitiers (avec des arbres de fort calibre)	-33 599	-32 733	-22 220	10 715	36

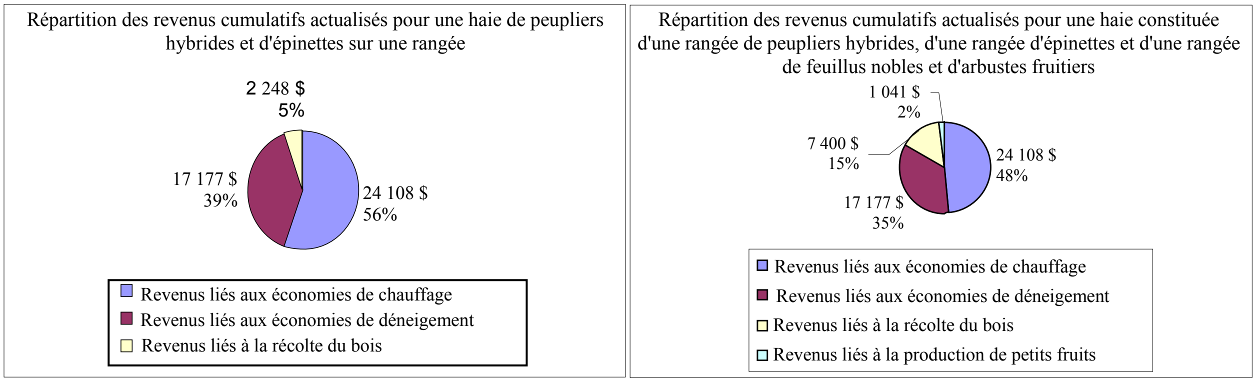


Fig. 1 : Répartition des revenus actualisés après 40 ans pour deux modèles de haies brise-vent.[1]

L'impact des différentes sources de revenus sur la marge cumulative actualisée est représenté à la Fig. 2. La pente d'accroissement de la marge cesse d'être négative à la cinquième année, avec le début des réductions des coûts du déneigement. Elle augmente significativement à partir de 10 ans, année qui marque le début de la réduction des coûts de chauffage. La récolte des arbres procure un revenu important l'année de la coupe.

Pour le modèle à une rangée de peupliers hybrides et d'épinettes en alternance, les coûts liés à l'entretien, sur une période de 40 ans, représentent 62 % des coûts totaux, le reste étant lié à la perte d'espace cultivable (26 %) et à l'implantation (12 %). Ces chiffres sont sensiblement les mêmes pour le modèle à 3 rangées (Fig. 3).

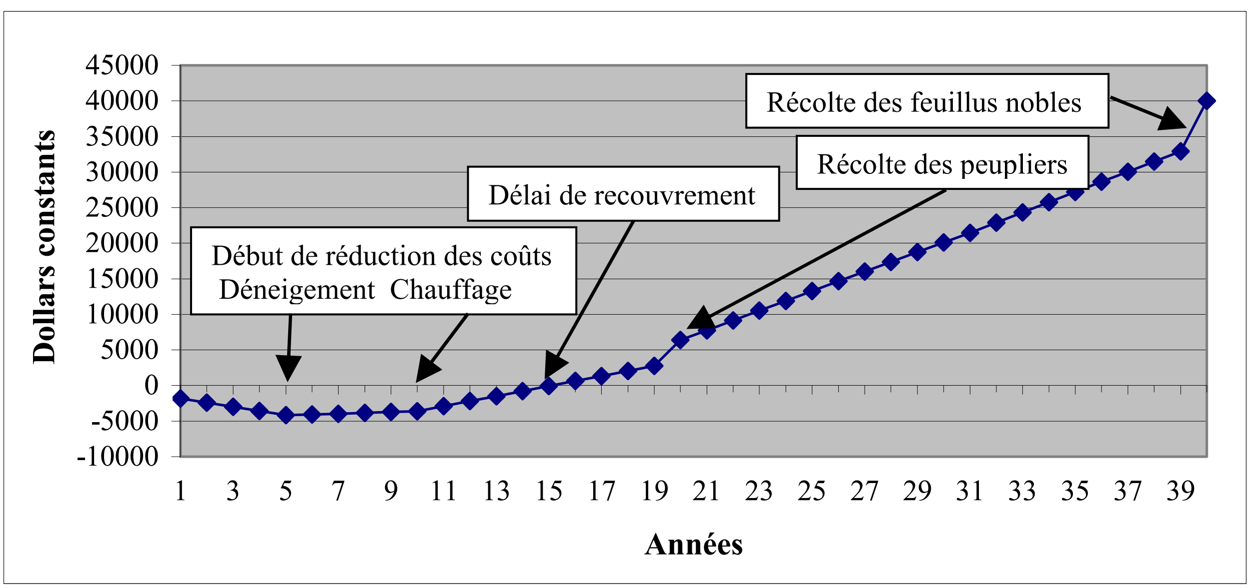
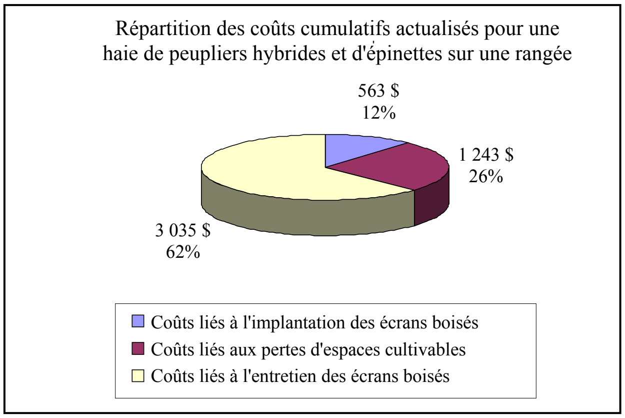


Fig. 2 : Évolution, sur une période de 40 ans, de la marge cumulative actualisée du modèle à 3 rangées (peupliers, arbres à feuilles persistantes et feuillus nobles/arbustes fruitiers).[1]

[1] Cette figure est en couleur dans la version électronique des Actes (CD)



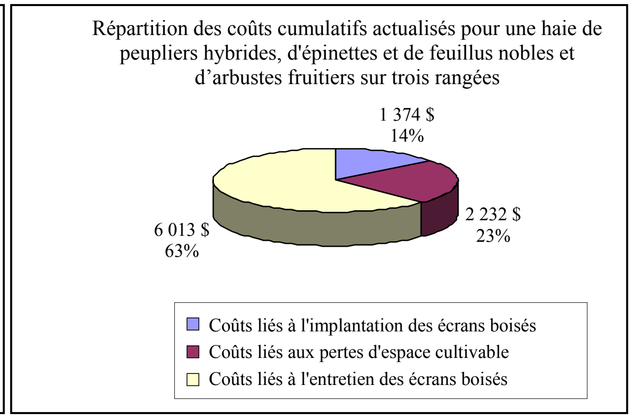


Fig. 3 : Répartition des coûts actualisés après 40 ans pour deux modèles de haies brise-vent.[1]

CONCLUSION

Les haies brise-vent autour des bâtiments d'élevage porcin constituent un investissement dont les bénéfices économiques sont palpables 10 à 20 ans suivant leur implantation, sauf pour la haie constituée d'arbres de gros calibre, où les coûts d'implantation élevés entraînent un temps de recouvrement de 35 ans.

Les réductions des coûts de chauffage et de déneigement constituent les principales sources de revenus. C'est pourquoi les modèles incluant une rangée d'arbres à feuilles persistantes présentent les marges actualisées les plus fortes (entre 35 000 $ et 40 000 $ après 40 ans). La haie constituée de trois rangées (peupliers hybrides, épinettes et feuillus nobles) est la haie qui présente la marge actualisée la plus élevée. Elle offre l'avantage d'offrir une protection rapide grâce aux peupliers et une possibilité de récolte de bois avec les peupliers et les feuillus nobles.

Les haies brise-vent autour des bâtiments d'élevage porcin peuvent aussi réduire les odeurs, les poussières et le bruit, et embellir le paysage, ce qui favorise une meilleure cohabitation entre les producteurs de porc et leur communauté. De plus, les haies peuvent contribuer à la biodiversité et à la réduction des gaz à effet de serre. Ces critères n'ont pas été tenus en compte dans cette étude, car ils sont plus difficilement quantifiables. Cependant, ils doivent quand être même considérés lorsque vient le temps de déterminer la composition et la structure de la haie. Ces gains environnementaux seront plus facilement atteignables en plantant trois rangées d'arbres plutôt qu'une, et cela, sans pénaliser à moyen terme le producteur agricole. Cependant, celui-ci devra être soutenu au moment de l'implantation (comme c'est le cas avec le programme Prime-vert) et idéalement lors des opérations d'entretien, si ont veut produire du bois de qualité.

Les résultats obtenus peuvent varier de façon importante en fonction des hypothèses de départ. C'est pourquoi le CEPAF et l'ITA, campus de La Pocatière, vont développer, en 2007, un outil permettant aux conseillers agroforestiers de simuler l'impact économique de différents types de haies brise-vent et de bandes riveraines boisées implantées dans des contextes différents. Cet

[1] Cette figure est en couleur dans la version électronique des Actes (CD)

outil, développé grâce à une subvention d'Agriculture Canada, permettra aux utilisateurs d'ajuster les paramètres économiques afin d'établir des projections fidèles à leur réalité.

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QUANTIFICATION OF SHELTERBELT CHARACTERISTICS USING HIGH RESOLUTION IMAGERY

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Abstract: The Agriculture and Agri-Food Canada PFRA Shelterbelt Centre in Indian Head, Saskatchewan has been actively distributing shelterbelt trees across the Prairie Provinces since 1903, mainly to reduce the effects of wind erosion. Shelterbelts also mitigate greenhouse gas emissions by acting as carbon reserves or by producing biomass for bioenergy. Visiting individual belts across each province is costly and too time consuming. High resolution satellite imagery offers a potentially quick and inexpensive method of identifying shelterbelt characteristics to calculate biomass. As resolution of imagery increases more information can be extracted as ground features are becoming increasingly prevalent. Although shelterbelts could be quickly analyzed across large sections of land, finer resolution comes at a price. Windbreaks have been examined not only using spectral reflectance from available multi-spectral bands but also shape, texture and other spatial properties associated with shelterbelts using object oriented image analysis in eCognition. Multiple Discriminate Analysis is used to determine if shelterbelt can be identified by species.

Résumé : Le Centre des brise-vent d'Agriculture et Agroalimentaire Canada à Indian Head, Saskatchewan a activement distribué des arbres pour les brise-vent à travers les provinces des Prairies depuis 1903, afin de réduire principalement les effets de l'érosion éolienne. Les brise-vent réduisent également les émissions de dioxyde de carbone en agissant comme un réservoir de carbone ou en produisant de la biomasse pour la bioénergie. Visiter les brise-vent à travers chaque province est trop cher et prend trop de temps. Donc les images satellites de haute résolution offrent une méthode potentiellement rapide et moins chère pour identifier les brise-vent. À mesure que la résolution des images satellites augmente, plus des données peuvent être extraites. Bien que des brise-vent pourraient être rapidement analysés à travers de grandes sections de territoire, une résolution plus fine deviendrait plus chère. Des brise-vent ont été examinés non seulement en utilisant la réflectivité spectrale des bandes multi-spectrales mais aussi la forme, la texture et d'autres qualités spatiales liées aux brise-vent en utilisant l'analyse d'image orientée objectivement dans l'eCognition. L'analyse statistique 'Multiple Discriminate Analysis' est employée pour déterminer si les brise-vent peuvent être identifiés à l'espèce.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

INTRODUCTION

The Agriculture and Agri-Food Canada PFRA Shelterbelt Centre in Indian Head, Saskatchewan has been actively distributing shelterbelt trees for farm and field belts across the Prairie Provinces since 1903. In 2006 alone 3.7 million tree seedlings were distributed to 7,000 clients in the agricultural regions of Manitoba, Saskatchewan, Alberta and British Columbia. Shelterbelts are vital to the sustainability of agriculture as they provide a variety of benefits to producers and society through the reduction of soil erosion, shoreline erosion, odours from animal production sites and pesticide drift while increasing wildlife habitats (Mah 2003), biodiversity and water quality through filtration. Shelterbelts also mitigate greenhouse gas emissions by acting as carbon reserves or by producing biomass for bioenergy (Turnock and Kort 1998).

Records exist that indicate the annual number, species type and area of distribution of trees in each province. Although it is important that conservation trees and shrubs are properly established so that they can effectively perform these functions, there is no spatial information that documents the presence and location of shelterbelts on the landscape. Visiting individual belts across the prairies is simply too costly and time consuming. The recent availability of high resolution satellite imagery enables managers to identify shelterbelts across large sections of land instantaneously. Remote sensing technologies offer potentially quick and inexpensive methods of determining if shelterbelts are being successfully established and effectively used as a Beneficial Management Practice (BMP).

OBJECTIVE

This paper has two main objectives:

1) Can high resolution imagery be used to generate an accurate inventory of shelterbelts across a vast landscape?

2) Can shelterbelts be identified by species from high resolution imagery?

This paper focuses on identifying shelterbelts using high resolution imagery and shape recognition software in a selected study area. It is the intention to use the results as the basis for an inventory tool at the PFRA Indian Head Shelterbelt Centre. There is also an examination of the identification of shelterbelt species using high resolution imagery, shape recognition software and multivariate statistics. This information may be later used for prairie biomass calculations.

METHODOLOGY

Study area

The study area is located in the Manitoba rural municipality of North Cypress located 150 km east of Winnipeg on the Trans-Canada Hiway. The land is mainly for used agricultural purposes including potato and cattle production and exhibits a wide variety of planted field and farm shelterbelts. The landscape is generally flat and follows the township and range layout with the majority of the field belts subdividing many of the sections of land.

Surface validation

Twenty-seven shelterbelts were visited during the summer months of 2006 and their locations were documented, using a GPS unit. Shelterbelts were chosen randomly within the study area with no prior knowledge of species type. Three sub-samples, each 30 m in length, were identified at the near-end, centre and far-end of each shelterbelt. The sub-sample locations were also documented with the GPS unit. Within each sub-sample, the species composition and tree density was recorded for each row and the width of shelterbelt was measured.

High resolution imagery

The high resolution imagery used in the analysis was aerial photography acquired August 4, 2004 using a total of six flight lines and 68 images at a scale 1:40,000. Data was captured using the blue, green and red portions of the electromagnetic spectrum. Imagery was then mosaicked and orthorectified to a spatial resolution of 62.5 cm using the Manitoba provincial digital topographic maps.

Image processing

The aerial photography was then brought into eCognition 2.1 for image segmentation. Segmentation is the process of grouping similar pixels or subdividing an image into clusters based on spatial location, spectral reflectance and image pattern. eCognition allows the user to segment an image based on the influence of the size of groups desired, color heterogeneity and shape characteristics such as smoothness and compactness. The raw image is segmented into vectorized polygons with a series of spectral, spatial and relational statistics for each newly created polygon attached.

Spectral attributes consisted of the mean reflectance value of pixels within each polygon and the standard deviation of pixels values from the polygon mean reflectance value for the blue, green and red wavelengths. Standard deviation can be interpreted as a measure of texture. A low standard deviation value represents a homogeneous polygon while a high standard deviation value represents a heterogeneous polygon.

Spatial statistics of the segmented polygons included area, length, width, length/width as well as a series of shape calculations. Asymmetry is a measure of linearity - the higher a polygon's linearity, the higher its asymmetry value. Asymmetry is calculated by placing an ellipse over a polygon and then dividing the minor axis by the major axis and subtracting by one (Definiens Imaging 2001). Shape index records the border length of the polygon divided by four times the square root of its area (Definiens Imaging 2001). Shape index can be thought of as a measure of shape smoothness for a polygon - the less complex a polygon is, the lower its smoothness value. A circle has a zero shape index value. Density is a measure of the polygon's area divided by its radius (Definiens Imaging 2001). Density describes the compactness of an image object with a square having a perfect compactness score.

The relational statistic records the mean spectral difference between a polygon's mean spectral value and its neighboring polygons spectral means. Neighboring polygons are weighted based on the amount of border length it shares with the original polygon. If an object is darker than its neighbors, a negative relationship exists and a positive relationship for a bright object surrounded by darker neighbors.

Shelterbelt identification

All vectors and associated statistical attributes were exported to ArcGIS (ESRI, Redlands, CA) in shape file format. The segmented shelterbelt database was then queried to only identify shelterbelts with the original aerial photography and nothing else. Each of the spectral, spatial and relational statistics were used in combination with one another using Standard Query Language (SQL).

Species separation

Surface validation information was linked to the eCognition vector output in ArcGIS using an assign by proximity merge function. It should be noted eCognition had no knowledge of shelterbelt species during the segmentation and vectorization process. Only single and double row shelterbelts were used in the analysis. Multiple row belts will be examined in a later study.

The database contained spectral, spatial and relational statistics as well as surface validation information. Only shelterbelt species information was retained from the field data as shown in Table 1. All other data was generated by the eCognition segmentation algorithm.

Table 1: Twenty-seven shelterbelts visited with segmented statistics linked to surface validation species type.

	Individual shelterbelts						
	1	**2**	**3**	**-**	**-**	**26**	**27**
Species	Acute willow	Acute willow	Acute willow	-	-	Green ash Poplar	Green ash Poplar
Blue - Mean	122.21	138.36	123.73	-	-	96.45	97.40
Blue - Stdv	20.99	16.41	23.09	-	-	22.98	27.85
Green - Mean	122.61	137.74	125.21	-	-	100.96	100.20
Green - Stdv	19.49	15.23	20.76	-	-	20.25	25.29
Red - Mean	87.60	98.53	89.90	-	-	65.31	65.98
Red - Stdev	19.78	16.04	21.11	-	-	18.02	21.99
Area	1015.63	617.19	1507.81	-	-	1264.06	98.05
Length	99.80	61.78	124.59	-	-	421.36	54.37
Width	10.18	9.99	12.10	-	-	3.00	1.80
Border length	442.50	310.00	483.75	-	-	1151.25	173.75
Length\width	9.81	6.18	10.29	-	-	140.45	30.15
Shape index	3.47	3.12	3.11	-	-	8.10	4.39
Density	1.15	1.66	1.10	-	-	0.85	0.63
Asymmetry	0.96	0.80	0.97	-	-	1.00	0.96

In total, there were six combinations of shelterbelt species visited for surface validation; acute willow (*Salix acutifolia*), American elm (*Ulmus americana*), trembling aspen (*Populus* *tremuloides*) and Manitoba maple *(Acer negundo*), green ash (*Fraxinus pennsylvanica*), green ash and caragana (*Caragana arborescens*) and finally, green ash and hybrid poplar (*Populus deltoides* X *P. petrowskyana*).

Multivariate analysis

Multiple Discriminate Analysis (MDA) is a multivariate method used to measure the between to within group sum of squares (Legendre and Legendre 1998). Unlike Principal Components Analysis in which groups that form are maximally similar reducing variance, MDA attempts to form maximally dissimilar groups increasing variance (Pal and Pal 1993). It is equivalent to running all bi-plots of all possible variable pairings simultaneously. Mean red spectral reflectance versus density, length versus asymmetry, etc. We used MDA on the eCognition segmented polygon statistics and field data species combined dataset to determine if eCognition segmented the original high resolution imagery into polygons that were separable by shelterbelt species.

RESULTS

Shelterbelt identification

By using Boolean logic in SQL to query the segmented shelterbelt database one attribute at a time and then combining all question statements together we were able to identify 96.3% of the shelterbelts that we collected surface validation data for. With each query statement we were able to systematically remove non-belt polygons from all segmented groupings based on quantitative attribute values produced in eCognition. The combination of unique spectral reflectance, shape statistics and relational information of shelterbelt contributed to the successful automated detection of 26 of 27 belts within the high resolution imagery. Table 2 exhibits the values used and logic for each of the segmented spectral, spatial and relational attributes.

Spectral statistics indicate the mean reflectance and standard deviation values of each polygon for each band. The optimal mean value for the blue and green channels to identify shelterbelts was less than 140 and 100 for the red channel. The standard deviation values remained constant for all three bands at 25.

The following shape characteristics proved to be most useful in separating shelterbelt polygons from non-belt polygons. We excluded any polygon that had an asymmetry value below 0.9. Since shelterbelts are generally linear, we only retained polygons that are long and narrow in shape. The shape index value we used was 2.7 and excluded any polygon less than that number. Segmented groupings can still be linear but have a complex shape such as a river or circular irrigation markings in a field. The shape index eliminates those types of features because it is a measure of shape simplicity or smoothness. The smoother a polygon value, the higher the shape index. A density value greater than 0.8 was used to exclude any polygons with a square-like or compact shape.

Table 2: Standard Query Logic (SQL) operant and quantitative values utilized to query each attribute from the segmented polygon database to identify shelterbelts on the landscape at an accuracy of 96.3%.

	Logic	Value
Blue – Mean	Less than	140
Blue – Stdv	Less than	25
Green – Mean	Less than	140
Green – Stdv	Less than	25
Red – Mean	Less than	100
Red – Stdv	Less than	25
Area	Not applicable	-
Length	Less than	850
Width	Not applicable	-
Border length	Not applicable	-
Length\width	Greater than	15
Shape index	Greater than	2.7
Density	Greater than	0.8
Asymmetry	Greater than	0.9
Mean difference to neighbours - Blue	Less than	-35
Mean difference to neighbours - Green	Less than	-35
Mean difference to neighbours - Red	Less than	-20

The relational statistics were useful when separating shelterbelts from their surrounding neighbors using values smaller than -35, -35 and -20 for the blue, green and red bands respectively.

Although there is no surface validation to support an accuracy assessment of all shelterbelts that fell within the study site it is anticipated that eCognition will be able to depict shelterbelts from the surrounding landscape using high resolution imagery with a high degree of accuracy.

Species separation

Since shape characteristics asymmetry, shape index and density all use length, width and\or area in their calculations, they are not truly independent of one another therefore only one could be used in the MDA. For the analysis presented we only used the density statistic but did find similar results using the asymmetry and shape index attributes. At the time of the analysis the relational parameters were not yet utilized but will be in future studies. A list of the variables used in the MDA is shown in Table 3 along with the mean values for each variable by species type.

The mean spectral reflectance values showed American elm belts to have the highest values and trembling aspen\Manitoba maple belts to have to lowest reflectance values in each of the blue, green and red channels. Within the shape parameters it is of interest to note the acute willow belts had the highest width, the green ash compellation of belts types had the highest length\width ratio and that aspen\Manitoba maple belts had the greatest degree of density.

Table 3: Mean species values for all attributes used in the MDA.

	Acute Willow	American Elm	Aspen MB Maple	Green Ash	Green Ash Caragana	Green Ash Poplar
Blue - Mean	84.44	110.2	57.26	90.23	69.83	73.9
Green - Mean	119.85	139.75	96.49	114.02	95.33	91.22
Red - Mean	119.39	138.08	86.97	105.95	83.48	79.6
Area	781.12	460.23	526.65	1066.24	512.02	640.39
Length	81.61	72.14	71.51	143.14	111.1	121.95
Width	8.91	6.57	7.92	6.4	4.89	4.52
Border length	350	276.75	317.78	458.38	343.7	446.25
Length \ width	9.04	11.35	10.32	24.51	30.04	24.25
Density	1.26	1.18	1.3	0.78	0.86	0.89

Table 4 lists the MDA coefficients for each belt polygon attribute used in the analysis on each MDA axis. When MDA attempts to maximally separate the belt attribute dataset variance by species it also reduces the numbers of dimensions to simplify the information. In this case we decreased from 9 dimensions or 9 attributes to 3 dimensions where the human brain is able to interpret what the analysis is extracting. The coefficient scores can be interpreted as the amount of influence each attribute has during the variance separation. Positive and negative values are relative in that separation is still being accomplished but using data variance in opposite directions.

Table 4 – MDA Coefficient scores for MDA axes MD1, MD2 and MD3.

	MD1	MD2	MD3
Blue - Mean	-0.2773	0.03522	0.05242
Green - Mean	0.20455	-0.23337	-0.07053
Red - Mean	0.00213	0.22401	0.01959
Area	-0.00184	0.00288	0.00007
Length	-0.00016	-0.04498	-0.03994
Width	0.30619	0.08203	-0.44183
Border Length	0.00388	0.00245	0.01761
Length \ Width	-0.02464	0.07864	-0.0136
Density	-0.30441	-0.18071	0.38398

We see that width had the largest influence during separation with density separating at nearly the same amount but in opposite directions on MD1. Both attributes decreased slightly on MD2 but had their largest influence on MD3. Spectral signatures provided high influence on MD1 and MD2 especially blue and green on MD1 and green and red on MD2. Length, area and length\width provided very little information when trying separate by belt species on all axes.

CONCLUSIONS

Although the results of the shelterbelt identification Boolean logic queries were very promising at 93.6%, we feel the results could be improved upon by using a range of values with a top and bottom limit parameter to identify belt characteristics. Instead of relying on greater than or less than logic on a single value, a range of values is likely more accurate by eliminating more polygons that do not share the more precise spectral, shape and relational range of values. Basically this would make the acceptance rules less forgiving to increase overall accuracy.

Using the relational statistic of spectral mean difference to neighbors proved to be problematic at times depending on the time of image acquisition and the main direction of the shelterbelt. If the imagery was captured early morning or late afternoon for a shelterbelt with a north\south orientation a large parallel shadow would appear within the segmented polygons dataset. Since the equally long, linear and dark shadow feature shared nearly half of the total border for that belt it was strongly weighted in the mean difference to neighbor attribute calculation. The shadow anomaly has a very low spectral signature in all channels forcing the typically negative spectral relationship to neighboring polygons to either an equal or positive value. This situation is avoidable by either excluded imagery acquired early morning or late afternoon or by adding a vector file with ancillary information that indicates time of acquisition and programming eCognition to avoiding using that imagery. Of course the actual time used in the exclusion process is variable depending on time of year and latitude of site. It should be noted the belts with an east\west orientation did not experience the same difficultly.

MDA species mean value results from Table 3 can be used to perform a supervised classification of only shelterbelt polygons. We can conclude if the shelterbelt in question has a large width value it is has the highest probability of being an acute willow shelterbelt. Acute willow has an average width of 8.91 m, higher than any other species type. The same can be concluded for a belt with high density, it has the highest probability of being a trembling aspen\Manitoba maple belt. Trembling aspen\Manitoba maple belts have a mean density of 1.30, again higher than any other species type. If a belt has a high length\width ratio value between 20 and 35 we can assume it has a green ash component within it with as those belts have a mean value between 24.51 and 30.04. All other species types average length\width ratio is between 9.04 and 11.35.

We can also use the MDA coefficient scores from Table 4 to provide influence to our findings from the species mean value results in a weighted supervised classification of shelterbelt polygons. Since width has a large influence on MD1 of 0.30619 our weight of a belt polygon with a high width value being acute willow should be large. The same can be said of density which has a large influence on MD1 of -0.30441 and therefore should also have a large weight of being trembling aspen\Manitoba maple. Conversely a belt polygon with a high length\width value should have a lower weight of containing green ash because the length\width attribute had a small influence on all MDA axes no greater than 0.07864.

It is through the combination of mean species attribute values and the influence of individual attributes have on the segmentation process that we feel it is possible to classify shelterbelts by species across a landscape using spectral, spatial and relational characteristics derived from high resolution imagery.

FUTURE WORK

The amount of surface validation data needs to be increased. We plan on tripling the amount of test data we have within the rural municipality of North Cypress during the summer months of 2007 to solidify our results.

We feel using a range of values for each belt attribute in combination with Boolean logic will increase overall accuracy in identifying shelterbelts on the landscape. This improvement should be a simple adjust within the existing SQL statements.

We feel standard deviation of shelterbelt polygons used in MDA may provide more separation between species as belts species do have differences in texture. Large species such as acute willow appear heterogeneous in high resolution imagery while caragana belts appear very homogeneous. There is also the theory that belt standard deviation may provide information on belt age. Old belts appear heterogeneous with complex crown structures and lots of shadow intermixed while young belts appear homogeneous with simple crown structures with little shadow intermixed. Age is a critical factor when calculating biomass.

PFRA currently has access to SPOT-5 panchromatic imagery at a spatial resolution of 2.5 m for the entire prairie province agricultural extent. Developing an inventory tool with the new SPOT-5 imagery will be the focus of any applied research work. PFRA is also in negotiations to cover the entire agricultural extent of Manitoba in the same aerial photography format of blue, green and red colour at 62.5 m resolution used in this study. It is anticipate more shelterbelt species identification work be done once this imagery is available.

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FIELD WINDBREAK / LIVING SNOW FENCE CROP YIELD ASSESSMENT

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Abstract: Field windbreaks and living snow fences, when placed in the proper locations, can serve a useful purpose and be very beneficial in enhancing rural landscapes. It is important to record crop yields around these plantings using modern yield monitoring equipment to show producers where the yield differences are, including yield increases and other positive benefits of these plantings.

This study funded by the Minnesota Department of Agriculture is designed to evaluate and document crop yields grown on both sides of field windbreaks or living snow fences for a 3 year period from 2005 to 2007. Yield data will be collected from modern GPS/yield monitoring and mapping systems which are on the combines of the cooperating farmers. We also hope to conduct a survey of producers who have planted these conservation practices to identify why they prioritized these practices on their farm and to document positive as well as negative comments about the plantings.

Previous USDA research suggests that there are yield advantages to these conservation tree and shrub plantings. These plantings showed an increase in yield of 12% in corn and 8% in soybeans. We would like to verify and update this research using various plantings in Minnesota. If crop yields are higher or equal to field averages, more producers may be encouraged to establish these plantings on their farm. Field windbreaks and living snow fences reduce winter fatalities and accidents, benefit wildlife, enhance rural aesthetics, reduce blowing snow problems, reduce snow removal costs, protect top soil, and much more.

Key Words: Field windbreaks, living snow fences, soil erosion, tree and shrub plantings.

EFFECTS OF VEGETATION CONTROL METHOD ON GROWTH OF AGROFORESTRY TREE SPECIES

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Abstract: Most tree species grown in agroforestry plantings (i.e. shelterbelts, riparian buffers, alleycropping) are intolerant to vegetative competition and sites must be intensively cultivated to eliminate weeds. Herbaceous vegetation provides an environment suitable for voles which may damage seedlings. In addition, weeds may inhibit growth through allelopathy and reduce the amount of resources available to trees, thereby limiting growth and survival. Many studies have been carried out to investigate what factors limit seedling growth because of the presence of vegetative competition, however in productive habitats such as agricultural sites there is disagreement about what resources are most limiting to tree growth. To design optimal agroforestry systems, we must identify the factors of greatest importance to the growth of different species.

From 2003 to 2006 the AAFC-PFRA Agoroforestry Division has conducted research to quantify and compare growth reductions of commonly used agroforestry species, *Populus* xWalker, *Larix sibirica*, *Picea pungens*, *Fraxinus pensylvanica* and *Pinus sylvestris*, in response to vegetative competition. The study also compares the long term impacts of different combinations of in and between row vegetation management on growth of tree species. This paper presents research data from the study and provides recommendations on vegetation control practices for establishment of agroforestry systems.

Key Words: Agroforestry, vegetation control, establishment, weed control.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

METHODOLOGY FOR DETERMINING SHELTERBELT POROSITY USING VISUAL ESTIMATION FROM DIGITAL IMAGES

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Abstract: Porosity is linked to the wind reduction by a shelterbelt, which results in the reduction of wind erosion, pesticide drift and snow movement. Porosity also affects habitat suitability for different organisms. It is difficult to define a consistent optical porosity in field assessment of shelterbelts. In order to simplify and standardize the classification of porosity a visual reference scale was developed to allow one to determine the porosity of shelterbelts. To further standardize the classification of porosity, digital images were used for porosity estimation in the office rather than using field estimation. Using an MS-Access database to display the porosity scale, shelterbelt photo and data entry form, one can quickly estimate the visual porosity of many different shelterbelts. Compared to field estimation, this allows for a more consistent visual porosity estimate because one is comparing the shelterbelt against the scale under constant lighting conditions and because many shelterbelts can be assessed in a short period so that variability is less. As the user becomes more familiar with the scale, the estimate of visual porosity should become more consistent. This will result in more efficient classification and allow for visual porosity to become an accurate and effective indicator of shelterbelt function.

Key Words: Optical porosity, digital images.

MICLOCLIMATE DIFFERENCES IN AGROFORESTRY AND GRASS BUFFERS

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Abstract: Microclimatic differences are believed to influence evapotranspiration and soil and biological properties within a watershed. The objective of this study was to determine if the establishment of grass contour buffers and agroforestry (grass + tree) contour buffers change microclimatic parameters in agricultural watersheds. The study was conducted at the University of Missouri Greenley Research Center in northeastern Missouri. The study site contains three agricultural watersheds planted in a corn-soybean rotation. In 1997, cool season grass contour buffers were established in one watershed area and agroforestry contour buffers in another. As a control, the third watershed was left without any vegetative buffers. The buffer dimensions were three to four m wide at 35 to 50 m intervals perpendicular to the slope of the watershed. Corn or soybeans were planted between the buffers. Observations were made of wind, temperature, humidity and radiation during part of the 2006 growing season when corn was grown. Wind speed over the crop at the start of the measuring period was lower between the tree buffers than between the grass buffers. The mean wind speed between the agroforestry buffers for the ten day period from Julian day 161 to 170 was 2.25 m s^{-1}, while that between the grass buffers was 2.53 m s^{-1}. The difference due to agroforestry and grass buffers on wind, temperature, and solar radiation diminished as the corn grew taller. Further studies will investigate whether the observed decrease in wind speed causes reduced evapotranspiration in the agroforestry buffers and in the adjoining cropped areas.

Key Words: Corn, Soybean, Oak, wind speed, solar radiation, relative humidity, temperature.

INTRODUCTION

Agroforestry practices have been considered to be more environmentally friendlier than row-crop agriculture due to improvements in soil and water quality. Research shows that agroforestyry and grass buffers on corn-soybean watersheds reduce non point source pollution in runoff and improve soil properties (Udawatta et al. 2002; Seobi et al. 2005; Udawatta et al. 2006). These improvements have been attributed to organic matter addition, roots of the permanent vegetation, nutrient uptake, water use, and changes in soil parameters.

The permanent vegetation within the buffers may also change microclimate and thus directly and indirectly influence evpotranspiration, soil water dynamics, soil enzyme activities, carbon sequestration, and nutrient dynamics. Research shows that larger trees act as a barrier to wind speed and thereby reduce evpotranspiration and crop damage from crop fields as compared to open fields (Bird 1998). Wind breaks or shelter belts have been shown to influence incoming flux density or the amount of energy per unit surface area per unit time in the adjacent areas (Brandle et al. 2004). Studies speculate that reduced energy levels under buffers and adjacent areas promote more soil moisture storage, less evaporation, and diverse microbial activity. Studies on windbreaks have shown increased crop yields, yield quality, on the leeward side (Bird 1998; Huth et al. 2002), however this is clearer in fruit and vegetable crops than grains and may be related as much to the protection from damage provided by the windbreak as alterations in the microclimate. The response also varies with crop, wind break type, geographic location, moisture condition, and soil properties (Brandle et al. 2004). For example, long-term benefits of planting trees to improve soil quality and land rehabilitation on farms have to be traded off against tree effect on soil moisture in the drier regions of Australia (Cleugh et al. 2002; Huth et al. 2002).

The windbreak generates turbulence which, downwind of the break, serves to increase vertical mixing of heat and moisture (Cleugh 1998). While the agroforestry buffers described in this study can be considered as porous windbreaks, the repeated linear structure adds complexity. In particular the proportion of the crop that may lie in the sheltered 'quiet zone', compared to that in the turbulent 'wake zone', is likely to be greater than in a single extended windbreak situation. The precise extent of the different zones is sensitive to the individual site's upwind surface roughness (turbulent structure of the incident wind), as well as the porosity of the windbreak.

In the 'quiet zone' one would expect less turbulent mixing resulting in warmer, moister conditions compared to those in the 'wake zone' which experiences greater turbulence and greater evapotranspiration (Cleugh 1998). However, the evapotranspiration process is complex due to the stomatal response of the vegetation to changing conditions and moisture availability, and it is possible that the opposite effect could be caused by the change in humidity and temperature.

Studies are limited that examined alley cropping buffer effects on microclimate. These buffer practices are different from windbreaks as they have been somewhat equally spaced creating crop alleys. In general the 'quiet zone' will extend downwind of the windbreak for a distance equal to a number of times the height, H, of the barrier (depending on the permeability of the buffer). In the agroforestry area the distance between buffer strips is only of the order of 10H. Therefore, the microclimate within crop alleys and buffers must be different from regular crop areas. The objective of this study was to evaluate differences in microclimatic parameters among crop, grass buffer, and agroforestry buffer areas. It is anticipated that the differences in microclimatic parameters could be used to explain water use, soil properties, enzyme activities, and carbon sequestration as well as environmental quality.

MATERIALS AND METHODS

Experimental site and management

The north-facing experimental watershed is located at the University of Missouri, Greenley Memorial Research Center near Novelty, Missouri (40° 01' N, 92° 11' W; Fig. 1). The watershed was under a corn (*Zea mays* L.)-soybean (*Glycine max* (L.) Merr.) rotation, with no-till land preparation and contour planting since 1991 (Udawatta et al. 2002). The 3.16 ha grass (CGS) buffer and 4.44 ha agroforestry (AGF) watersheds consist of 4.5 m wide buffer strips at 36.5 m apart (22.8 m at lower slope positions). The grass-legume combination planted throughout the buffer strips included redtop (*Agrostis gigantea* Roth), brome grass (*Bromus* spp.), and birdsfoot trefoil (*Lotus corniculatus* L.) that were established in 1997. Pin oak (*Quercus palustris* Muenchh.) trees were planted in the center of the buffer strips at 3-m spacing in the agroforestry watershed. Grass waterways on both watersheds consist of Kentucky 31 fescue (*Schedonorus phoenix* (Scop.) Holub). Details on watershed management, parent material, soils, experimental design, and climatic data can be found elsewhere (Udawatta et al. 2002; 2006). The experiment was established in June 2006 during a corn-year. Corn was planted on April 14, 07 at 87,000 seeds ha^{-1} and harvested on September 27. Average corn yield across the two watersheds was 8.5 Mg ha^{-1}.

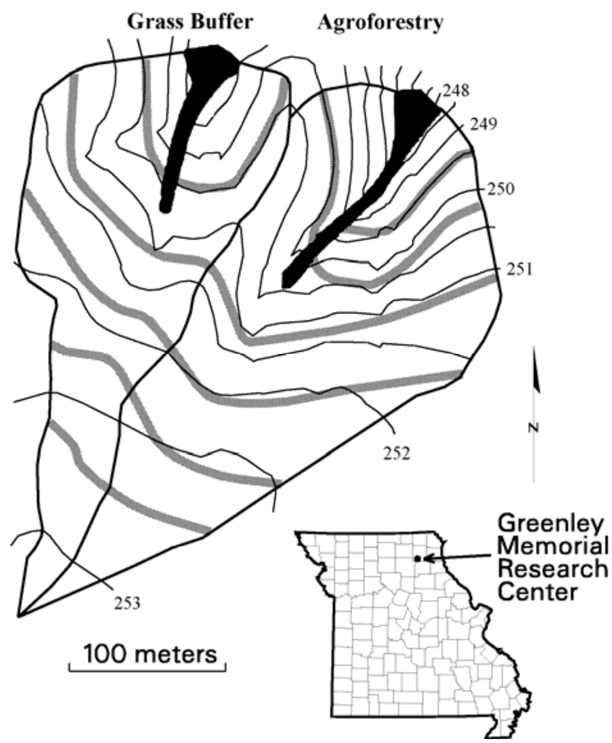

Fig. 1: Grass buffer (grass only) and agroforestry (grass+trees) buffer watersheds with 0.5 m interval contour lines (black), buffers (gray), grass waterways (wide black) and microclimate station locations (circle). The inset map shows the study watershed location at the Greenley Research Center, Missouri.

Parent material, soil, and climate

The soil parent materials are glacial till and wind-blown Peorian loess (Unklesbay and Vineyard 1992). Soils on the two watersheds include, Putnam silt loam (fine, smectitic, mesic Vertic Albaqualf), Kilwinning silt loam (fine, smectitic, mesic Vertic Epiaqualf) and Armstrong loam (fine, smectitic, mesic Aquertic Hapludalf; Watson 1979). About 600 mm of the 920 mm long-term average annual precipitation falls from April through September in the area (Owenby and Ezell 1992). Mean annual air temperature is approximately 11.7°C with an average monthly low of -6.6°C in February and an average monthly high of 31.4°C in July (Owenby and Ezell 1992). Snow can stay on the ground for extended periods and snowfall averages about 590 mm per year.

Microclimate stations and data collection

Treatments are crop areas, grass buffers, and agroforestry buffers. Microclimate stations consisting of net radiometers, wind speed, wind direction, relative humidity, and temperature sensors were installed on a mast. Cables from the sensors were connected to a CR23X data logger to store microclimate data at 10 minute intervals. Two microclimate stations were installed on the agroforestry watershed approximately 12 and 3 m south from the third buffer (Fig. 1). One microclimate station was installed on the crop area of the CGS watershed approximately 12 m south from the third buffer. Two additional microclimate stations, one on each watershed, were installed on the third buffer on the grass buffer of the CGS and agroforestry buffer of AGF watersheds. The instruments within the crop areas are placed at a height of 3m such that they remain above the canopy whether the crop is corn or soybeans.

Observations were made of solar radiation, temperature, humidity, wind speed and direction each 10 minutes and averaged to hourly values. These are the meteorological parameters required to estimate the potential evapotranspiration (Monteith 1981). For this paper we will be concerned with the observations of wind speed, which are expected to be directly affected by the buffers, and the temperature and humidity, which may be affected by changes in turbulence. Incoming solar radiation was not analyzed at this stage as the buffers do not significantly contribute shading at this latitude (40°N; Cleugh 1998). Average solar radiation, wind speed, humidity, and temperature were calculated for each day to compare differences among the three treatments and differences among the three crop areas with varying distances from buffers. For the second analysis the data was averaged for ten-day periods (dekads). Results were analyzed and graphical products created using Matlab.

RESULTS AND DISCUSSION

In the plots presented each data field has been averaged over ten days and the points plotted at the center of the ten day period. For example, the mean temperature for the ten day period from day 200 to 210 is plotted at day 205. The mean fields for each parameter were calculated for the twenty-four hour periods, and then also for daytime hours (estimated as 0700 – 1900 CDT). The first of these is to identify whether trends are more noticeable if one removes the night-time hours for which the various fields are expected to show less variation between sites such that the inclusion of overnight observations only serves to smooth the readings and reduce the differences. The second limited period corresponds to the mid-day period during which there is the greatest insolation and highest temperatures which produce the largest fluxes of moisture and energy.

In the first year of the study the crop in place was corn and the instruments were installed in June. This was part way into the growing season and, as such, restricted the ability to capture the variations between crop areas in the important, early part of the season. When the instruments were set up on day 160 the canopy was already at a height of 1m and as the crop grew through the season it approached the height of the instruments. This meant that detailed examination and comparison of the observed parameters is problematic as the height of the observation above the canopy decreases over time. The crop was harvested around day 268.

Wind

The most interesting field is that of wind. One would expect that the different buffer strips would have a direct impact on the wind velocity and turbulence. The question is whether this influence produces a significant difference between the crop sites. The indirect impact of turbulence variations could be reduced mixing between the canopy and the atmosphere leading to differences in near-surface humidity and temperature. The major influence on the wind speed in all locations is that of the growing crop. What is observed is a consistent reduction in wind speed as the distance between the canopy top and the anemometer decreases at all sites. However, as shown in Fig. 2, there is no significant difference between the speeds observed at each of the sites until the time the corn is cut. In fact the observations between agroforestry buffers show slightly higher speeds than between the grass buffer, but as the crop canopy is so close to the instrument height this may well be due to extreme microscale influences of the canopy morphology in the vicinity of the anemometers. After the crop is cut on day 268 there is a clear signal that the wind is reduced in the crop area by the presence of the tree buffer, and this may be a precursor of what will be found when soybeans are planted.

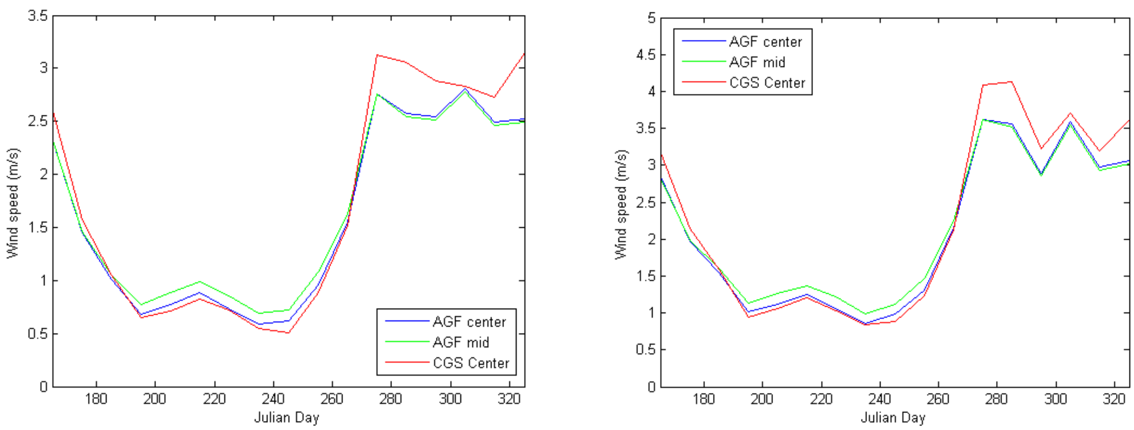

Fig. 2: 10-day mean wind speeds over corn at center of agroforestry buffered crop (blue), 3m into agroforestry strip (green) and center of grass buffered strip (red). The first plot shows the averages using all data, while the second plot uses only data taken during the daytime hours (0700-1900 CDT).[1]

When the crop is cut there is a sharp rise in the wind speed at all three locations as the canopy height changes rapidly from instrument height to surface level, 3 m below instrument level. However, the increase in wind speed over the crop with grass buffers is greater than that observed over the crop with forestry buffers. Figure 3 shows detailed wind speed observations from the period around harvest time. At the start of the period the two observations are similar with the speeds observed in the tree buffered area slightly greater at times. Then, after the crop is cut,

[1] This figure is in colour in the electronic version of the Proceedings (CD)

around day 268, it is clear that at most times stronger winds are observed at the site within strip bordered by the grass buffers.

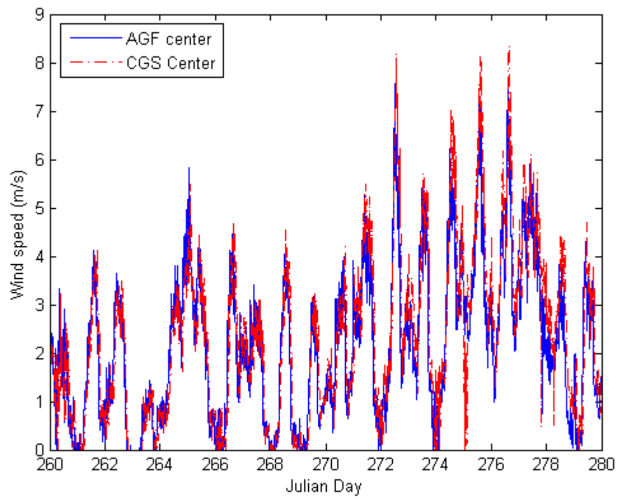

Fig. 3: 10-minute wind speed observations for the 20-day period over the time the corn is cut. The red line shows the observations in the center of the area bordered by the grass buffer, and the blue line shows the wind speed at the center of the tree-buffered strip.[1]

Temperature

As shown by the temperature record in Fig. 4 there is no observable significant difference in the temperatures observed at the three sites.

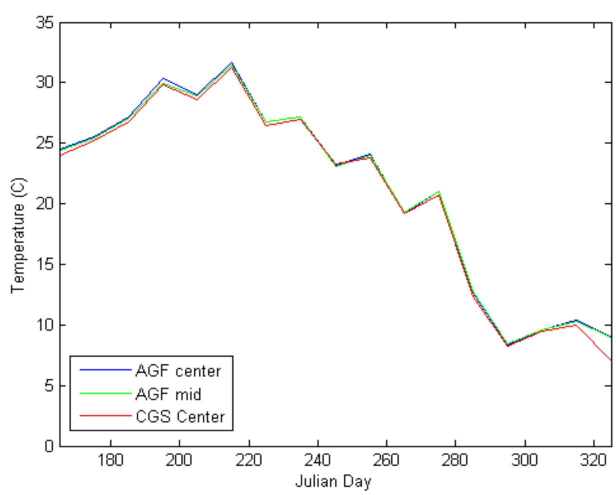

Fig. 4: 10-day mean temperatures over corn at center of agroforestry buffered crop (blue), 3m into agroforestry strip (green) and center of grass buffered strip (red).[1]

[1] This figure is in colour in the electronic version of the Proceedings (CD)

Humidity

In the observed humidity record it is seen that the grass buffer site generally has a greater relative humidity (Fig. 5). It is unclear what causes this while the corn is in place, as the impact of the canopy being extremely close to the instruments makes unequivocal data interpretation problematic. However, after the corn is cut the relative humidity between the grass buffers is still greater than that between the tree buffers. Increased humidity can be a result of lesser turbulence, therefore it is possible that turbulent mixing caused by the row of tree acts to reduce the humidity in their wake. Although one might expect the instruments to lie in the 'quiet zone', the necessity of placing the instruments high enough to remain above the crop canopy, also results in the instruments being close to the height of the windbreak at this stage in the growth of the trees. Also, the trees appear quite porous so that they may again act more to increase turbulence in their wake rather than produce a less turbulent 'quiet zone'. In order to resolve this issue it will be necessary to stratify the various observations based on the wind direction. The instrument that is 3 m south of the agroforestry, is also approximately 30m north of the next buffer strip. Therefore one would expect the observations at this site to be different depending on whether the wind is generally northerly or southerly.

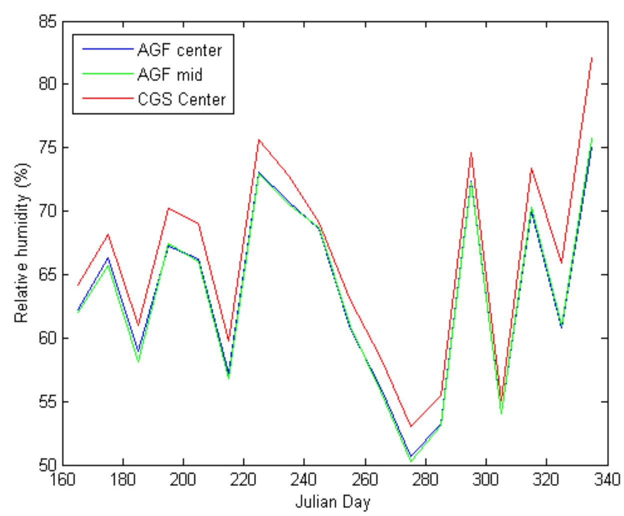

Fig. 5: 10-day mean relative humidity over corn at center of agroforestry buffered crop (blue), 3m into agroforestry strip (green) and center of grass buffered strip (red).[1]

SUMMARY/CONCLUSIONS

As the microclimatological instrumentation was not in place at the start of the growing season there is no information from that crucial crop development period regarding the variation of the atmospheric conditions over the crop that may have been caused by the different buffer types. Once the instrumentation is in place the corn has grown to an extent where it dominates the microclimate and any impact of the buffers in not discernable. However, the changes observed at

[1] This figure is in colour in the electronic version of the Proceedings (CD)

and after harvest time act as an indication of the influence of the buffers on the conditions over the crop.

Future work

In 2007 the crop will be soybeans. This crop will have a much lower canopy height providing a greater and more consistent distance between the canopy top and the instruments. On top of this the trees are growing rapidly meaning that the difference in canopy top between the trees and the crop will increase year to year. It should be possible with a crop with lower canopy height, and one with which the separation between instruments and canopy top remains fairly constant to more clearly determine the effect of the different buffer strips on the microclimatological conditions above the crop. With this in mind the winter 2006/7 period acts as a baseline for wind conditions with no crop in place, although winter winds are generally stronger than those in the growing season.

In 2007 we will be able to collect data for the entire growing season, including the critical early season period. This will allow assessment of the impact on the crops throughout that season. When the crop returns to corn in 2008 it will be possible to assess conditions before the corn grows to the height where it dominates the observation of the instrumentation. In particular estimation of evapotranspiration will be possible. Once observations have been collected for an entire growing season we will conduct comparisons of dekadal and seasonal patterns of measured climatic parameters including estimated evapotranspiration using a Penman-Monteith approach. Other possible avenues to pursue include stratifying by wind direction to see if turbulence and moisture are impacted differently by winds parallel to the buffer strips compared to winds across the buffers. More seasonal and diurnal cycles can be determined as more data is gathered.

ACKNOWLEDGEMENT

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SECTION 2

Bandes riveraines / Riparian Buffers

KEYNOTE SPEAKER

ECOLOGICAL FUNCTIONS OF RIPARIAN FOREST BUFFERS – FONCTIONS ÉCOLOGIQUES DES BANDES RIVERAINES BOISÉES

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Abstract: As an agroforestry practice, riparian forest buffers (RFB) can be either planned or unplanned combinations of trees, shrubs, and herbaceous vegetation adjacent to streams in agricultural settings. Depending on local conditions, RFBs may be wetlands or include wetlands within the system. When planned and applied as a conservation practice RFBs may encompass other practices including engineered structures and wetlands. In addition to providing cover and food for upland wildlife and generating farm income, RFBs serve three major functions related to water resources: 1) they filter sediment, nutrients, pesticides, and other contaminants from surface runoff and subsurface flow; 2) they provide shade, detritus, and large woody debris inputs to aquatic ecosystems; 3) they stabilize stream banks and reduce flood velocities. In order to capture these functions, we designed a three zone buffer model which can be modified for uses in specific settings. The three zone buffer system includes an herbaceous filter strip between the forest buffer and the source area (usually row-crops). The second zone is managed forest and the first zone is permanent vegetation along the stream or water body. The most general water quality function of riparian forest buffers is to control the aquatic environment. In regions where woody vegetation was the original native vegetation, re-establishment of riparian forest buffers of native vegetation is essential for restoration of aquatic habitats. The role of riparian forest buffers in removing pollutants is less generalizable because it depends on the hydrologic connection between pollutant sources and the water bodies of concern. On one extreme, in hydrologic systems with relatively minor artificial drainage and little groundwater recharge, almost all flow is through RFBs. On the other extreme, with artificial subsurface drainage (drain tiles) or high amounts of groundwater recharge little of the flow will go through RFBs. Agroforestry practices including RFBs can essentially add hydrologic storage lost through agricultural and urban development. Bank stability provide by RFBs depends on roots biomass and the ability of trees to help de-water stream banks thus decreasing the likelihood of saturated banks failing. Examples of managed, restored, and natural RFBs from the Southeastern U.S. (Little River, GA), the U.S. Corn Belt (Bear Creek, IA), the northeastern U.S. (White Clay Creek, PA) and Eastern Ontario, Canada that include multiple conservation practices and have multiple objectives will be used to illustrate their functions.

Résumé : Les bandes riveraines sont une pratique agroforestière qui consiste à mettre en place en milieu agricole, volontairement ou non, des arbres, des arbustes et de la végétation herbacée dans le voisinage de cours d'eau. Tout dépendant des conditions locales, les bandes riveraines peuvent être des milieux humides ou comprendre des milieux humides. Lorsqu'intégrées dans un plan d'aménagement, les bandes riveraines peuvent faire appel à d'autres méthodes d'exploitation, dont l'ajout de structures et de milieux humides artificiels. En plus de servir d'habitat à la faune

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

riveraine, de lui offrir un accès à la nourriture, de représenter une source de revenu pour les exploitations, les bandes riveraines remplissent trois fonctions associées aux ressources hydriques : 1) filtrer les sédiments, les nutriments, les pesticides et autres contaminants provenant des écoulements de surface et des eaux de ruissellement ; 2) fournir de l'ombre aux écosystèmes aquatiques et l'alimenter en déchets et débris ligneux ; 3) stabiliser les rives des cours d'eau et diminuer la vitesse des crues. Pour mesurer ces fonctions, nous avons mis au point un modèle modifiable constitué de trois zones tampons pouvant être réutilisées dans des conditions précises. Le système à trois zones tampon est formé d'une bande riveraine d'herbacés insérée entre une bande forestière et une zone source (habituellement la culture en rangs). La seconde zone est une forêt aménagée et la première est formée de végétation permanente de part et d'autre du cours d'eau. La fonction principale des bandes riveraines touchant la qualité de l'eau est le contrôle de l'environnement aquatique. Dans les régions où la végétation ligneuse représente la végétation d'origine, le rétablissement de bandes riveraines composées de végétation indigène est essentiel à la restauration des habitats aquatiques. Le rôle des bandes riveraines quant à l'élimination de polluants présente moins de potentiel de généralisation étant donné le lien hydrologique entre la source des polluants et les plans d'eau touchés. D'un côté, dans le cas de systèmes hydrologiques disposant d'un petit bassin versant artificiel et de peu d'alimentation en eau souterraine, la circulation de l'eau se fait presque exclusivement au sein des bandes riveraines. À l'autre extrême, dans un contexte où l'on retrouve des tuyaux de drainage ainsi qu'une importante alimentation en eau souterraine, peu d'eau circule dans les bandes riveraines. Les méthodes agroforestières faisant appel aux bandes riveraines peuvent essentiellement contribuer à augmenter le potentiel de stockage hydrologique lequel aura souffert du développement agricole et urbain. La stabilité des rives des cours d'eau découlant des bandes riveraines dépend de la biomasse racinaire et de la capacité des arbres à assécher les rives des cours d'eau, et ainsi aider à diminuer la probabilité d'une défaillance de la saturation des rives. Des exemples de bandes riveraines aménagées, restaurées et naturelles se trouvant dans le sud-est des États-Unis (Little River, Géorgie), dans la région du maïs (Bear Creek, Iowa), dans le nord-est des États-Unis (White Clay Creek, Pennsylvanie) et dans l'est de l'Ontario au Canada incluant plusieurs méthodes de préservation et visant plusieurs objectifs serviront à illustrer les fonctions qu'elles remplissent.

RÉDUCTION DE LA POLLUTION DIFFUSE D'ORIGINE AGRICOLE À L'AIDE DE BANDES ENHERBÉES ET ARBORÉES

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Résumé : L'agriculture intensive est ciblée comme étant une source importante de contamination des eaux de surface et souterraine. L'objectif de ce projet consistait à mesurer, sous conditions naturelles, l'efficacité de bandes enherbées et arborées à filtrer les eaux de ruissellement et de drainage provenant des parcelles de maïs-grain fertlisées au lisier de porcs. Le site expérimental se composait de 4 blocs aléatoires comprenant chacun 3 traitements : (T1) une parcelle témoin occupée uniquement par une culture de maïs-grain sur une distance de 30 m, (T2) une parcelle occupée par une culture de maïs-grain suivie par une bande enherbée de 5 m de longueur et (T3) une parcelle occupée par une culture de maïs-grain suivie par une bande enherbée-arborée de 5 m comprenant huit peupliers hybrides. Les parcelles étaient munies de systèmes collecteur d'eau de ruissellement et de drainage reliés à des cabanons où se retrouvaient les équipements de mesure et d'échantillonnage. L'efficacité des bandes végétales (T2 et T3) par rapport au témoin sans bande (T1) a été calculée pour chaque paramètre de qualité de l'eau (MES, azote, phosphore, *E. coli*) sur la base des charges totales annuelles exportées des parcelles. Les résultats de l'année 2004 indiquent que la présence des bandes végétales s'avère très efficace pour atténuer les charges de polluants exportées par ruissellement. Par contre, ces bandes végétales augmentent considérablement les charges exportées par l'eau d'infiltration. De plus, l'ajout de jeunes peupliers (2 ans en novembre 2004) aux bandes enherbées n'a pas augmenté significativement le pouvoir épurateur de ce traitement.

Mots-clés : Bandes végétales filtrantes, pollution diffuse, ruissellement, drainage.

INTRODUCTION

L'agriculture intensive est souvent ciblée comme étant une source importante de contamination des eaux de surface et souterraines (Troeh et al. 2004). Les bandes végétales peuvent alors être utilisées pour filtrer le ruissellement et favoriser la sédimentation des particules transportées en suspension et des polluants qui leur sont associés (Duchemin et al. 2002; Duchemin et Majdoub 2004). Cette mesure de mitigation répond bien au contexte socio-économique du Québec qui favorise l'adoption de pratiques agroenvironnementales simples et peu coûteuses pour contrôler la qualité des eaux et gérer les engrais de ferme. Cependant, il existe une grande variabilité spatiale dans l'efficacité des bandes végétales filtrantes dues au climat, aux sols, à la topographie et à la végétation (Schultz et al. 1997; Schmitt et al. 1999; Damboise et al. 2001; Lee et al. 2003). L'ajout d'arbres à croissance rapide tel que le peuplier hybride aux bandes enherbées étant supposé augmenter leur capacité filtrante (Henri et Johnson 2005; Leguédois et al. 2005). L'objectif de ce projet consiste à mesurer, sous conditions environnementales québécoises, l'efficacité des bandes enherbées-arborées à améliorer la qualité physico-chimique des eaux de ruissellement et d'infiltration (drainage) provenant des parcelles de maïs-grain fertlisées au lisier

Dans Olivier, A. et S. Campeau, éd. 2007. *Associer arbres et cultures*. Actes du 10e Congrès nord-américain d'agroforesterie, Québec, Canada, 10-13 juin 2007.

de porcs. Le projet vise également à promouvoir l'utilisation de bandes végétales filtrantes mixtes comme mesure de mitigation pour réduire la pollution diffuse d'origine agricole (Duchemin et al. 2005).

DISPOSITIF EXPÉRIMENTAL

L'étude s'est effectuée à la Ferme expérimentale de l'IRDA située à Saint-Lambert-de-Lauzon, à environ 25 km au sud de la ville de Québec. Le site expérimental se compose de 12 parcelles aménagées sur un loam limono-argileux dont la pente est de 3 %, soit 4 blocs aléatoires comprenant chacun 3 parcelles de 5 m de largeur par 30 m de longueur (Fig. 1).

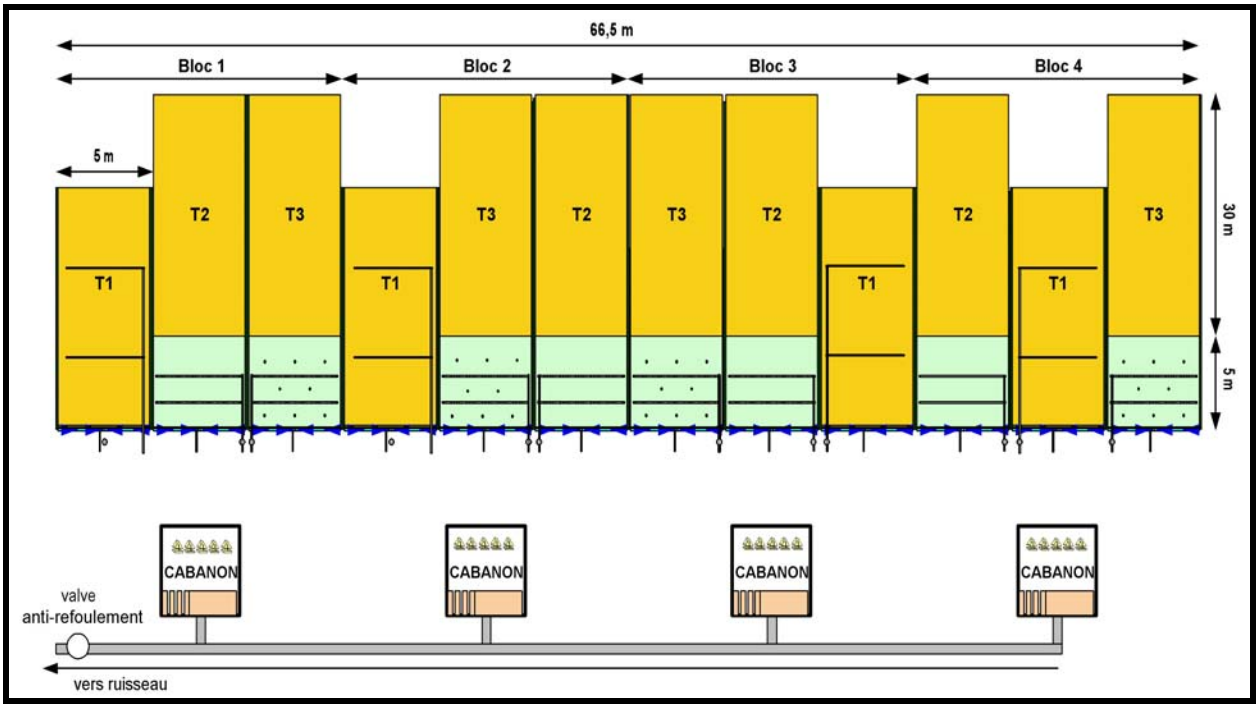

Fig. 1 : Dispositif expérimental composé de 4 blocs de 3 parcelles.[1]

Pour chaque bloc, on retrouve 3 traitements : (T1) une parcelle témoin occupée uniquement par une culture de maïs-grain sur une distance de 30 m, (T2) une parcelle occupée par une culture de maïs-grain suivie par une bande enherbée de 5 m de longueur composée à 45 % de fétuque rouge traçante (*Festuca rubra* L.), 45 % d'agrostide blanche (*Agrostis alba* L.) et 10 % de ray-grass vivace (*Lolium perenne* L.) et (T3) une parcelle occupée par une culture de maïs-grain suivie par une bande enherbée-arborée de 5 m. Cette dernière comprend huit arbres (peupliers hybrides CLONE 3230 *Populus trichocarpa* X *Populus deltoïdes* cultivar 'Boelare') aménagés en trois rangées sur l'espace enherbé (Fig. 2). Duchemin et al. (2004) présentent avec plus de détails l'aménagement du dispositif expérimental.

[1] Cette figure est en couleur dans la version électronique des Actes (CD)

Fig. 2 : Aperçu du dispositif des bandes enherbées et arborées.

Au début de chaque année, une culture de maïs-grain (*Zea mays* L.) fertilisée au lisier de porc (40 t/ha) a été établie sur les parcelles. Les parcelles sont munies de systèmes collecteur d'eau de ruissellement et de drainage reliés à des cabanons où se retrouvent les équipements de mesure et d'échantillonnage (Fig. 3 et Fig. 4).

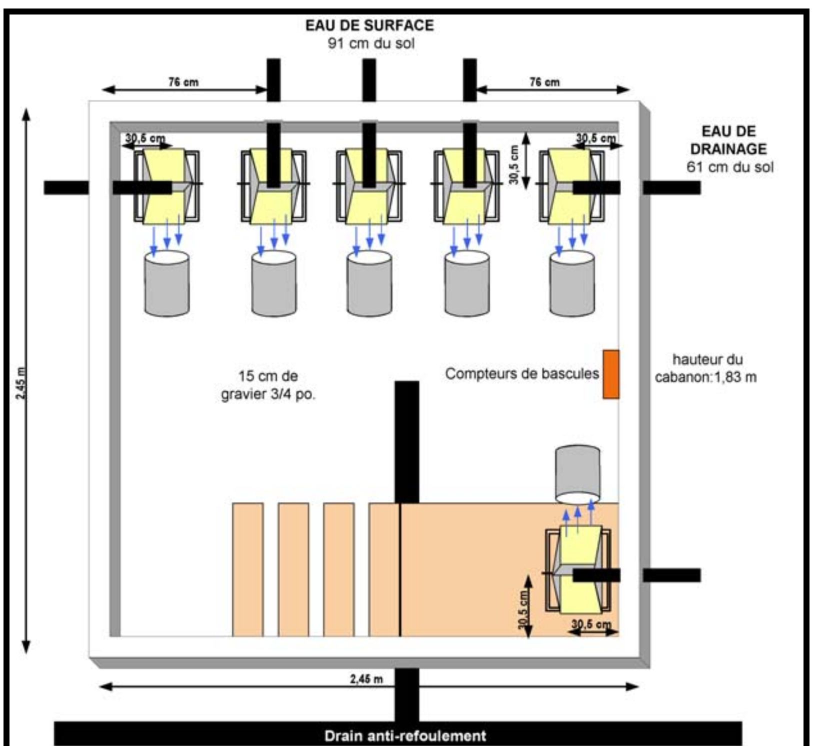

Fig. 3 : Cabanon abritant les équipements de mesure et d'échantillonnage.[1]

[1] Cette figure est en couleur dans la version électronique des Actes (CD)

Fig. 4. Augets basculeurs, bacs échantillonneurs et compteurs électroniques dans un cabanon.

Les paramètres mesurés sont les volumes d'eau (surface et souterraine), les pertes en matières en suspension (MES), en azote (ammoniacal NH_4, nitrate NO_3), en phosphore (P total, P soluble) et en indicateur microbien (*Escherichia coli*). L'efficacité filtrante des bandes enherbées et arborées a été établie en comparant les charges de polluants provenant des parcelles avec bandes à celles provenant des parcelles sans bande (témoins).

RÉSULTATS POUR L'ANNÉE 2004

L'efficacité des bandes végétales (T2 et T3) par rapport au témoin sans bande (T1) a été calculée pour chaque paramètre de qualité de l'eau sur la base des charges totales annuelles exportées des parcelles. Les Figures 5 et 6 présentent l'efficacité des bandes enherbées (T2) et enherbées-arborées (T3) à réduire les charges totales annuelles de polluants dans les eaux de ruissellement (R) et dans les eaux de drainage (D) pour l'année 2004 (mai à octobre).

Comme l'indique la Figure 5(A), les traitements avec bande végétale T2 et T3 ont réduit de 40,0 % et de 34,7 % respectivement les volumes d'eau de ruissellement évacués des parcelles. L'eau de ruissellement provenant des parcelles de maïs-grain a subi une importante perte de vitesse au contact des bandes végétales, augmentant ainsi sa rétention et son infiltration par le couvert herbacé. La présence de bandes végétales a réduit considérablement les charges annuelles de MES et de P total transportées par ruissellement, soit 86,7 % et 86,4 % pour le traitement avec bande enherbée T2 comparativement à 85,2 % et 85,3 % pour le traitement avec bande enherbée et arborée T3. Les charges annuelles de P dissous ont été réduites de 64 % et 57 % pour les traitements T2 et T3, respectivement. Les bandes végétales ont réduit de 57,1 % (traitement T2) et 46,8 % (traitement T3) les charges annuelles de NH_4 transportées par ruissellement. Dans une moindre importance, les charges annuelles de NO_3 des eaux de ruissellement ont été réduites de 33,2 % et 30,4 % pour les traitements T2 et T3 respectivement. Les bandes végétales T2 et T3 ont permis de réduire de 47,8 % et 56,7 % respectivement, les charges totales de *E. coli* transportées par ruissellement. L'ajout de peupliers aux bandes enherbées n'a pas eu d'impact significatif sur l'efficacité du traitement T3 à réduire les charges de polluants transportées par ruissellement durant cette première année de suivi.

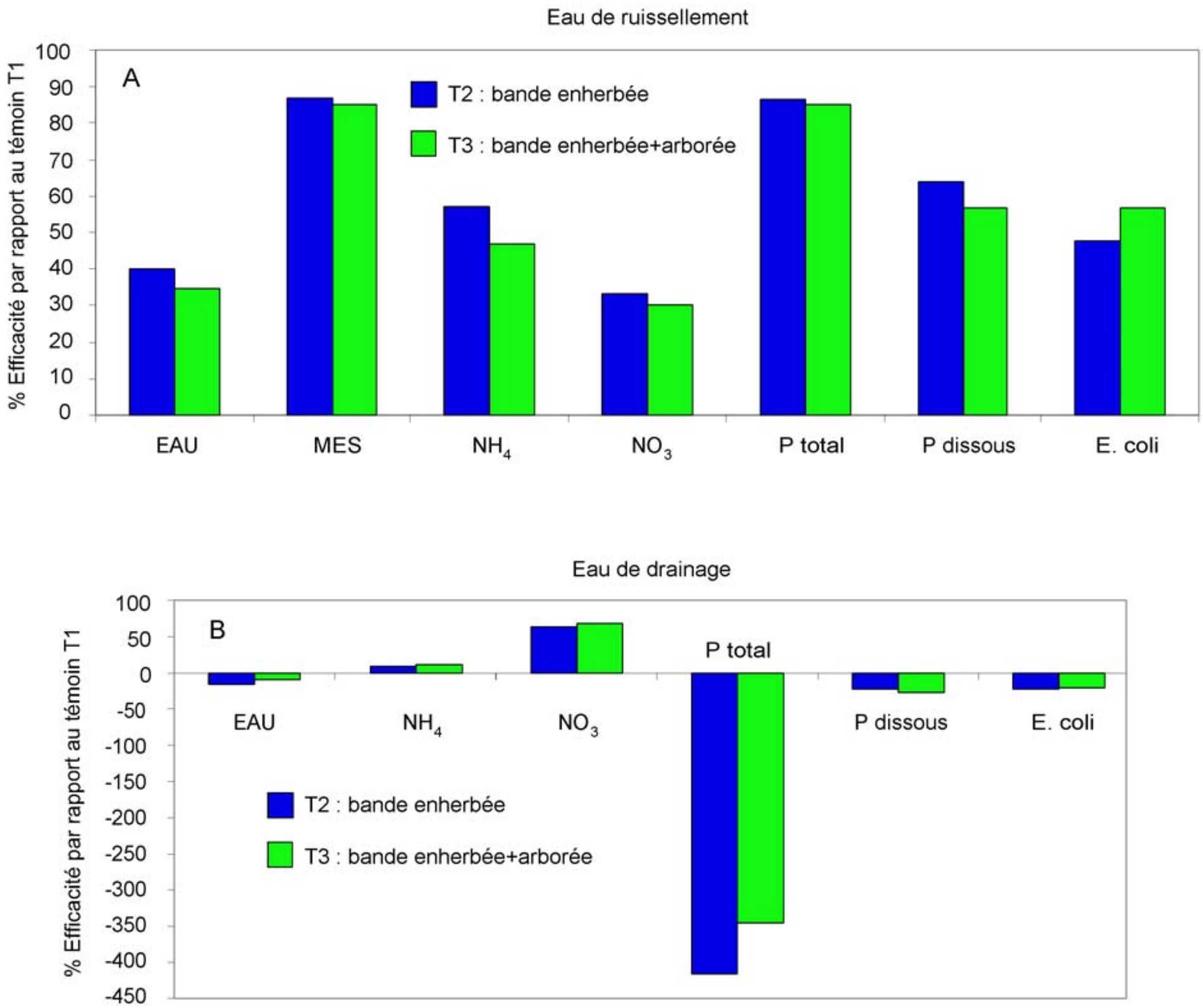

Fig. 5 : Efficacité des bandes enherbées (T2) et des bandes enherbées+arborées (T3) à réduire les charges totales annuelles de polluants dans les eaux de ruissellement (A) et de drainage (B) provenant de parcelles en maïs-grain fertilisées au lisier de porcs (année 2004).[1]

La présence de bandes végétales à l'aval des parcelles a considérablement influencé les quantités d'eau qui se sont infiltrées sous le couvert herbacé (Fig. 5B). En permettant un ralentissement des vitesse d'écoulement des eaux de ruissellement, les bandes végétales ont favorisé leur infiltration. En conséquence, les volumes d'eau drainés pour les traitements avec bande végétale T2 et T3 ont augmenté de 16,3 % et 8,2 % respectivement, par rapport au témoin sans bande végétale T1. Les charges en P dissous ont augmenté respectivement de 22,2 % et 28,2 % pour les traitements avec bande végétale T2 et T3. Cependant, ce sont les charges annuelles en P total qui ont subi les plus fortes hausses dans les eaux de drainage, soit 417 % et 346 % pour les traitements T2 et T3 respectivement. La présence d'une forte quantité de MES dans les eaux de drainage serait, en

[1] Cette figure est en couleur dans la version électronique des Actes (CD)

partie, responsable de cette situation. Les bandes végétales ont réduit considérablement les charges annuelles de NO_3 transportées par drainage, soit 63,3 % pour le traitement T2 comparativement à 68,1 % pour le traitement T3. Dans une moindre importance, les charges annuelles de NH_4 dans les eaux de drainage ont été réduites de 8,4 % et 10,9 % pour les traitements T2 et T3 respectivement. Finalement, les bandes végétales ont provoqué une augmentation des charges de *E. coli* dans les eaux de drainage, soit 22,2 % pour le traitement T2 et 28,2 % pour le traitement T3. Aucune différence significative n'a été observée entre l'efficacité annuelle des traitements avec bande enherbée T2 et avec bande enherbée et arborée T3.

La Figure 6 présente l'efficacité des bandes enherbées (T2) et des bandes enherbées+arborées (T3) à réduire les charges totales annuelles de polluants dans les eaux de ruissellement et de drainage (R+D). L'efficacité des bandes végétales à réduire les volumes totaux d'eau ruisselée et drainée a atteint 14,4 % pour le traitement T2 et 15,1 % pour le traitement T3. Une forte réduction des charges totales de MES et de P total a été observée dans les eaux (R+D) évacuées à la sortie des parcelles avec bande végétale, soit 86,9 % et 75,7 % respectivement pour le traitement T2 et 85,2 % et 76,2 % respectivement pour le traitement T3. Les charges en NH_4 et NO_3 ont également subi des réductions importantes en présence de bandes végétales, soit 53,4 % et 59,4 % pour le traitement T2, comparativement à 44,1 % et 63,2 % pour le traitement T3. Finalement, les bandes végétales ont permis de réduire de 21,6 % et 28,2 % les charges annuelles totales (R+D) de *E. coli* évacuées à la sortie des traitements T2 et T3, respectivement.

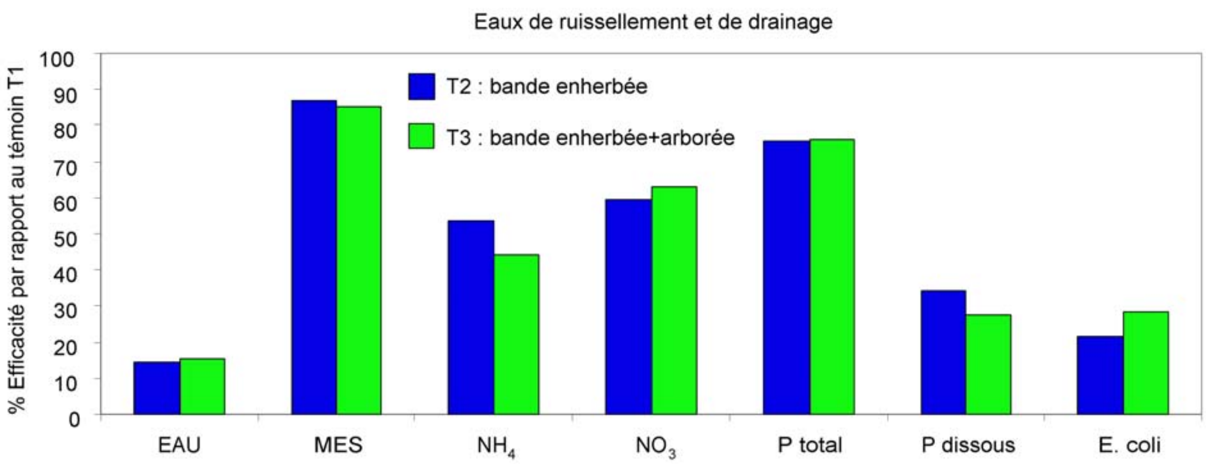

Fig. 6 : Efficacité des bandes enherbées (T2) et des bandes enherbées+arborées (T3) à réduire les charges totales annuelles de polluants dans les eaux de ruissellement et de drainage (R+D) provenant de parcelles en maïs-grain fertilisées au lisier de porcs (année 2004).[1]

CONCLUSION

Les résultats de l'année 2004 indiquent que, comparativement à une parcelle témoin sans bande végétale, la présence de bandes enherbée et arborée s'avère très efficace pour atténuer les charges de polluants exportées par l'eau de ruissellement. En contre partie, ces bandes végétales

[1] Cette figure est en couleur dans la version électronique des Actes (CD)

augmentent considérablement les charges exportées par l'eau d'infiltration. Cette situation résulterait, entre autre, du ralentissement des écoulements de surface lors de la rencontre de la lame d'eau ruisselée avec les bandes végétales. L'augmentation de rugosité attribuable à la présence du couvert végétal conduirait à une réduction de la vitesse de ruissellement qui favoriserait une augmentation de l'infiltration, et par conséquent, du transfert des polluants dans l'eau de drainage. Cependant, lorsque l'on considère le bilan global des charges exportées par le ruissellement et le drainage (R+D), la présence de bandes végétales assure une réduction importante de la pollution diffuse d'origine agricole. En effet, la présence de bandes végétales conduit à une réduction globale (R+D) d'environ la moitié des charges totales exportées. Les résultats de la saison d'étude 2004 montrent que l'aménagement de bandes végétales filtrantes à l'aval des parcelles agricoles constitue une mesure de conservation efficace pour réduire la contamination agricole attribuable à l'emploi de lisiers. Toutefois, l'ajout de peupliers aux bandes enherbées utilisées seules n'a pas augmenté significativement le pouvoir épurateur de ce traitement. Le système racinaire peu développé des jeunes peupliers (2 ans en novembre 2004) pourrait expliquer, en partie, ce manque d'efficacité.

REMERCIEMENTS

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ASSESSING RIPARIAN BUFFERS RESTORED OVER THE LAST TWENTY YEARS IN THE GRAND RIVER WATERSHED

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Abstract: An assessment of existing riparian buffers was conducted throughout the Grand River Watershed to determine the ecological performance of the buffers and the socio-economic implications to the landowners. Nineteen sites were assessed throughout the watershed that had been restored by fencing and/or tree planting over the last two to twenty years. Ecological assessments included fish populations, benthic surveys, vegetation inventories, and stream morphology. Fish populations were determined by electro-shocking following the Ontario Stream Assessment Protocol. Benthic surveys were conducted using the methodology for the Ontario Benthos Biomonitoring Network. Vegetation surveys were adapted from the Greenline Transect methodologies and stream morphology was adapted from various rapid assessment protocols. The study replicated any previous assessments that were completed in order to track changes in community composition at each site. As well, the other ecological assessments were completed to provide a baseline for future monitoring and comparison across sites. These ecological assessments provide an indication of wildlife habitat (on-shore and in-stream), stream bank stabilization, sediment and pollution entrapment, and cleaner water and give an understanding of overall stream health. A survey was also conducted to determine socio-economic perceptions from the landowners' perspective. Another component of this study, to put the buffers in context of the watershed, was to determine the upstream activities and their effect on the buffers downstream. This research will be used to promote buffers through the development of case studies and build on current buffer design and establishment.

Key Words: riparian, buffer, assessment, fish, benthic, survey, Grand River, index of biotic integrity

INTRODUCTION

Riparian Buffers in the Agricultural Landscape

A riparian buffer can be defined as an area of permanent vegetation (grass, shrubs, and trees) alongside a watercourse or wetland that can provide a variety of social, economic, and environmental benefits (Huel 1998; GRCA, n.d.; Lane, n.d.). These areas often comprise a small percentage of the landscape but have a disproportionately higher percentage of wildlife and perform a larger variety of functions compared to upland habitats (Fischer and Fischenich 2000). Some of the benefits and services provided by buffers are:

- stabilize stream banks through deep-rooting plants,
- filter sediments, nutrients, and pesticides from adjoining croplands,

- reduce flood and drought impacts,
- decrease operating costs,
- improve herd health,
- provide aquatic and wildlife habitat,
- connect areas by providing travel corridors, and
- allow for recreation and aesthetic value.

The increase in urbanization and agriculture has resulted in the loss of riparian buffers and a reduction in the services that they provide. This has resulted in reduced water quality, loss of productive aquatic and wildlife habitat, and soil loss. Research suggests that buffers can reduce the potential negative impacts of agriculture and improve the general health of agroecosystems (Lovell and Sullivan 2006). Riparian buffers along streams have been advocated as one method to restore biological integrity in managed landscapes (Wenger 1999) by providing a variety of services. Research also suggests that riparian buffers can improve watercourses, reduce soil erosion, and increase biodiversity (Lovell and Sullivan 2006).

The Grand River watershed

The Grand River watershed is located in Southern Ontario and is one of the largest inland river systems in Ontario (see Fig. 1). The river is 298 km long from the headwaters around Dundalk to the mouth located at Lake Erie and the drainage basin is 6,980 km^2. According to the 2001 census, approximately 67% of the land base is actively farmed and it has one of the fastest growing populations in Ontario.

The Grand River Conservation Authority (GRCA) has been helping landowners implement buffers for almost 20 years. The first riparian buffer demonstration site was established in 1987 through the Ministry of the Environment's Clean Up Rural Beaches program. In the early 1990s, five more demonstration sites were established through Agriculture and Agri-Food Canada's National Soil and Water Conservation Program. In addition to these sites, approximately 200 buffers have been established through the GRCA Rural Water Quality Program (RWQP). Currently, over 100 kilometres of stream have been fenced or buffered through the RWQP program throughout the watershed.

OBJECTIVE

The objective of the project is to carry out assessments of existing riparian buffers across the Grand River Watershed in order to verify the ecological performance of the buffers as well as the economic and social implications to landowners. The project will engage the landowners in the verification process and provide feedback to the landowners about the importance of their projects.

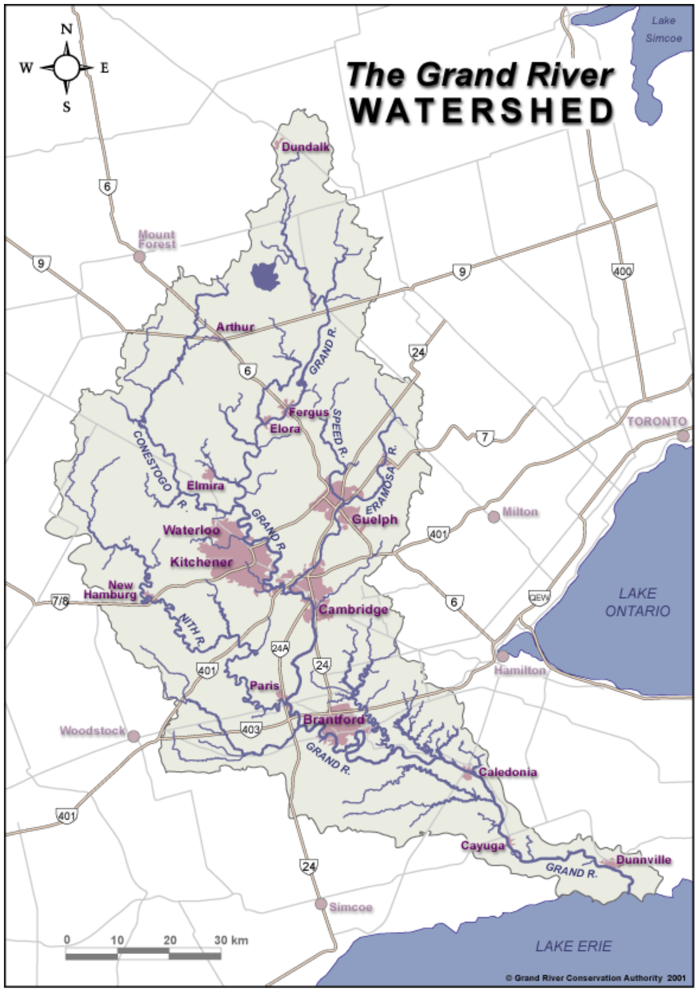

Fig. 1: The Grand River Watershed (Source: GRCA 2001).[1]

APPROACH

Study sites

Nineteen sites have been identified throughout the Grand River watershed for the buffer assessments. These sites were chosen based on their age, variety, and past assessments that were conducted. These include aquatic assessments of fish populations, invertebrate surveys, vegetation inventories and photo records. The focus of the research will be to replicate any assessments done previously and to provide a benchmark for future assessments.

Fish data

Fish sampling will be done by electroshocking the stream at various points. The fish are momentarily stunned which allows them to be netted and inventoried. Fish are one of the most

[1] This figure is in colour in the electronic version of the Proceedings (CD)

widely used and useful organisms for measuring water quality. They are typically present even in the smallest streams and are easily sampled and identified with the proper equipment and training. Fish are a diverse group of organisms and have a wide range of life requirements. Some fish are sensitive to changes in water temperature, substrate composition, stream flow, or various water chemistry parameters, while others are tolerant of change in their environment. The structural and functional variety of fish communities make them excellent indicators of water quality and provide an integrated view of stream health.

The sampling protocol for fish followed the protocol found in the Ontario Stream Assessment Protocol and Ministry of Natural Resources Field Collection Records. Fish data will be analyzed using the Index of Biotic Integrity (IBI) as developed by Karr (1981) and modified for use in Southern Ontario by Steedman (1988). Fish data was collected in 2006.

Benthic data

Aquatic invertebrates are organisms which live part or all of their lives in the water and have no internal skeletal system. By knowing what species or groups of bugs live in a water body, biologists are able to evaluate the ecological health and productivity of a system. There can be thousands to tens of thousands of individual bugs per square meter of streambed and hundreds if not a thousand or more unique species in a healthy reach. Each species has specific habitat needs and so each species responds differently to changes in either the chemical, physical, or biological components of their habitat. Some aquatic insects complete their life in a few weeks, whereas others may take 2-3 years and non-insect invertebrates, such as some mussels have been found to live for 100 years. Aquatic invertebrates do not generally move around as much as fish and they are easy to collect. Invertebrates can be used to detect both recent and more historic impacts as well track the recovery of a disturbed system.
The sampling protocol for benthos will follow the Ontario Stream Assessment Protocol and the Ontarion Benthos Biomonitoring Network and analyzed using an IBI. Benthic data will be collected in 2007.

Index of Biotic Integrity

It is important to use a number of different indicators to get a true assessment of stream health. One of the approaches to be used is the Index of Biological Integrity (IBI). This index is a scientifically validated tool using attributes of biological communities. A typical IBI will use 8-12 attributes (termed metrics) of a biological assemblage related to taxa richness, community composition, trophic structure, reproductive function, tolerance to human disturbance, abundance, and condition.

Each metric in the IBI denotes a quantifiable attribute of the biological assemblage that changes in a predictable way with varying levels of human influence. For example, species considered tolerant of some form of human disturbance like sedimentation could form a "tolerant" metric – degraded site would tend to have more of these tolerant species.
Ratings are assigned to each metric and summed together, the resulting index score characterizes the underlying biological or "health" of a site. A high IBI score indicates the biological assemblage is similar to a minimally impacted (reference) site of comparable size and type in the same geographic region. A low IBI score indicates the biological assemblage is significantly

different or degraded compared to regional reference sites. Narrative descriptions can be used to rate the integrity of a site as excellent, good, fair, poor, or very poor. The IBI index will be compared to other index tools to determine if the outcomes are similar.

Vegetation Data

The sampling protocol for vegetation will follow a modified version of the Greenline Transect methodology as described by Winward (2000). The vegetation will be inventoried to determine the presence and absence of native or invasive plants as well as the growth of the trees. The changes in vegetation will be noted. The vegetative assessment will also look at the presence of agricultural weeds. Discussions with the landowner will look at the perception of weed problems in the buffer. Vegetation data will be collected in 2007.

Rapid Assessment

Numerous rapid assessment tools exist for landowners to assess the health of watercourses on their property. A stream assessment tool has been developed by Trout Unlimited Canada for rural landowners and will be used to determine if there is correlation between this tool and the other methodologies. The rapid assessments will be conducted in 2007.

Social and Economic Data

The data will be collected through interviews and the use of a survey based on Graham and Ryan (2000). This questionnaire will be updated to gather information on social and economic benefits, as well as landowner attitudes. This information will be helpful in determining if landowner attitudes change as the buffer matures as well as to provide guidance for establishing new buffers. The surveys will be completed in 2007.

OUTCOME

Existing demonstration projects will be rejuvenated and renewed to increase the exposure of mature projects. Promotion of this project will be done both at the local and the provincial level via field days, factsheets, website and media releases. A report outlining the results of the project with recommendations for buffer establishment and assessment will be delivered at the end of the project. The report will also contain a series of case studies which will also be put on the GRCA and Conservation Ontario websites.

Preliminary results for the fish data show a general increase of 78% of total species across all sites from pre-restoration to post-restoration. As well, there was a 9% increase in number of species found across all sites from pre- to post-restoration. Photographs from pre- and post-restoration also show a positive change in vegetative cover and naturalization of the buffer. The photographs also provide evidence of bank stabilization and channel re-formation from the previously degraded sites (see Fig. 2 and Fig. 3).

Fig. 2: Campbell Drain tributary, pre-restoration 2001 (Source: GRCA).

Fig. 3: Campbell Drain tributary, post-restoration 2005 (Source: GRCA).

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STIMULATED RHIZODEGRADATION OF ATRAZINE BY SELECTED PLANT SPECIES

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Abstract: The efficacy of vegetative buffer strips (VBS) in removing herbicides from surface runoff is related to the ability of plant species to promote rapid herbicide degradation. A growth chamber study was conducted to investigate the rhizodegradation of ^{14}C-atrazine and the relationship of degradation with soil enzyme activities in the rhizosphere of eight selected plant species. The plant species included: 1) switchgrass, 2) eastern gammagrass, 3) tall fescue, 4) orchardgrass, 5) smooth bromegrass, 6) perennial ryegrass, 7) Illinois bundle flower and 8) hoary tick-trefoil. All plant treatments were grown in pots containing Mexico silt loam. Pots containing soil without plants were used as controls. Forages were grown to maturity (~3 months), and the rhizosphere soil was separated by hand from the plants. Radio labeled atrazine was then applied to the rhizosphere soil and incubated in the dark for 100 days. Rates of atrazine degradation in plant rhizospheres were significantly enhanced by 84 to 260% compared to the control. All plant plant species significantly enhanced atrazine degradation compared to the control, but eastern gammagrass showed the highest capability for promoting bio-degradation of atrazine in the rhizosphere. More than 90% of atrazine was degraded in the eastern gammagrass rhizosphere compared to 24% in the control. Biological dealkylation of atrazine strongly correlated with increased enzymatic activities of β-glucosidase (GLU; $r = 0.96$), dehydrogenase (DHG; $r = 0.842$) and fluorescein diacetate (FDA) hydrolysis ($r = 0.702$). The incorporation of forage species, into VBS designs will significantly promote the degradation of atrazine transported to the VBS. Microbial parameters widely used for assessment of soil quality, e.g., DHG and GLU activities, are promising as useful tools for evaluating the overall degradation potential of various vegetative buffer designs for atrazine remediation.

Key Words: Atrazine, β-glucosidase, dehydrogenase, fluorescein diacetate hydrolysis.

INTRODUCTION

Atrazine (ATR) has been used extensively in corn production for decades and an estimated 36.3 million kg of ATR were applied annually to more than 66% of all U. S. corn acreage (U.S. Department of Agriculture 2006). Recently, contamination of surface and ground water by ATR and its chlorinated metabolites has raised public health and ecological concerns (Hayes et al. 2002; Swan et al. 2003).

Multi-species vegetative riparian buffers strips (VBS) have been recommended as a potentially cost-effective conservation practice to reduce non-point source pollution to adjacent waterways (Schultz et al. 2000; Krutz et al. 2003). Previous researches investigating VBS used in agroecosystems have shown that this practice reduces the transport of both dissolved and sediment-bound ATR in surface runoff (Hoffman et al. 1995; Lowrance et al. 1997). The enhanced infiltration of runoff into the filter strips was identified as the major physical mitigation process (Misra et al. 1996).

Following the deposition of ATR, plant uptake has been shown to be limited and rhizodegradation was considered as the primary biotic mechanism for ATR dissipation in VBS (Lin 2002; Lin et al. 2004; Singh et al. 2004). The degradation of ATR in the rhizospheres of VBS could be accelerated through either physicochemical or biochemical processes. More than 15 degradation products that have been identified through theses processes (Jensen 1982; Fig. 1). The potential mechanisms for enhanced ATR degradation presumably results from increased soil enzyme activities and microbial biomass in the rhizosphere associated with incorporation of grass and woody species.

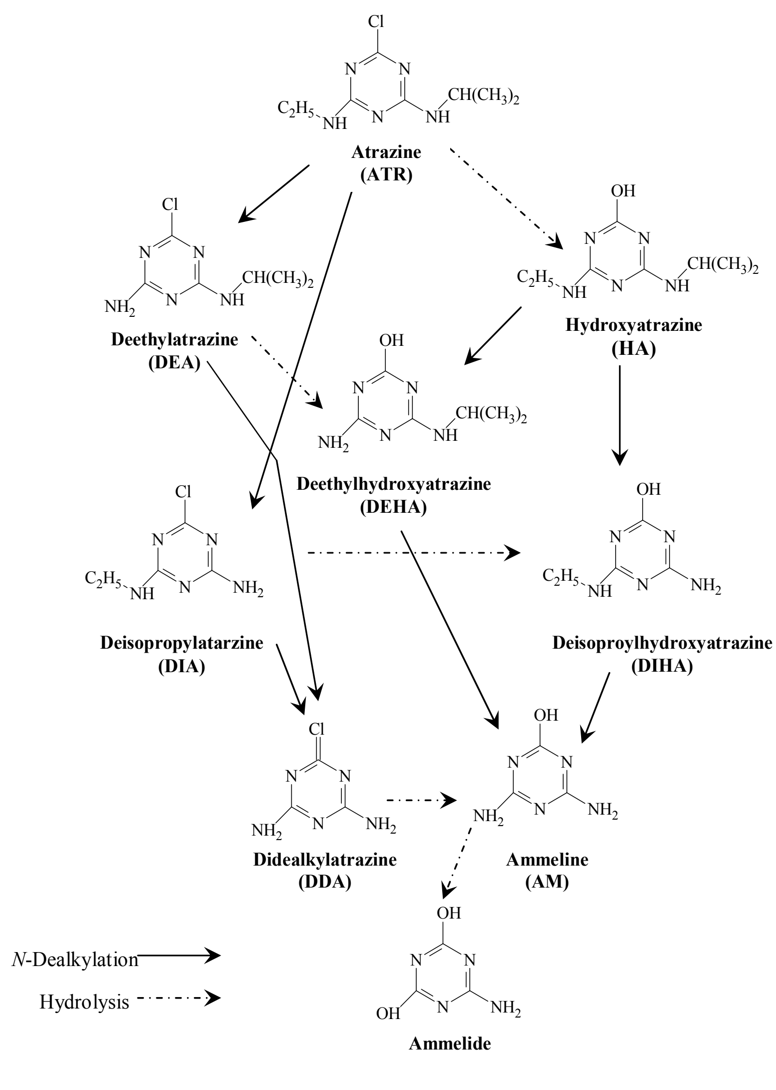

Fig. 1: Atrazine degradation pathway

The microbial degradation of ATR in rhizospheres usually requires a group or 'consortium' of microorganisms (Mandelbaum et al. 1993; Sadowsky et al. 1997). The associated biochemical processes involve a wide spectrum of enzymatic reactions, e.g., dealkylation, de-esterification, hydroxylation, dehalogenation, and oxidization (Bollag and Liu 1990; Ambus 1993; Mandelbaum et al. 1993). In addition, some soil enzymatic parameters utilized to assess soil quality in the past might be useful as indicators to evaluate the overall potential for herbicide biodegradation in VBS (Bergstrom et al. 1998; Zablotowicz et al. 2000). For instance, fluorescein diacetate (FDA) hydrolysis rates were used to estimate total microbial activity in soils (Schnurer and Rosswall 1982; Bandick and Dick 1999). FDA is a substrate for a wide variety of enzymes, including proteases, lipases, and esterases. Recent findings suggested that FDA hydrolytic activity was highly correlated with the de-esterification of fenoxaprop-ethyl (Zablotowicz et al. 2000). Reduction rates of triphenyl-tetrazolium chloride (TTC) have been used to estimate the overall metabolic activity of dehydrogenases in soil. In this assay procedure, dehydrogenases utilize TTC as an electron acceptor. Dehydrogenases are usually required to catalyze the oxidation and dehalogenation of a number of herbicides and other organic compounds (Waarrde et al. 1993; Beller et al. 1996). To date few studies have compared the effectiveness of different plant rhizospheres in enhancing dissipation of ATR.

Various VBS designs have been prescribed in the United States to encourage deposition of dissolved and sediment bound ATR in the surface runoff (Tim and Jolly 1994; Udawatta et al. 2004). However, there is relatively little information about the impacts of species selection on the rhizodegradation of ATR deposited in VBS. The objectives of this study were to investigate the effect of plant species on soil microbial enzyme activities and their association with the fate of ATR in selected plant rhizospheres.

MATERIALS AND METHODS

Experimental design

The experiment was conducted in a walk-in growth chamber with triplicate replications of seven forage species: 1) orchardgrass (*Dactylis glomerata* L., OR); 2) smooth bromegrass (*Bromus inermis* Leyss., SM); 3) tall fescue (*Festuca arundinacea* Schreb., TALL); 4) Illinois bundle flower (*Desmanthus illinoensis*, IB); 5) perennial ryegrass (*Lolium perenne* L., RYE); 6) switchgrass (*Panicum virgatum* L., SW); and 7) eastern gammagrass (*Tripsacum dactyloides*; EG). A control treatment with no plants was also included. Plants were allowed to grow to maturity (~3 months) in a mixture of 60% sand and 40% Mexico silt loam soil (fine, smectitic, mesic Aeric Vertic Epiaqualfs) collected from the A horizon of the soil profile. The rhizosphere soil was separated from the plants, and 0.1 µCi of ^{14}C-ATR was then added to the soil (100 µg/kg). Prior to ^{14}C-ATR application, a sub-sample of the rhizosphere soil was also collected at this time for determination of the β-glucosidase (GLU), dehydrogenase (DHG) and fluorescein diacetate hydrolytic (FDA) enzyme activities. The herbicide treated soil was then incubated in sealed jars for 100 days at 25 ^{o}C in the dark. Atrazine mineralization was measured using alkali traps (2 M NaOH) placed in the jars, and the traps were periodically replaced throughout the incubation period.

Chemical analysis

After 100-days incubation, 14C-ATR and its degradation products were sequentially extracted with 250 mL of 90% MeOH. The final extracts were concentrated and injected into a Shimadzu SCL-10Avp high performance liquid chromatography system (HPLC). ^{14}C-ATR and its degradation products were separated using a silica based Columbus C8 column (4.6 mm x 250 mm, 5 µm; Phenomenex, Torrance, CA). The radioactivity was detected by an in-line IN/US ScinFlow β-Ram Model 3 flow scintillation analyzer (HPLC–FSA). Metabolites were identified by retention times of unlabeled standards based on HPLC-UV detected at 220nm (Fig. 2A and Fig. 2B). Pairwise correlation analysis was performed to determine the relationships between the 14C-ATR degradation and soil enzyme activities.

RESULTS AND DISCUSSION

Atrazine degradation

Compared to the control, the extent of ATR degradation in the plant rhizospheres was significantly enhanced by 84 to 260%, through both enhanced *N*-dealkylation and hydroxylation activities (Fig. 3A and Fig. 3B). Among the plant species, eastern gammagrass showed the highest capability for promoting ATR degradation. More than 90% of ATR in the rhizosphere of eastern gammagrass was degraded to less toxic forms as compared with 24% in the control. *N*-dealkylation was the primary detoxification mechanism in the eastern gammagrass treatment, accounting for 58% of the ATR degradation. The extent of ATR degradation ranged from 46-65% in the other grass treatments. Rhizospheres of orchardgrass, smooth bromegrass and switchgrass showed comparable ATR degradation potential, with more than 60% of the applied ^{14}C degraded in these three treatments. Similar results from a field lysimeter study by Lin et al. (2005) also showed significantly enhanced microbial dealkylation and hydroxylation of soil ATR by many of the same forage species.

Enzyme activities and atrazine mineralization

Microbial enzymatic activities were significantly higher in plant rhizospheres than in the control bulk soil treatment (Fig. 4). When compared to the enzyme activities in the control, the FDA, GLU, and DHG activities in the plant rhizospheres were enhanced by 29-913%, 37-600% and 32-853%, respectively. The highest GLU and DHG activities were found in the eastern gammagrass treatments and the highest FDA activities were found in the switchgrass treatments. As expected, the higher enzyme activities in the plant rhizospheres led to higher mineralization rates of ring-labeled ATR (Fig. 4). Eastern gammagrass rhizospheres promoted ATR mineralization to the greatest extent, but mineralization was still less than 10% for all treatments. The ATR mineralization rates were highly correlated with the soil enzyme activities for GLU ($r = 0.857$) and DHG (0.763), but poorly correlated with FDA ($r = 0.494$; Fig. 4).

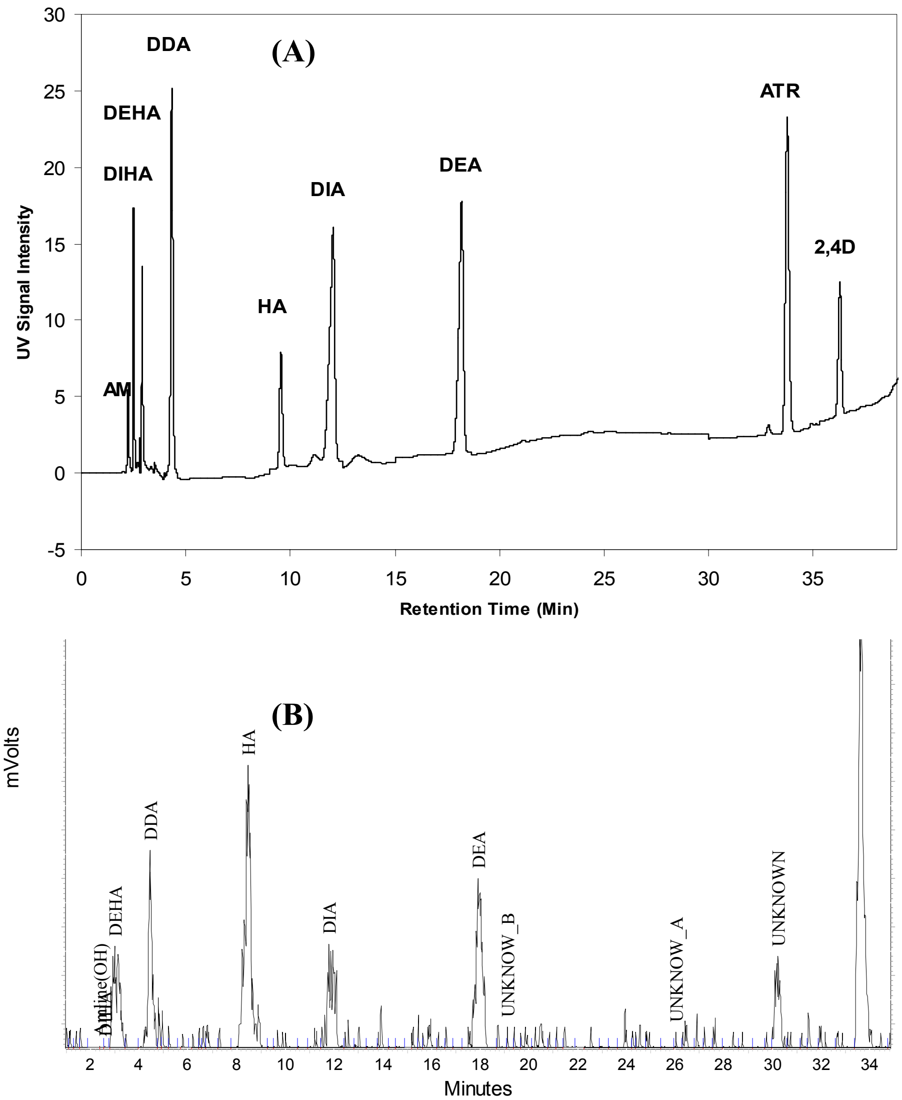

Fig. 2: Retention times of atrazine and its metabolites in HPLC-UV (A), and HPLC-FSA (B) analysis.

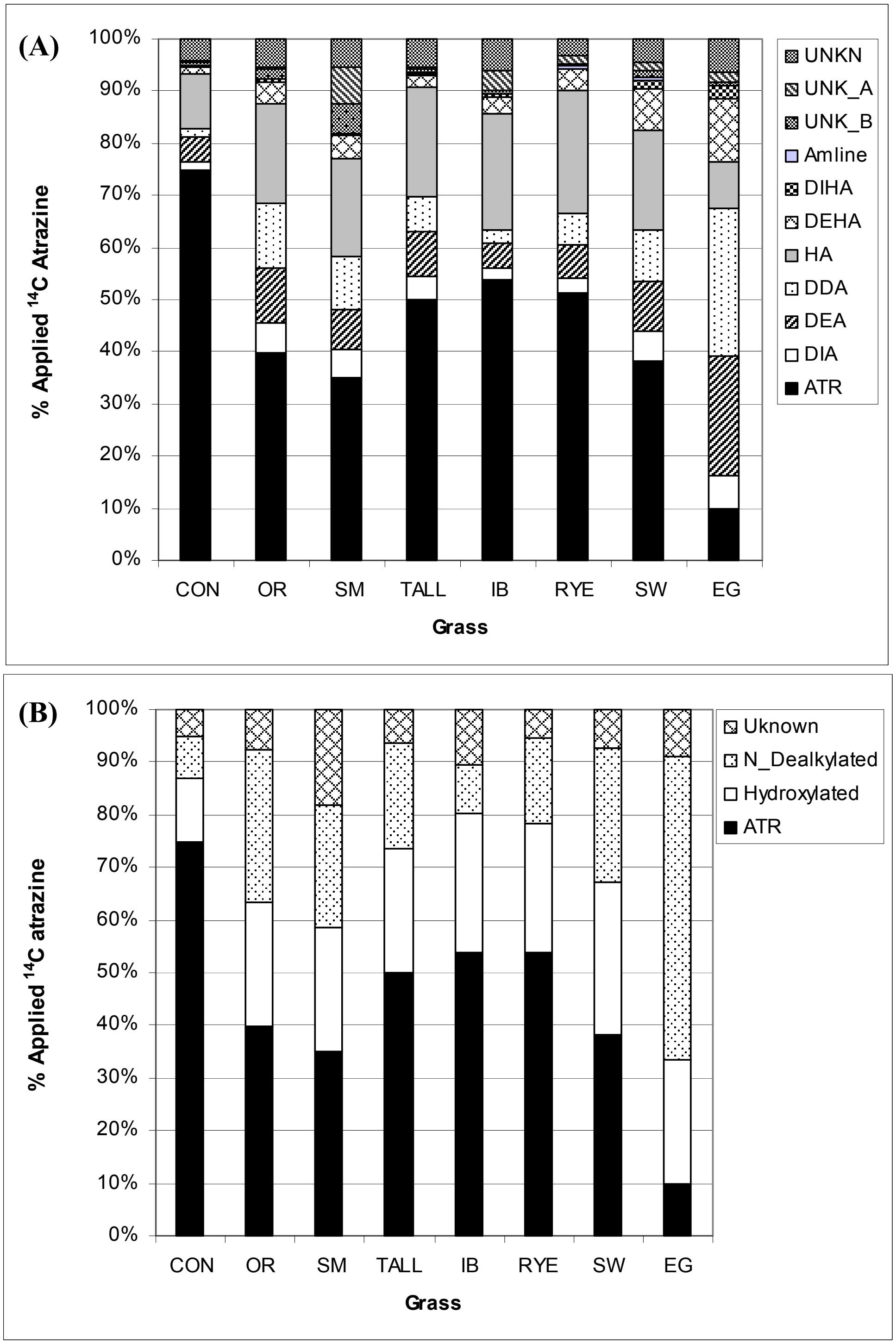

Fig. 3: Distribution of ^{14}C-atrazine and its metabolites in the soils collected from rhizospheres after 100-days incubation (A). Degradation products were categorized into parent, hydroxylated, *N*-dealkylated, and unknown metabolites (B). Bare ground control (CON), orchardgrass (OR), smooth bromegrass (SM), tall fescue (TALL), Illinois bundle flower (IB), perennial ryegrass (RYE), switchgrass (SW), and eastern gammagrass (EG).

The finding is consistent with the results of many previous studies investigating the fate of ATR in plant microcosms. Both laboratory and greenhouse tests by Marchand et al. (2002) also revealed a higher mineralization potential in planted than in bulk soils (i.e., no plants). The low mineralization rates were mainly associated with the lack of microbial enzymes to catalyze the cleavage of the triazine ring (Mandelbaum et al. 1993). However, a few degraders, such as *Pseudomonas* sp. strain ADP, isolated from sites heavily contaminated with ATR have evolved to utilize ATR and its metabolites as C and N sources (Mandelbaum et al. 1993). These degraders contained a series of identified Atz genes encoded on a self-transmissible plasmid pADP-1 (109-kb) responsible for various processes of ATR degradation and ring cleavage that rapidly mineralize the ATR into carbon dioxide. There is a need for future study to investigate the behavior and activities of these ATR degraders in VSB rhizospheres.

The pairwise correlation analysis revealed that the overall ATR degradation and *N*-dealkylation were strongly ($p<0.05$) correlated to the activities of all three enzyme activities, but GLU activity consistently has the highest correlation coefficients, particularly with respect to the formation of N-dealkylated metabolites (Fig. 5). In contrast, the formation of hydroxylated metabolites was not significantly related to any of the enzyme activities, suggesting that ATR hydrolysis in the rhizosphere soils was predominantly abiotic (Fig. 5). The strong correlation between these enzyme activities and ATR degradation rates suggested that any of these enzyme activities widely used for assessment of soil quality, particularly GLU, are very useful indicators of overall ATR degradation potential in soils.

The observed differences in enzymatic activities and ATR degradation potential among the forage species may result from their morphological and physiological differences. Eastern gammagrass and switchgrass, both C_4 species, partition more of their plant total fresh weight to roots than C_3 cool-season grasses (Jiang et al. 2002; Dhawan and Goyal 2004). Greater partitioning of carbohydrates to the root system likely resulted in higher concentrations of root-derived, bioavailable organic carbon and other nutrients in the rhizospheres of the C_4 species. Thus, the C_4 species apparently created more favorable rhizosphere conditions for various biochemical degradation processes to occur (Bollag and Liu 1990). Therefore, C_4 plant rhizospheres have a tendency to sustain higher ATR degradation activities and to support higher numbers of atrazine degraders than C_3 plants (Mahmood and Renuka 1990; Qian et al. 1997). Also, many oxidative and hydrolytic compounds contained in root exudates of C_4 species, such as hydroxamic acids, have been shown to be capable of directly hydrolyzing ATR and its chlorinated metabolites, resulting in rapid formation of the hydroxylated metabolites (Martin-Neto et al. 1994; Wenger et al. 2005).

The work reported here has identified eastern gammagrass as an outstanding candidate to be incorporated into VBS for mitigating the off-site transport of ATR via its ability to facilitate rapid ATR degradation in the rhizosphere. In addition, the results of a field rainfall stimulation study conducted at University of Missouri also demonstrated the superior performance of an eastern gammagrass buffer over other cool-season grass buffers in reducing both dissolved and sediment-bound ATR transport in surface runoff. Approximately 75-80% of the dissolved and sediment-bound ATR transported in surface runoff was removed by a four meters of eastern gammagrass buffer (Lin et al. 2007). Additionally, a four meters of eastern gammagrass buffer resulted in much greater reductions in transport of ATR than an eight meters of tall fescue VBS. Thus, the implementation of buffers utilizing eastern gammagrass could effectively improve both deposition and subsequent degradation of ATR with less land taken out of production.

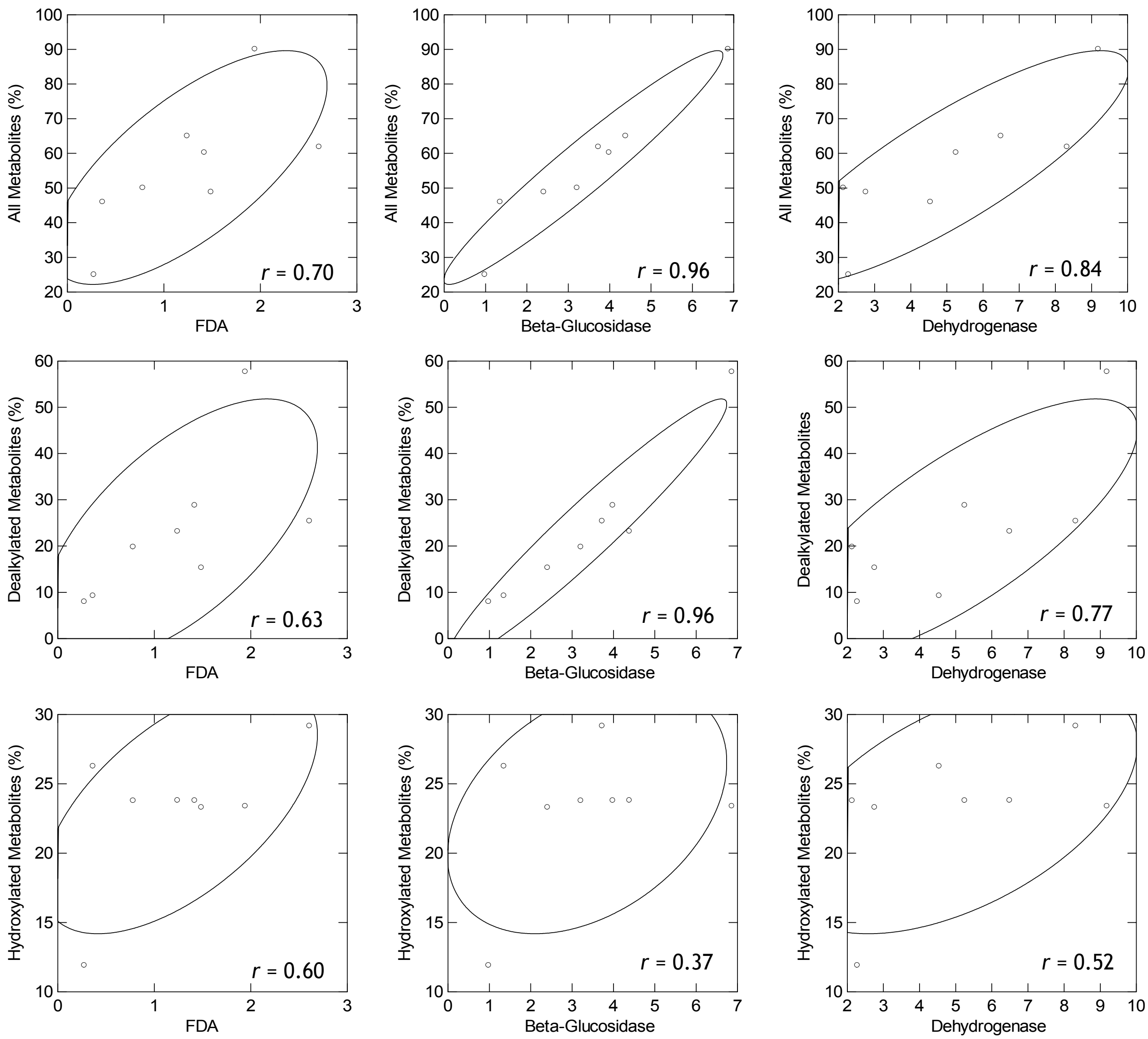

Fig. 5: Pairwise correlation between atrazine degradation and soil enzyme activities. The level of confidence ellipse = 0.68.

CONCLUSION

All plant species tested significantly enhanced ATR degradation by creating conditions that enhanced microbial activity in the rhizosphere. The incorporation of eastern gammagrass into VBS designs are highly recommended to promote rapid dissipation of ATR transported from croplands and deposited in the VBS. The results from this study also suggested that the microbial enzyme activities widely used for assessment of soil quality, particularly GLU activity, are promising as indicators for evaluating the overall ATR degradation potential of various vegetative buffer designs.

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IMPACTS OF RIPARIAN ZONES AND DIFFERENT LAND-USES SYSTEMS ON THE TERRESTRIAL NITROGEN CYCLE AND WATER QUALITY IN SOUTHERN ONTARIO, CANADA

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Abstract: Nitrate (NO_3^-) is mobile in soil and groundwater and it can be a significant water pollutant. Many studies have demonstrated the importance of riparian buffers in NO_3^- removal from non-point sources. The objective of this study is to assess the impact of riparian buffer strips on the nitrogen cycle with special emphasis on NO_3^-. This research was conducted at Washington Creek, which is predominantly an agricultural stream, subjected to a variety of different environmental degradations. Four different land-uses systems were studied in the area. Natural forest (NF), Livestock (LS), Agriculture-Grass buffer (AP), and Rehabilitated riparian area buffer-agriculture (RA). Net mineralization rates were calculated using ammonification and nitrification rates. Net N mineralization rates were generally found to be higher within the buffer zones when compared with the outside buffer rates. For example, in the RA site, net N mineralization rates, within and outside the buffer were 92.37 vs -7.48 mg m^{-2} d^{-1}, respectively. However, when in situ soil extracts were analyzed for extractable NO_3-N, values within the buffer were lower than outside the buffer, indicating a rapid absorption if NO_3-N by the buffers. This was further validated by the analysis of the groundwater samples obtained within and outside the buffer zones. In July, within the buffer in RA groundwater samples had an average 4.77 mgL^{-1} compared with outside buffer where groundwater recorded an average of 27.33 mgL^{-1}. The results from this study can contribute towards the development of Best Management Practices for high nitrate leaching agricultural lands.

Key Words: Nitrate, riparian buffer zones, nitrogen cycle, land-uses systems.

CHANGES IN SOIL CHEMICAL PROPERTIES WITH FLOODING AND EFFECTS ON RIPARIAN VEGETATION

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Abstract: Periodic flooding of rivers and floodplains can result in stagnant or flowing water over soils under agricultural or forested conditions. Soil inundation during flooding transforms the soil, creating an anaerobic environment and increasing the presence of reduced mineral ions. Flooding has been shown to alter nitrogen cycle dynamics and thus influence nutrient availability. In order to support on-going investigations of flood tolerance at an outdoor, field laboratory we monitored changes in soil redox potential, pH, temperature, volumetric water content and dissolved oxygen over the course of 3- and 5-week flood treatments with automated sensors. Pre- and post-flood soil samples were collected and analyzed for inorganic nitrogen content, total N, total C, and total soluble polyphenolics. Sensor data revealed a decrease in redox potentials with flooding, however no trends in pH with flood treatment or over time were observed. Soil temperatures gradually increased over the course of the experiment; soils in the control channels were slightly cooler than soils in the flooded channels. Soils in the flooded channels did not differ from each other in either volumetric water content or in dissolved oxygen levels; however they did differ from soils in the control channels, at least initially. Pre- and post-flood samples showed differences in nitrate and ammonium content, however changes in C:N ratio and total soluble polyphenolics were not observed. Additional analyses of changes in soil chemistry were conducted, including isolation of specific polyphenolic compounds.

Key Words: Redox potential, in situ monitoring, soil inundation, soluble polyphenolics, inorganic N.

ASSESSING RIPARIAN BUFFER EFFECTIVENESS

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Abstract: Research sites were installed to evaluate the water quality-improving effectiveness of young, planted riparian buffers, and to compare them to native, mature riparian woodlands and grass-only filter strips.

The buffer vegetation was established in 1996, consisting of warm season native grasses, American plum, and fallow or natural succession plots. The fallow plots contain a mixture of annual and perennial grasses and forbs, and some shrubs. Surface runoff and subsurface flow were sampled at the edge of the crop field and as water passes through for nitrogen, phosphorous, and suspended solids.

The surface runoff collectors have several parts. A bucket is buried in the ground behind a meter-wide collection weir. As runoff enters the bucket a bilge pump is activated, pumping the water up to the stainless steel splitter trough. A series of baffles within the splitter allocate the water to the various tubes, with most of the water running back onto the buffer. A 1/8 and a 1/32 sample is collected in a jug. This allows a representative sample to be collected from both large and small storms. Runoff was collected from 4 events in 2001, and simulated runoff was applied 3 times in 2002.

Early results show a steep decline in the concentration of pollutants as water flows through the buffers. All riparian buffer vegetation types reduced runoff pollution, from 60-90% for suspended solids down to 35-55% for total nitrogen.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

UTILIZING VEGETATIVE BUFFER STRIPS TO REMOVE DISSOLVED AND SEDIMENT-BOUND ATRAZINE, METOLACHLOR AND GLYPHOSATE FROM SURFACE WATER RUNOFF

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Abstract: Multiple species vegetative buffer strips (VBS) have been recommended as a cost-effective approach to mitigate herbicide transport in surface runoff derived from agronomic operations. However, the effect of buffer designs and species composition on reducing herbicide transport has not been well documented. An experiment consisting of three VBS designs and one cultivated fallow control replicated in triplicate was conducted to assess effectiveness in reducing herbicide transport for claypan soils. The four VBS treatments include: (1) continuous cultivated fallow (control), (2) perennial fescue, (3) fescue with a switchgrass barrier, and (4) native vegetation (largely eastern gamagrass). Rainfall simulation was used to create uniform antecedent soil moisture content in the plots and to generate runoff. Runoff collection equipment is installed across the plots at 1 m above (upslope) the filter strips and at 1, 4, and 8 m into the VBS treatments. The results show a much higher proportion (40-60%) of glyphosate transported with suspended sediments in surface runoff as compare to that of atrazine and metolachlor (<3%). All VBS significantly reduced the transport of both dissolved and sediment-bound atrazine, metolachlor and glyphosate in surface runoff. VBS with native species were most consistently effective at reducing transport of these herbicides. Four meters of native VBS removed about 75-80% of the atrazine, metolachlor and glyphosate in surface runoff. The additional length of native VBS had little effect on removal rates. Additionally, four meters of native species VBS resulted in much greater reductions in transport of these herbicides than eight meters of the other tall fescue VBS designs. Thus, the implementation of native species buffers could provide desired reductions in herbicide transport with less land taken out of production.

Key Words: Herbicide transport, riparian grass buffer, bioremediation, water quality.

INTRODUCTION

Due to solute transport processes, the contamination of surface and ground water sources by herbicides and their degradation products have been widely reported in Midwestern states (Lerch et al. 1995). Surface water resources in the Midwestern U.S. claypan region are particularly vulnerable due to the formation of a perched water table during wet seasons. Subsequently, lateral flow, runoff, erosion, and agrichemical loss during storm events are increased during times critical for farming operations (Blanco-Canqui et al. 2004).

Among several management practices, a well-designed vegetative buffer strip (VBS) is recognized as one of the most cost-effective approaches to mitigate impact of agricultural pollutants in surface runoff. Previous research has clearly documented significant reductions in herbicide loss when VBS are integrated into agroecosystems (Misra et al. 1996; Lowrance et al. 1997; Krutz et al. 2003a). Enhanced infiltration rates within vegetative buffers have been identified as the major physical mitigation process by which herbicides transported in surface runoff are intercepted (Zins et al. 1991; Misra et al. 1996). The ability of VBS to enhance water infiltration, compared to cropped fields or bare soil, appears to be the initial mechanism by which VBS mitigate the transport of moderately sorbed herbicides (2004). However, once water containing dissolved-phase herbicides enters VBS soil, sorption and degradation become the key mitigation processes. Krutz et al. (2003b) reported VBS trapping efficiencies (TE) (i.e., the combination of infiltration and sorption) for dissolved-phase atrazine and its metabolites to be in the range of about 17-23%. VBS TE for dissolved-phase metolachlor were similar to atrazine, but the TE for ethanesulfonic and oxanilic acid metabolites of metolachlor were only about 15%, which is significantly lower than that of the parent compound.

Proper plant species selection and VBS designs play a significant role in VBS effectiveness for mitigating agrichemical transport. However, the effects of VBS designs and species composition on transport of the herbicides have not been carefully studied to date. The objectives of this study are to (1) assess the effectiveness of three buffer designs and species composition in reducing transport of atrazine, metolachlor and glyphosate in runoff, (2) determine the required buffer width to achieve targeted removal rates.

MATERIALS AND METHOD

Experimental design

The study was conducted at the University of Missouri Bradford Research and Extension Center near Columbia, MO. Twelve 1.5 m by 16 m plots with four treatments replicated three times were arranged in a randomized complete block design (Fig. 1). VBS treatments included: 1) tall fescue, 2) switchgrass hedge in combination with tall fescue, 3) native warm-season grass including eastern gamma grass, switchgrass and forbs species, and 4) continuous cultivated fallow as a control (Fig. 1). Runoff collection equipment was installed at 1 m above the buffers (-1 m) and within the buffers at 1, 4, and 8 m below the upslope end of the VBS. Each plot is designed with a 1.5 m by 8 m source area managed under continuous cultivated fallow located directly upslope of the VBS treatments. Each plot was enclosed by 2.5-mm thick corrugated steel at depths of 20-25 cm below the soil surface to prevent cross-contamination between plots. Three herbicides, atrazine (ATR), glyphosate (GLY), and s-metolachlor (MET), were uniformly applied to the source areas about 24 hours prior to rainfall application. Application rates were: ATR 2.2 kg/ha; MET 1.7 kg/ha; and GLY 1.5 kg/ha. A rotating-boom rainfall simulator was used to create uniform antecedent soil moisture content in the plots and to generate runoff. The rainfall rate was ~5 cm/h.

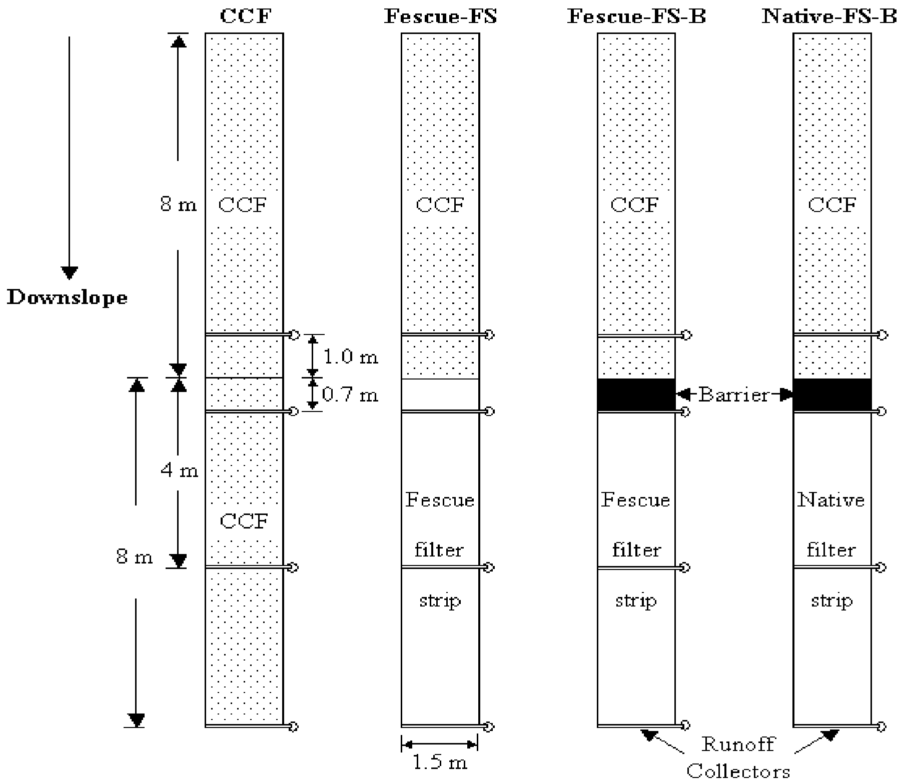

Fig. 1 : Schematic diagram showing vegetative buffers and control. (CCF = continuous cultivated fallow; Fescue-FS = fescue filter strip; Fescue-FS-B = fescue filter strip + switchgrass buffer; Native-FS-B = native plant filter strip + switchgrass barrier.

Sample collection, herbicide analyses and load calculations

Water and suspended sediment samples were collected starting with the initiation of runoff at the 8m sampler; samples were collected for a duration of 5 seconds at 10 minute intervals for 60 minutes. Individual sample volumes were recorded in the field, and then composited to create a single sample for each of the four samplers. The concentrations of ATR, MET, and GLY in filtered water samples were quantified using Enzyme-Linked Immunosorbent Assays (ELISA) (Abraxis Kits Warminster, PA).Herbicide concentrations in sediment were determined following addition of a flocculant (Al2(SO4)3) to promote settling of the suspended sediment and to facilitate recovery of sufficient sediment mass for analyses. ATR and MET were extracted twice with 80% MeOH followed by liquid-liquid extraction with chloroform and then solvent exchange into ethyl acetate. Concentrations of ATR and MET were determined by GC/MS. GLY was extracted with 1 M NaOH and concentrations were determined by ELISA.

To determine the relative load of herbicide transported in surface runoff, the concentration of herbicides were multiplied by the total flow volume derived from the integrated hydrographs at all sampling positions. The herbicide mass at each sampling position were then normalized to the total mass at the -1m samplers.

RESULTS AND DISCUSSION

Herbicide transport pooled across all treatments showed that relative ATR losses in runoff were significantly higher than that of MET and GLY (Fig. 2). Relative losses of GLY were similar to MET, despite the higher proportion of sediment-bound transport for GLY (Fig. 3, Fig. 4 and Fig. 5). More than 90% of ATR and MET were transported in the dissolved-phase. About 40-60% of transported GLY was sediment-bound (Fig. 5).

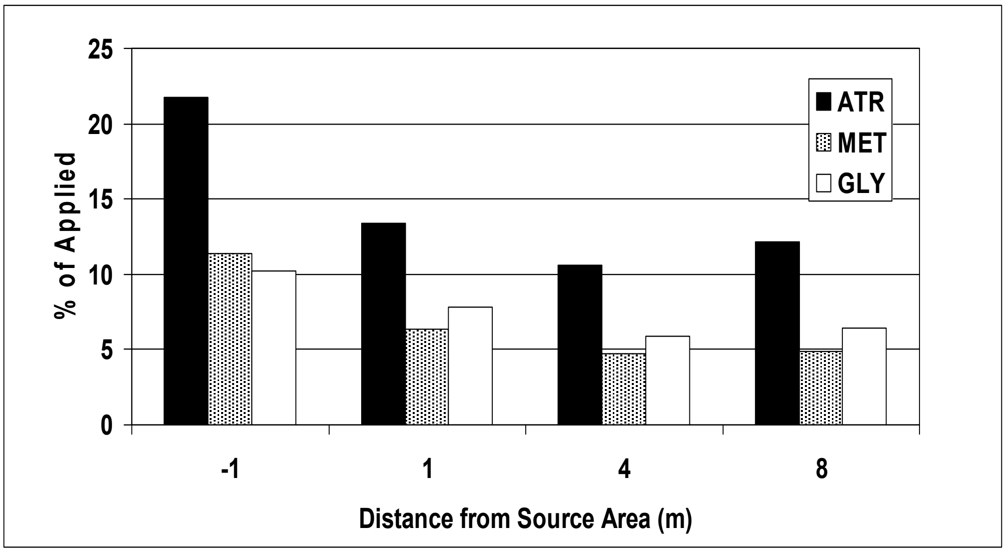

Fig. 2: Relative herbicide transport in surface runoff. Data were pooled across all treatments.

Grass buffers significantly reduced both dissolved-phase and sediment-bound herbicide transport in surface runoff (Fig. 3, Fig. 4 and Fig. 5). VBS with native species were most consistently effective at reducing transport of these herbicides. Four meters of native VBS removed about 75-80% of the ATR, MET, and GLY from surface runoff. Switchgrass hedges plus tall fescue VBS were effective at reducing sediment-bound GLY compared to tall fescue VBS, and showed initial reductions in dissolved-phase ATR and MET transport at 1 m. Although switchgrass hedges promoted initial infiltration of water and dissolved-phase herbicides, yet much of the reductions in load observed at 1 m resurged at the surface, resulting in higher dissolved-phase loads at 8 m. All VBS were effective at trapping sediment and thereby reducing GLY transport, but native VBS showed the greatest reductions in sediment-bound GLY. The primary mechanism by which VBS reduced dissolved-phase herbicide transport was enhanced infiltration resulting from plant evapotranspiration and greater water holding capacity in the soil.

Four meters of the native VBS provided similar mitigation to 8 meters of tall fescue VBS (Fig. 3, Fig. 4 and Fig. 5). The additional length of native VBS had little effect on removal rates. Therefore, the implementation of native species VBS could potentially provide desired reductions in herbicide transport with less land taken out of production

In the Midwestern U.S., the highest seasonal herbicide losses in surface runoff occur from April-June, following herbicide application to row-crop fields. Thus, early and late season herbicide transport more closely coincides with the enhanced growth period of C_3 species. However, at mid-season, surface runoff events will correspond to the enhanced growth period of C_4 species. Therefore, from a management standpoint, field implementation of VBS that employ both C_3 and C_4 grasses may be most effective for reducing herbicide transport.

CONCLUSION

VBS significantly reduced both dissolved and sediment-bound herbicide transport in surface runoff. VBS with native warm-season species displayed the greatest effectiveness for reducing herbicide transport. The implementation of native species VBS could provide desired reductions in herbicide transport with less land taken out of production while improving wildlife habitat. Field implementation of VBS that employ both C_3 and C_4 grasses could enhance season-long effectiveness for reducing herbicide transport because of their complementary growth patterns.

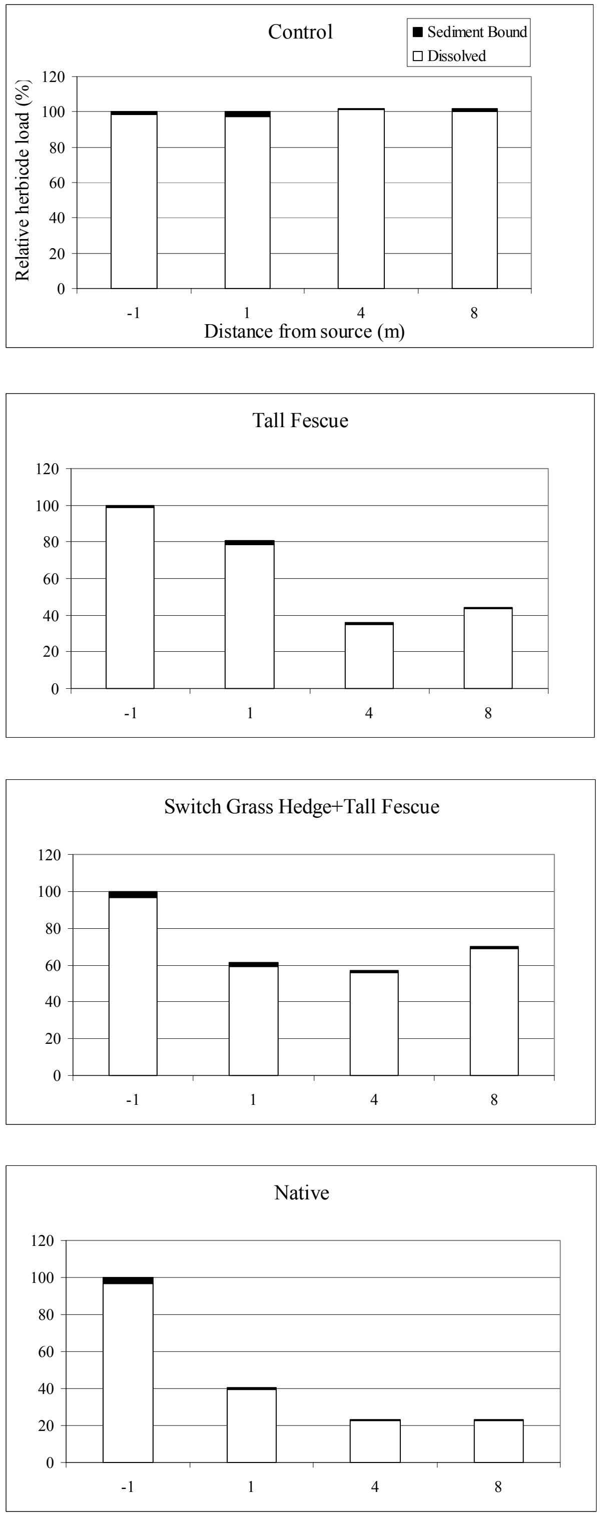

Fig. 3: Relative atrazine loads (%) as a function of buffer length (n=3). Data are normalized to the loads at the -1m sampler for each experimental plot.

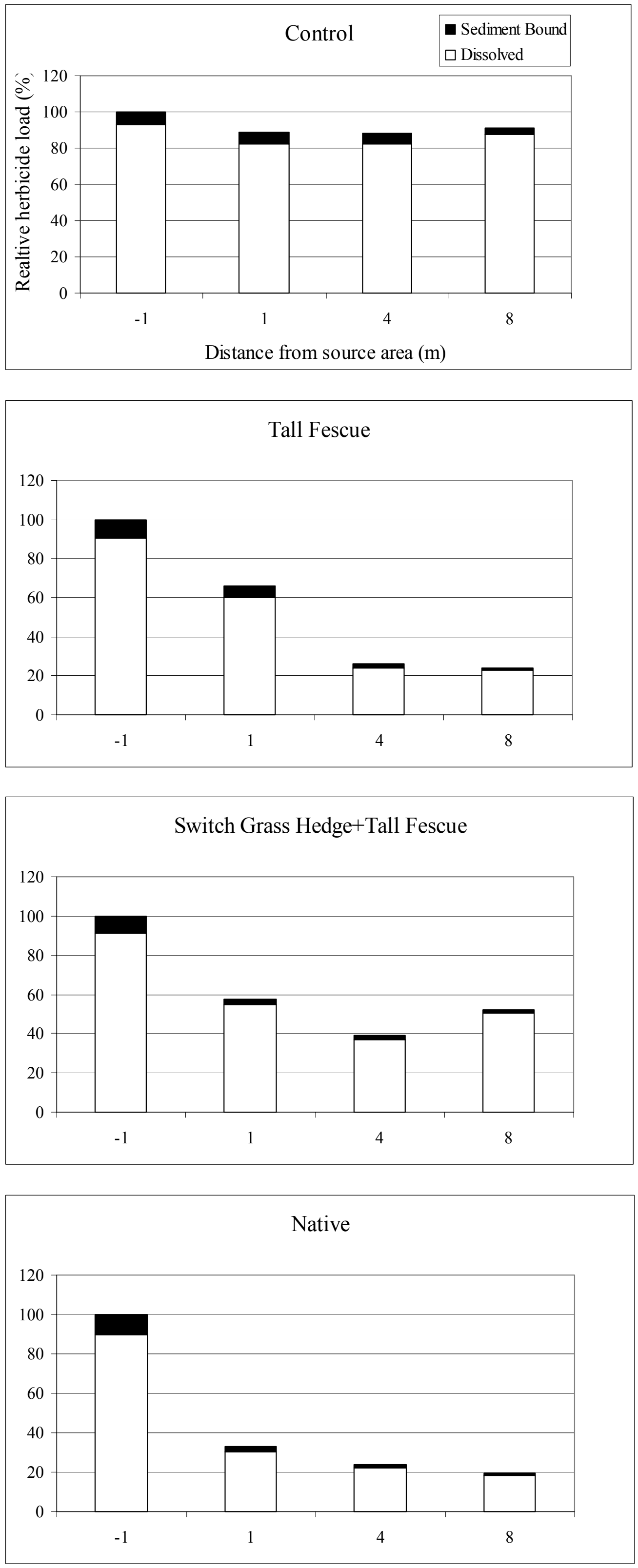

Fig. 4: Relative metolachlor loads (%) as a function of buffer length (n=3). Data are normalized to the loads at the -1m sampler for each experimental plot.

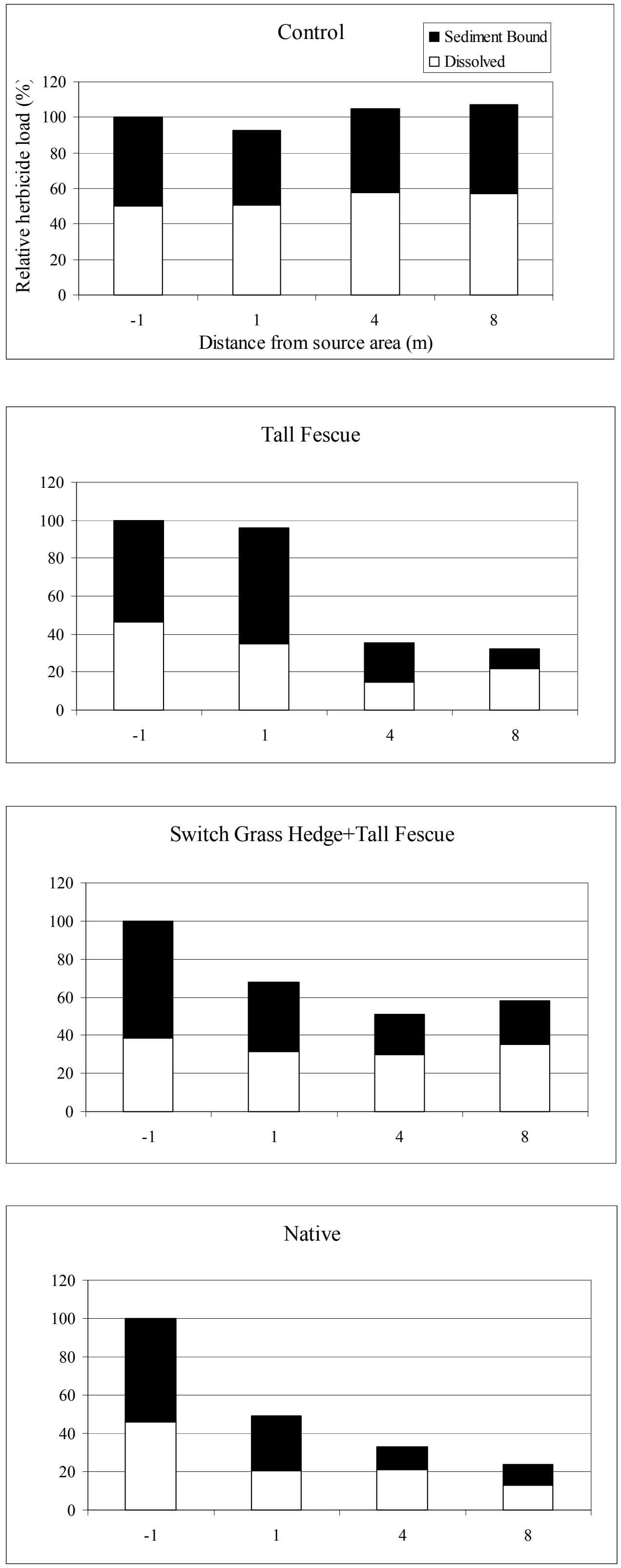

Fig. 5: Relative glyphosate loads (%) as a function of buffer length (n=3). Data are normalized to the loads at the -1m sampler for each experimental plot.

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SECTION 3

Cultures intercalaires / Intercropping Systems

KEYNOTE SPEAKER

BIOPHYSICAL INTERACTIONS IN TEMPERATE TREE-BASED INTERCROPPING SYSTEM: A 21-YEAR-OLD CASE STUDY ANALYSIS
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INTERACTIONS BIOPHYSIQUES DANS UN SYSTÈME TEMPÉRÉ DE CULTURE INTERCALAIRE AVEC ARBRES : ANALYSE D'UN SYSTÈME ÂGÉ DE 21 ANS

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Abstract: Tree intercropping is a promising agroforestry option in southern Ontario, Canada. Understanding the biophysical interactions between trees and crops in such intercropped systems provides the basis for designing efficient systems with potential for wider applicability. Results from experiments conducted at the Agroforestry Research Site in the last 21 years, suggests two distinct zones across a 15 m wide cropping alley. The first zone – the *competitive* zone – can be demarked as the area just adjacent to the tree row, which is 2 m on either sides of the tree row (between two tree rows this zone will be, in total, 4 m wide). The second zone – the *complementary* zone – will be the remaining area in the centre of the alley, which is 11 m wide. The competitive zone is characterized by competition for mainly moisture and light. However, the complementary zone is characterized by many favourable growing conditions influenced by the long-term presence of trees. In this zone, historical research has shown the following processes to be enhanced: nutrient cycling, nitrogen mineralization, soil organic carbon addition, earthworm activity, carbon assimilation. In addition, there appears to be lower soil temperature, low evapotranspiration, and reduced wind turbulence.

Many favourable results, in terms of *private* and *public* goods, have been recorded in the *complementary* zone. Yields of C_3 crops intercropped with trees, as well as growth of trees, did not differ from those in corresponding sole-stand (conventional) systems of crops and trees. But, soil organic carbon content and bird and insect diversity increased in the intercropped area. The abundance and distribution of earthworms were higher closer to the tree rows indicating improved soil health. The C sequestration potential in fast-growing tree (hybrid-poplar)-based intercropping systems was four times more than that reported for conventional agricultural fields in the region. A study conducted to validate the safety-net hypothesis in temperate tree-based intercropping system has revealed significant reductions in nitrate-N leaching (up to 50%) and *E. coli* strain (*E. coli* NAR) losses (up to 40%) from the tree-based intercropping system.

In 2006, a short-rotation woody crop clonal trial (willow hybrids from SUNY, Syracuse) was established in this *complementary* zone in an agroforestry setup (willow clones planted in between widely spaced mixed trees, predominantly black walnut [*Juglans nigra*]). It is hypothesized that the favourable growing conditions prevailing in the *complementary* zone, as

influenced by the presence of mature trees in an agroforestry set-up, will enhance short-rotation biomass production yields when compared with conventional (control) yields.

Tree/crop intercropping is one agroforestry system that shows great potential for this region. We suggest that this land-management option can be placed above conventional agriculture in terms of long term-productivity and sustainability.

Résumé : La culture intercalaire avec arbres est une approche prometteuse de l'agroforesterie dans le sud de l'Ontario, au Canada. La compréhension des interactions biophysiques entre les arbres et les autres cultures dans un système de cette nature permet de constituer des systèmes efficaces qui pourraient éventuellement paver la voie à d'autres applications potentielles. Les résultats d'expériences effectuées au Site de recherches en agroforesterie au cours des 21 dernières années suggèrent la présence de deux zones distinctes dans les allées de 15 m de largeur où s'effectuent les cultures. La première zone (compétitive) est celle qui est tout juste adjacente à la rangée d'arbres, soit à 2 m de part et d'autre de cette rangée. La seconde zone (complémentaire) est constituée du reste (centre) de l'allée, et a donc 11 m de largeur. C'est la compétition pour l'humidité et la lumière qui caractérise la zone compétitive. On trouve par contre dans la zone complémentaire des conditions de croissance favorables influencées par la présence à long terme des arbres. Dans cette zone, des recherches historiques ont montré que les processus suivants sont accrus ou accélérés : le recyclage des nutriments, la minéralisation de l'azote, l'ajout dans le sol de carbone organique, l'activité des vers de terre et l'assimilation du carbone. De plus, les températures du sol, l'évapotranspiration et la turbulence due aux vents semblent plus faibles à cet endroit.

La zone complémentaire est bénéfique à plus d'un titre, que ce soit pour la production de biens privés ou de biens publics. La production de plantes en C_3 dans les systèmes où les arbres sont présents, de même que la croissance de ces arbres, ne diffèrent pas des systèmes où les plantes agricoles ou les arbres sont produits de manière isolée. Le contenu en carbone du sol et l'activité des oiseaux et des insectes sont plus élevés dans les systèmes de culture intercalaire. On trouve davantage de vers de terre lorsqu'on se rapproche des rangées d'arbres ce qui indique que les sols y sont en meilleure santé. Dans une même région, le potentiel de séquestration du carbone est quatre fois plus élevé dans les systèmes de culture intercalaire intégrant des peupliers hybrides à croissance rapide que dans les champs agricoles cultivés de manière conventionnelle. Une étude effectuée pour valider l'hypothèse du filet de sécurité dans les systèmes de culture intercalaire avec arbres dans les régions tempérées a révélé que ces systèmes réduisent de manière significative le lessivage des nitrates (jusqu'à 50 % de réduction) et entraînent des pertes de la souche E. *coli* résistante à l'acide nalidixique (jusqu'à 40 %).

En 2006, une rotation rapide de cultures ligneuses clonales (saules hybrides en provenance de l'Université de l'État de New York à Syracuse) a été établie dans la zone complémentaire d'un dispositif expérimental, les clones de saules étant plantés entre des rangées d'arbres très distancées constituées de différentes espèces, mais surtout de noyer noir (*Juglans nigra*). Nous avons émis l'hypothèse que les conditions de croissance favorables qui prévalent dans la zone complémentaire, conditions qui résultent de la présence d'arbres matures à proximité, augmentera la production de biomasse à rotation rapide par rapport à ce que l'on observe dans les systèmes conventionnels.

En somme, les systèmes de culture intercalaire avec arbres constituent des systèmes agroforestiers qui ont un potentiel élevé pour cette région de l'Ontario. Nous suggérons que cette façon d'utiliser les terres soit favorisée à l'avenir par rapport au mode de culture plus conventionnel si l'on vise à obtenir des terres plus productives à long terme et des systèmes plus durables.

SPATIAL ARBUSCULAR MYCORRHIZAL FUNGAL COMMUNITY COMPOSITION OF SOYBEAN CROP AND HYBRID POPLAR IN A TEMPERATE AGROFORESTRY SYSTEM IN SOUTH-WESTERN QUEBEC

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Abstract: To the best of our knowledge, it is the first study where the AM (arbuscular mycorrhizal) fungal community is assessed in order to highlight both qualitative and quantitative differences in agroforestry systems and conventional forestry systems. The goals of the work are to identify the AM fungal species involved in root colonization of soybean crop (*Glycine max*) and poplar (*Populus nigra* x *maximowiczii*) growing in arable fields in the south-west of Quebec, using RFLP-PCR amplification of SSU rRNA genes, and to determine whether their distribution reflects host species and the location. In addition, we took a look at AM fungal spores abundance and distribution. We hypothesize that 1) there is a higher AM fungal diversity in agroforestry system than in forestry system, 2) there is a dissimilar AM fungal community composition between co-occurring soybean and poplar roots, 3) there are negative effects of soybean crop on AM fungal diversity of poplar, and 4) there are spatial changes of AM fungal community composition and AM fungal spores distribution in the agroforestry system correlated with distances from poplar. The first results revealed that in the agroforestry system, the AM fungal spore abundance and crop yield increased significantly with distance from poplar, light transmittance, soil P and N content, while all this factors were more homogenous in forestry system. The AM fungal community colonizing soybean crop differed from that colonizing poplars, providing evidence for AM fungal host preference.

Key Words: SSU rRNA sequence, arbuscular mycorrhizal (AM), spore number, agroforestry, community composition, host-plant preference, spatial distribution.

NITRATE AND *E. COLI* NAR ANALYSIS IN TILE DRAIN EFFLUENT FROM A MIXED TREE INTERCROP AND MONOCROP SYSTEM

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Abstract: Tile drain effluent from two adjacent agricultural systems (a mixed tree intercrop and a monocrop) was collected from April to November during 2005 and 2006 from a paired mini watershed area of 17,200 m^2. An area of 1350 m^2 in each system was subject to application of a mixture of water and a biotracer *E. coli* NAR, a naturally occurring strain that is resistant to naladixic acid and has been shown to be safe for introduction into the environment. The effluent was analyzed for concentrations of the biotracer and nitrate (NO_3-N). The premise of this study is to determine if the safety-net hypothesis is valid in a temperate intercropping system. This hypothesis states that the incorporation of trees into agricultural systems will allow for a more efficient use of resources.

NO_3-N levels were similar in 2005 (57.37 and 54.74 kg ha^{-1} leached from the monocrop and intercrop sites, respectively) and were much higher in the monocrop effluent (164.67 kg ha^{-1}), than that of the intercrop (88.59 kg ha^{-1}) in 2006. Few significant differences were found in *E. coli* NAR outputs during both years; however, there is an indication that intercropping systems and perhaps trees in general have a potential mitigating effect on *E. coli* movement to the groundwater. For the same number of samples collected, the total CFU's found in the monocrop and intercrop effluents, respectively was 4040 and 3558 in 2005. In 2006, 34025 and 28401 were enumerated from the monocrop and intercrop treatments, respectively, given the same number of samples.

INTRODUCTION

Leaching of nutrients, particularly NO_3-N, into groundwater has become a major environmental issue over the past several years. Nitrogen (N) and phosphorus in runoff can cause eutrophication of lakes, rivers and other surface waters (Carpenter et al. 1998). In turn, this can cause toxic algae blooms and fish kills, and loss of biodiversity due to lack of oxygen (Carpenter et al. 1998; Snyder et al. 1998). Excess nitrogen in drinking water can also cause several health effects in infant children and animals because their intestinal tracts can reduce NO_3-N to nitrite, which when combined with hemoglobin can cause methemoglobinemia or "blue baby syndrome" (Liang and Mackenzie 1994; U.S. Environmental Protection Agency 1999).

Another major concern is contamination of drinking water by bacteria such as, *Escherichia coli* O157:H7 (*E. coli* O157:H7). The recent tragedy in Walkerton, Ontario in which seven people died and thousands became extremely ill, has brought the issue of *E. coli* contamination to a forefront, on a national basis (O'Connor 2002). Studies have shown that more than 25% of rural

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wells in Ontario are contaminated with levels of nitrate and/or bacteria that are above drinking water limits (Exner and Spalding 1985; Rudolph and Goss 1993; Goss et al. 1998).

A potential solution to these problems is the use of tree roots to intercept and absorb nutrients and potentially harmful bacteria, which would have otherwise leached through the system, reducing contamination of ground water. In many alley-cropping systems, crop and tree roots occupy different depths in the soil profile, due to competition, plasticity and predisposed growing patterns, utilizing nutrients from different areas within the soil profile (Schroth 1995; Lott et al. 1996; Schroth 1999). Trees that are deep rooted are able to make use of nutrients from soil depths that most agricultural crops cannot (Huxley et al. 1994). This concept is called the safety-net hypothesis.

Although the safety-net hypothesis is mainly applied and studied in tropical climates, it has been shown to be applicable in temperate climates. For example, in a cotton (*Gossypium hirsutum* L.) and pecan (*Carya illinoensis* K.) alley cropping system in the southern United States, cotton roots demonstrated plasticity, growing at shallower depths when the pecan roots were present (Wanvestraut et al. 2004). Cotton yield did not differ when grown in association with pecan roots, and without. In the same study, there was a 34% reduction in NO_3-N levels at 0.9 m depth when there was no barrier impeding cotton roots from the area (Allen et al. 2004). This indicates that in this system, pecan roots function as a safety net.

There have been limited studies investigating the ability of tree roots to mitigate movement of bacteria to the groundwater. However, several studies have demonstrated that *E. coli* survival in the presence of root exudates is greatly reduced due to predatory and competitive indigenous microbes, such as amoeba (Morel et al. 1989; Gagliardi and Karns 2002; Recorbet et al. 1992).

This study focuses on the effectiveness of tree roots, including that of a hybrid poplar (*Populus* spp. clone DN 177), silver maple (*Acer saccharinum* L.) and several other species to filter, mitigate, and/or absorb NO_3-N and bacteria such as *E. coli*.

MATERIALS AND METHODS

The experiments were performed from April to November of 2005 and 2006 at the Agroforestry Research Station at the University of Guelph in southern Ontario, Canada. The research site is composed of two land-use areas: a monocrop system (traditional agricultural system) and an intercrop system (rows of trees are incorporated into an agricultural system). Within the intercrop system, the uncultivated tree rows (tree age $\leq$ 20 years), approximately 1 meter wide, are separated by crop alleys, of which four are 15 meters in width and one is 9 meters (Fig. 1). Tree spacing within the row is 6 meters.

Fig. 1: Photo of a crop alley separated by rows of trees at the Agroforestry Research Station at the University of Guelph.

The crop planted during 2005 was winter wheat (*Triticum aestivum)*, to which a starter fertilizer (6-28-28) was applied at a rate of approximately 146 kg ha^{-1} in the fall of 2004. In the spring of 2005, urea (46-0-0) was added at approximately 225 kg ha^{-1}). The crop in 2006 was corn (*Zea mays* L.), to which a MAP fertilizer (11-52-0) was applied with the corn at a rate of approximately 56 kg ha^{-1}. An additional fertilizer (36-0-13) was added upon emergence of the corn at a rate of approximately 344 kg ha^{-1}. The monocropped section was used as a no-tree control.

The study site consists of two sections of equal area (1.75 ha), but with different dimensions: the intercrop site is 250 x 70 m and the monocrop site is 291 x 60 m (see Fig. 2). Each section is tile drained equally and independently. The tile drains run down the center of the alley rows in the intercropping system. Both drainage systems are designed so that all water that enters each tile drain system (either monocropped or intercrop) will flow to separate main drains and will be directed to two ISCO 6700 portable tile drain monitors, where sub-samples can be collected.

Within each section there is one 50 x 22 m sub-section in which an *E. coli* biotracer (*E. coli* NAR), which is a strain of *E. coli* that is resistant to nalidixic acid, was applied. The sub-section in the intercropping site had two tree rows running through it; a hybrid poplar row separating two crop rows and a silver maple row on the edge of one crop row. The biotracer is a naturally occurring strain of *E. coli* (although occurrences are rare), that can be isolated from the environment and has been used extensively to give accurate assessments in research and as an indicator microorganism to gauge water quality (Dean and Foran 1992; Roll and Fujioka 1997; Shadford et al. 1997; Jamieson et al. 2005). Biotracer application took place on April 14th in 2005 and April 19th in 2006.

For culture preparation, 0.1 mL of frozen stock *E. coli* NAR supplemented with naladixic acid was added to 25 mL of sterile Trypticase Soy Broth (TSB) in a 125 mL Erlenmeyer flask, and incubated at 20°C for 24 hours with gyratory shaking at 200 rpm. 1 mL of culture was then added to 500 mL of sterile TSB in a 1 L Erlenmeyer flask and incubated for 24 hours at 20°C with slow magnetic stirring.

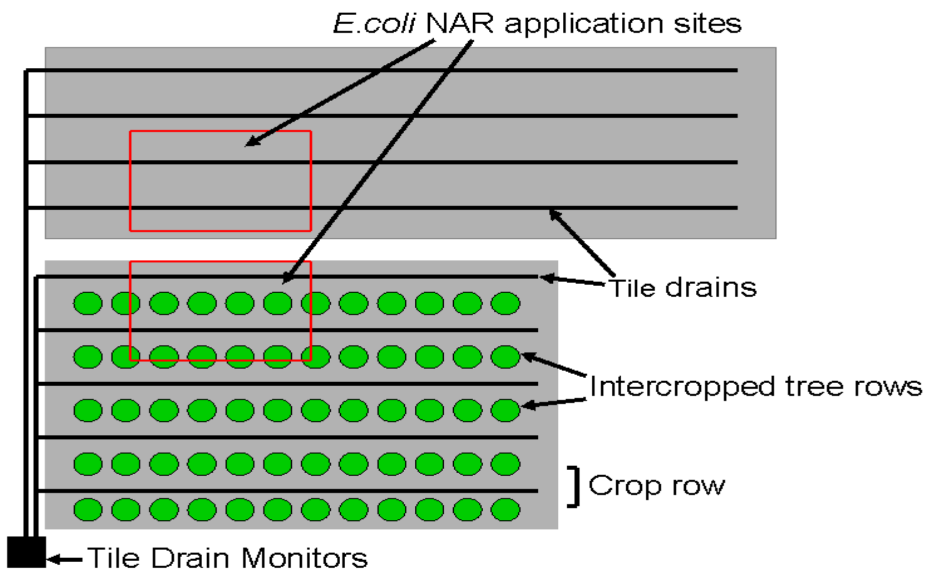

Fig. 2: Diagram of monocrop (top) and intercrop (bottom) sites. Each site has different dimensions but equal areas, with equal total lengths of tile drain. Within each site there is an equal area where *E. coli* NAR was applied (as outlined by the red rectangles).[1]

An 18 000 L liquid manure tanker was used to mix and apply the biotracer/water solution to both treatments. When the tanker was approximately half full, the inoculum was added, and mixed with the tanks churning mechanism while the balance was being filled. The tanker then transported the water/biotracer mixture to the study site.

Approximately 9000 L of the water/biotracer mix was applied to each sub-section in 2005 and 10500 L in 2006. The tanker applied the water/inoculum mix at a constant velocity and output rate, ensuring equal distribution between the two sub-sections (Fig. 3).

To determine the concentration of *E. coli* NAR in the water/biotracer mixture being applied to the field surface, 20 plastic cups were implanted into each sub-section and collected after the application. During the first application (2005), 2 L of inoculum was added to the tanker, resulting in a mean count of 1.26×10^5 CFU mL^{-1}. During the second application (2006), 12 L of inoculum was added to the tanker, resulting in a mean count of 8.05×10^5 CFU mL^{-1}.

Prior to application, water used to mix with the inoculum, tile drain effluent, and soils within the sub-section were sampled to determine background *E. coli* NAR levels.

Sampling procedures differed between study years. In 2005, when flow was detected, the monitors were programmed to collect a 200 mL sample after 10 m^3 of water had passed through the tile drain. From these samples, taken 3 times a week, 12 samples were collected for NO_3-N analysis and 3 for *E. coli* NAR analysis. In 2006 samples were collected every hour for the first

[1] This figure is in colour in the electronic version of the Proceedings (CD)

week of flow, thereafter every 2 hours. These samples were used for *E. coli* NAR analysis. Five samples were taken daily for NO_3-N analysis.

Fig. 3: Biotracer and water mixture application to the intercrop treatment with a liquid manure tanker on April 14th, 2005.

Effluent samples being analyzed for *E. coli* NAR had first to be centrifuged at 300 rpm for 5 minutes to separate the bacteria from the sediments. 10 - 100 mL of the sample was then filtered (depending on the concentration) using Gelman sterile cellulose-acetate filters (0.45 μm). The filters were then placed on mTEC agar that had been supplemented with naladixic acid in 60 x 15 mm Petri plates. The plates were then incubated at 37 °C for 24 hours, followed by a recovery period of 1 hour at 20 °C. Colonies appeared purple against the white filter.

Concentrations (ppm) of NO_3-N combined with the total daily tile drain flow values were used to determine the losses in the tile drain effluent on a Kg ha^{-1} day^{-1} basis. *E. coli* NAR was enumerated and presented on a CFU per 100 mL basis. To test for significant differences in NO_3-N and *E. coli* NAR concentrations between the treatments, a paired sample t-test was used with a Type I error rate of 5%. All error bars represent the standard error of the mean for the samples on a given date or time period.

Due to the design of the study site, replication was not possible. Analysis was undertaken using pseudoreplication over time. All statistical analysis was completed using SPSS v.14.00 statistic software (SPSS, Chicago, ILL).

RESULTS AND DISCUSSION

During 2005, the sampling period went from April 7th to November 31st. For the purposes of analysis, all samples were grouped together into the 3 following groups (April 7th to May 21st; August 18th to September 30th; and November 8th to 31st).

In 2006 the sampling period was March 21st to November 21st. For purposes of analysis, samples were grouped together into the 4 following groups (March 21st to April 30th; May 1st to June 12th; July 4th to August 7th; and September 28th to November 21st). Gaps in the data are due to absence of samples during that time period, either due to periods when the sampler was not functioning properly or lack of tile drain effluent.

Tile drain flow and rainfall

Tile drain flow typically peaked and remained at a capacity of approximately 80 m^3 ha^{-1} day^{-1} for much of the study. Much more tile drain flow occurred in 2006. Flow lasted much longer in the spring, began much earlier in the fall and occurred more frequently during the summer months of 2006. Daily flow quantities followed a similar pattern in the tile drain systems during both years, while there was often slightly more removed from the monocrop system. In total there was 3841 and 3645 m^3 ha^{-1} tile drain effluent from the monocrop and intercrop treatments during the sampling period of 2005. Comparatively, there was 10699 and 9806 m^3 ha^{-1} tile drain effluent from the monocrop and intercrop treatments during the sampling period of 2006. These large differences between the years are likely due to the differences in cumulative rainfall values during the sampling periods (631.5 mm fell in 2005 and 782.0 mm in 2006).

NO_3-N analysis

2005

Mean daily loss via leaching values are consistently significantly greater in the monocrop effluent, than that of the intercrop. As a result of this, coupled with slightly greater tile drain flows in the monocrop effluent, total loss via leaching for all sampling dates during 2005 are greater in the monocrop than the intercrop (57.37 and 54.74 kg ha^{-1}, respectively; Table 1). This is a total difference of 2.63 kg ha^{-1} (4.6%).

Table 1: Mean daily and total loss (kg ha^{-1}) of NO_3-N via leaching for three time periods during 2005.

Date	Mean Daily Loss via Leaching (kg ha^{-1})		p-value	Total Loss via Leaching (kg)	
	Monocrop	Intercrop		Monocrop	Intercrop
April 7th – May 21st	1.05 ± 0.016	0.93 ± 0.013	< .001	44.46	43.73
Aug 18th – Sept 30th	0.09 ± 0.011	0.02 ± 0.003	< .001	0.71	0.19
Nov 8th – 31st	0.87 ± 0.058	0.76 ± 0.06	< .001	12.20	10.81
Total				57.37	54.74

2006

Mean daily loss via leaching was consistently significantly greater in the monocrop effluent, than that of the intercrop. In total, for all sampling dates during 2006, 164.67 and 88.59 kg NO_3-N ha^{-1} was removed via tile drain effluent from the monocrop and intercrop fields respectively (Table 2). This is a total difference of 76.08 kg ha^{-1} (46.2%). A study by Allen et al. (2004) showed similarly large differences in leached nitrate values. A polyethylene root barrier was used to separate tree roots from interfering with crop roots in a cotton and pecan intercropping system. At a depth of 0.3 m there was 121.94 and 63.84 kg NO_3-N ha^{-1} leached from the barrier and non-barrier treatment, respectively. Additionally at a depth of 0.9 m there was 45.56 and 13.05 kg NO_3-N ha^{-1} leached from the barrier and non-barrier treatment, respectively. The additional uptake of water by the tree roots was given as the main cause of these differences by the author.

Table 2: Mean daily and total loss (kg ha^{-1}) of NO_3-N via leaching for four time periods during 2006.

Date	Mean Daily Loss via Leaching (kg ha^{-1})		p-value	Total Loss via Leaching (kg)	
	Monocrop	Intercrop		Monocrop	Intercrop
Mar 21st – Apr 30th	1.09 ± 0.023	0.59 ± 0.017	< .001	44.33	24.67
May 1st – June 12th	1.16 ± 0.016	0.58 ± 0.011	< .001	44.52	22.20
July 4th – Aug 7th	0.76 ± 0.034	0.54 ± 0.027	< .001	14.66	9.86
Sept 28th – Nov 21st	1.11 ± 0.021	0.58 ± 0.021	< .001	61.16	31.86
Total				164.67	88.59

Higher rainfall rates during 2006 as compared to 2005 contributed to more frequent and longer lasting tile drain flow periods. Additionally, it is important to consider the timing of the rainfall events and how that affects quantity of tile drain water. Typically, tile drain flow occurred during the spring and fall months of both years. Total rainfall during the spring months of April and May (82 mm in 2005 and 188.5 mm in 2006) and during the fall months of September and October (116 mm in 2005 and 269.5 mm in 2006) are considerably different between the two years. There are comparatively low precipitation values in the spring and fall of 2005, where tile drain flow stopped much earlier (May 20th) as compared to June 12th in 2006 and started to flow consistently much later (November 20th) as compared to September 30th in 2006. Because of this relationship, more water and subsequently more NO_3-N was removed from both systems in 2006.

The differences are much more pronounced during 2006 than 2005 and unlike the study by Allen et al. (2004), in this study there was only a relatively small difference in water removed via tile drainage between treatments. Concentrations of NO_3-N in the effluent were much greater in the monocrop effluent, and were a main factor in the greater overall NO_3-N outputs. From March 21st to April 30th concentrations of NO_3-N were 15.37 ± 0.27 and 9.03 ± 0.21 in the monocrop and intercrop effluents, respectively. From May 1st to June 12th concentrations of NO_3-N were 16.50 ± 0.41 and 10.11 ± 0.30 in the monocrop and intercrop effluents, respectively. From July 4th to

August 7th concentrations of NO_3-N were 11.69 ± 0.42 and 9.57 ± 0.36 in the monocrop and intercrop effluents, respectively. From September 28th to November 21st concentrations of NO_3-N were 15.83 ± 0.35 and 9.08 ± 0.40 in the monocrop and intercrop effluents, respectively.

Other varying factors between the years that may have influenced the NO_3-N output are crop type, fertilizer application and mineralization rates.

There was slightly more N fertilizer applied during the 2006 season (see materials and methods). However, it should also be considered that corn, grown in 2006, is a larger plant that requires greater nutrient input than winter wheat (grown in 2005).

More total NO_3-N was mineralized in 2006 than 2005 in both treatments, while during those years mineralization was greater in the intercrop than monocrop treatments. From May to September of 2005 the cumulative mineralization of NO_3-N was 106.79 and 119.04 kg ha^{-1} in the monocrop and intercrop treatments, respectively. In comparison, from May to September of 2006 the cumulative mineralization of NO_3-N was 115.43 and 132.78 kg ha^{-1} in the monocrop and intercrop treatments, respectively.

These findings suggest that given conditions where the risk of NO_3-N leaching is heightened (high rainfall and NO_3-N levels in the soil), intercropping systems are more efficient at reducing leaching. These findings are assumed to be due to the increased uptake of water and nutrients in the intercropping system, because of the presence of trees and their roots. Through the safety net effect, in which additional water and nutrients are absorbed by tree roots, NO_3-N leaching to the ground water was significantly lower when environmental conditions existed that can promote increased leaching.

With the positives of the reduced NO_3-N leached to the groundwater, it is also important to realize that crop yield can be reduced when tree roots compete for resources with the crop roots. In a study by Rowe et al. (2006) it was noted that despite the potential of intercropping to reduce nutrient loss via leaching there is risk that competition will reduce yields, and it is therefore important to choose a deeply rooting tree species.

During this study there was an 18.5 and 23.5% reduction in yield in 2005 and 2006, respectively. Similarly, in a black walnut and corn intercrop, where it had been shown that tree and crop roots were in competition with each other, there was a 33 and 35% reduction in yields where a polyethylene barrier had not been installed (Jose et al. 2000). In contrast, a study by Wanvestraut et al. (2004) in a cotton and pecan intercrop, found no significant difference in yields of cotton in the barrier and non-barrier treatment.

The findings of this study and others demonstrate that intercropping can be successful in terms of stewardship and productivity, given proper planning in terms of types of trees used. However, crop productivity may be reduced in conditions where root competition exists. Because there were more than 10 different tree species in the intercropping treatment, it is very likely that some do indeed have shallow rooting systems which compete heavily for resources with the crops, which may have resulted in reduced yields. However, it is also important to take into account that a minimum of a 1 meter wide tree row is present every 15 m in the intercrop system.

E. coli NAR analysis

2005

E. coli NAR movement to the tile drain system continuously decreased from April 13th to May 20th, 2005, when flow ceased, at which time concentrations were very low (0 or 1 CFU 100mL^{-1}). Breakthrough of *E. coli* NAR into the tile drain system occurred within one day after application of the biotracer in both treatments, at which point concentrations were at their highest point of the study. Concentrations decreased consistently throughout the study, with the exception of two sampling dates (April 25th and May 16th; Fig. 4). These increases appear to be correlated with high rainfall events, where 30 mm of rainfall occurred between April 23rd to 24th and 12 mm of rainfall occurred between May 14th and 15th. During these peaks, total CFU in the effluent appear to be greater in the monocrop effluent than that of the intercrop; however, on these days there is no significant difference.

Although concentrations of *E. coli* NAR appear to be greater in the monocrop effluent than that of intercrop during most sampling dates, few were significantly different. As Table 3 illustrates, significant differences only occurred during the last two weeks of analysis, where significantly higher concentrations were present in the monocrop effluent.

Overall, total CFU found in the same number of samples collected in 2005 were 4040 and 3558 in the monocrop and intercrop samples, respectively. This was a difference of 482 CFU and an 11.9% difference.

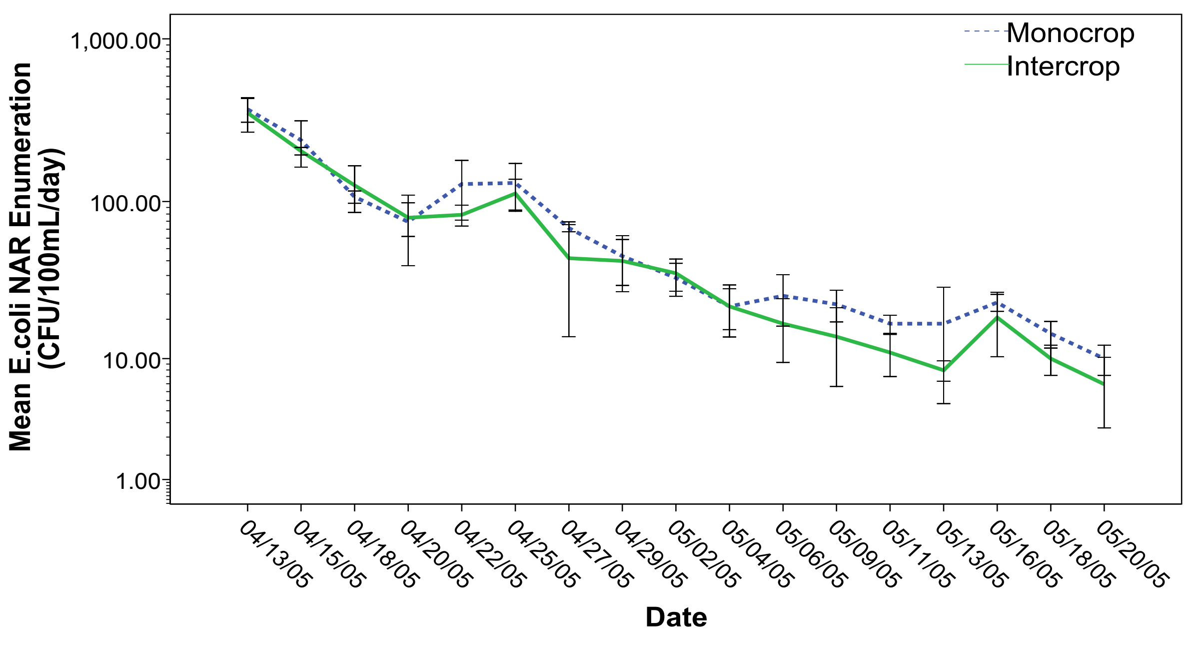

Fig. 4: Mean daily *E. coli* NAR enumeration (CFU 100 mL^{-1}), on a log scale, from April 13th to May 20th, 2005.[1]

[1] This figure is in colour in the electronic version of the Proceedings (CD)

Table 3: Mean *E. coli* NAR concentration (CFU 100mL^{-1} sample^{-1}) throughout the 6 week period in which the biotracer was present in the tile drain effluent during 2005.

	Mean Monocrop CFU	Mean Intercrop CFU	P-value
Week 1 (Apr 12th – 15th)	303.83 (± 36.50)	278.00 (± 37.91)	0.496
Week 2 (Apr 16th – 22nd)	103.11 (± 11.92)	95.89 (± 9.99)	0.610
Week 3 (Apr 23rd – 29th)	81.33 (± 14.15)	66.33 (± 12.94)	0.217
Week 4 (Apr 30th – May 6th)	27.00 (± 2.59)	24.89 (± 3.43)	0.441
Week 5 (May 7th – 13th)	18.89 (± 2.15)	11.11 (± 1.47)	0.003
Week 6 (May 14th – 20th)	17.78 (± 2.24)	16.00 (± 2.07)	0.015

2006

Concentrations of *E. coli* NAR found in the effluent of the monocrop and intercrop tile drains consistently decreased from April 19th, when the biotracer was applied, to June 10th, after which no CFU were found (Fig. 5). A steady decline, after an original peak in concentration also occurred in the biotracer tile drain studies by Reaume (1994), Shadford et al. (1997) and Ogden et al. (2001).

Breakthrough of *E. coli* NAR into the tile drain systems occurred three and two hours after application of the biotracer to the field surface in the monocrop and intercrop treatments, respectively. Similarly a study by Dean and Foran (1992), where a biotracer was surface applied to several tile drained fields, showed breakthrough times of 20 minutes to 6 hours. These quick breakthrough times were attributed to preferential flow. Likewise, the relatively rapid breakthrough times in this study are likely due to preferential flow to the tile drain system.

The highest concentration of the biotracer in the tile drain effluent occurred within a couple days after application (Fig. 5). A study by Joy et al. (1998) also found that the highest concentrations in tile drain water throughout a 3 year study occurred when high rainfall events took place shortly after application. In this study, although not directly after application, the three most significant peaks in concentration; May 11th to 12th, May 16th and June 1st to 2nd occurred after large rainfall events where 33.5 mm fell on May 11th, a total of 33 mm fell on May 15th and 16th, and 22 mm fell on May 31st. Studies by Reaume (1994), Shadford et al. (1997), Ogden et al. (2001), and Oliver et al. (2005) also demonstrated that *E. coli* concentrations increased in tile drain effluent after large rainfall events.

Monocrop and intercrop effluent concentrations of *E. coli* NAR appear to follow a similar pattern over time, with the monocrop treatment appearing to have a generally higher concentration for a majority of the dates. *E. coli* NAR concentrations differed significantly at all sampling periods except weeks 1, 3 and 6 (Table 4). It is interesting to note that concentrations in the monocrop and intercrop effluent are significantly different in weeks 4 and 7, during which the three largest rainfall events occurred (mentioned above). This suggests that after periods of high rainfall, the intercrop system was more effective at reducing movement of *E. coli* NAR to the tile drain systems.

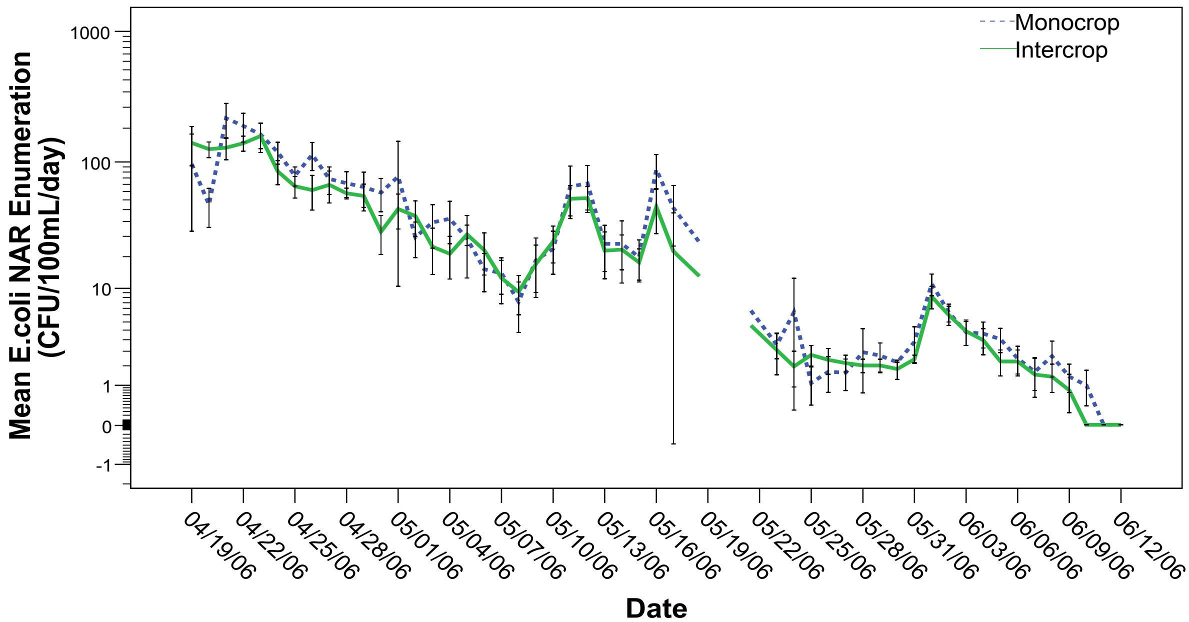

Fig. 5: Mean daily *E. coli* NAR enumeration (CFU 100 mL^{-1}), on a log scale, from April 19th to June 12th, 2006. The gap in data is due to a period of time when the tile drain monitors were not functioning.[1]

[1] This figure is in colour in the electronic version of the Proceedings (CD)

Table 4: Mean *E. coli* NAR concentration (CFU $100mL^{-1}$ $sample^{-1}$) throughout the 8 week period the biotracer was present in the tile drain effluent during 2006. There is no data during week 5 because the tile drain monitors were not functioning properly during this time.

Week	Mean Monocrop CFU (Standard Error)	Mean Intercrop CFU (Standard Error)	P-value
Week 1 (Apr 19 – 25)	131.95 (± 8.88)	119.20 (± 5.39)	0.170
Week 2 (Apr 26 – May 2)	71.37 (± 6.21)	50.54 (± 2.94)	0.002
Week 3 (May 3 – 9)	21.14 (± 2.07)	18.02 (± 1.33)	0.143
Week 4 (May 10 – 16)	43.67 (± 4.52)	33.00 (±2.57)	0.004
Week 5 (May 17 – 23)	na	na	na
Week 6 (May 24 – 30)	2.47 (±0.47)	1.95 (± 0.11)	0.274
Week 7 (May 31 – June 6)	4.87 (± 0.38)	4.03 (± 0.31)	0.029
Week 8 (June 7 – 12)	1.03 (± 0.15)	0.60 (± 0.12)	0.009

Overall, the total CFU found in all samples taken over the course of the 2006 study period (same number of samples for each treatment) were 34 025 and 28 401 in the monocrop and intercrop samples, respectively. This is a difference of 5 624 CFU and a 16.5% difference.

The mean concentrations of *E. coli* NAR are typically smaller during 2006 than 2005 (particularly in week 1). This is surprising considering a much higher concentration of *E. coli* NAR was applied in 2006. Perhaps the small sampling regime during 2005 produced a misrepresentation of the *E. coli* NAR concentration in tile drain effluent. Another possibility is the differing crops (winter wheat and corn in 2005 and 2006, respectively) and associated microbial populations may have varying effects on the survival of *E. coli* NAR.

CONCLUSIONS

Analysis of NO_3-N leaching between the two years produced very different results. Both years showed significantly more NO_3-N leaching from the monocrop treatment; however, the differences in 2006 were much more pronounced (4.6% and 46.2% reductions in 2005 and 2006, respectively). The main differences between the two years were 1) different crops (winter wheat in 2005 and corn in 2006); 2) more NO_3-N in the soil in 2006 available for plant uptake or leaching (via fertilization and mineralization); and 3) greater rainfall in 2006, particularly during the spring and fall months, resulting in prolonged tile drain flow. In 2006, because there were larger amounts of NO_3-N available for leaching and much greater movement of water to the tile drains, the potential for leaching can be considered high. Given that there was a 46.2% reduction in leached NO_3-N from the intercrop treatment, as compared to the monocrop treatment, in 2006, when the potential for leaching was high, it can be concluded that given conditions when the risk of leaching is high, the intercrop site studied can significantly mitigate NO_3-N leaching. This can also give an indication for the potential of temperate intercropping systems to mediate NO_3-N leaching.

During both years of the study, few significant differences were found in *E. coli* NAR leached to the tile drain systems. However, when there was a significant difference, there were greater amounts leached from the monocrop system. Additionally, there was 11.9% and 16.5% more total *E. coli* NAR CFU recovered from the monocrop tile drain effluent in 2005 and 2006, respectively, given the same number of samples from each treatment in each year. This indicates that the intercrop system may have a negative effect on *E. coli* NAR survival.

The presence of tree roots is very likely the reason for any mitigating properties the intercrop system would have. Studies have shown that increased microbiological activity, which is often associated with tree roots, particularly within the rhizosphere, has a detrimental effect on *E. coli* survival (Morel et al. 1989; Recorbet et al. 1992; Gagliardi and Karns 2002). It is very possible that the microbial communities in the intercrop system negatively affected the *E. coli* NAR survival, through predation and/or competition, however additional research is needed to determine if this is accurate and to what extent. For example, soil core experiments would allow for greater repetition, control over precipitation and temperature, selection of tree and/or plant type and associated microbial populations, as well as for varying *E. coli* quantities to be applied. Additionally, perhaps in a field study where more trees are present, with subsequently more root coverage (for example as a buffer system), results would be more pronounced.

Overall, the intercrop site demonstrated its ability to mitigate leaching of NO_3-N to the groundwater, particularly when the risk is high. Also, there is an indication the intercrop site may posses the ability to reduce leaching of *E. coli* NAR to the groundwater; however, more research is necessary.

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TREE-BASED INTERCROPPING SYSTEMS INCREASE SPATIAL HETEROGENEITY OF SOIL MICROBIAL COMMUNITIES

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Abstract: Soil quality can be assessed through a variety of indices such as fertility, soil structure, absence of pathogens and contribution to environmental health. Another more neglected aspect of soil quality is the diversity and spatial heterogeneity of microbial communities and their effects on the stability of microbial functions. Quadrats of agro-forestry research plots in Saint-Rémi (Québec) and at Guelph University (Ontario) were intensively sampled along a 56 point grid pattern to elucidate differences in microbial diversity and heterogeneity between intercropping and conventional agricultural systems. Phospholipid fatty-acids (PLFAs) were extracted from each sample, purified and methylated, and subsequently analyzed by gas chromatography. Whole PLFA profiles were analyzed through multivariate statistical methods (PCA, PERMDISP) and individual PLFA variance through Levene's and Moses' tests. In addition, we tested the hypothesis that higher microbial beta-diversity in agro-forestry plots correlated with higher microbial community tolerance to disturbance. To do so, we developed a test that monitors changes in microbial biomass after bulk soil samples from the sample grids were stressed using increasing concentrations of a heavy metal (Cu) contaminant. Data were fitted to decreasing exponential functions and first-order rate constants were then used to compare soil samples from agro-forestry and conventional systems. Results suggest that tree-based intercropping systems enhance soil microbial diversity compared to conventional cropping systems, but we have yet to demonstrate that this results in higher resistance of microbial functions to environmental stress.

Key Words: Agro-forestry, diversity-stability relationship, microbial beta-diversity, PLFA, spatial heterogeneity.

Résumé : La qualité du sol peut être évaluée à l'aide d'indices comme sa fertilité, sa structure, l'absence de pathogènes et sa contribution à la santé environnementale. Un aspect plus négligé de la qualité du sol est la diversité et l'hétérogénéité spatiale des communautés microbiennes et leurs effets sur la stabilité des fonctions microbiennes. Des parcelles agroforestières et des parcelles agricoles conventionnelles, à Saint-Rémi (Québec) et à Guelph (Ontario), ont été échantillonnées sur 56 points d'une grille pour comparer l'hétérogénéité spatiale (bêta-diversité) et la stabilité des communautés microbiennes. Des acides gras–phospholipides (PLFAs) ont été extraits de chaque échantillon, purifiés et méthylés, et ensuite analysés par chromatographie en phase gazeuse. Les profils complets des PLFAs ont été analysés à l'aide de statistiques multivariées (PCA, PERMDISP) et la variance des PLFAs individuels a été comparée avec les tests de Levene et de Moses. De plus, nous avons testé l'hypothèse selon laquelle une plus grande bêta-diversité microbienne dans les parcelles agroforestières soit corrélée avec une plus grande tolérance microbienne aux stress. Pour y parvenir, nous avons développé un test qui examine les changements de biomasse microbienne dans des mélanges de sol provenant des grilles échantillonnées, après l'application de différentes concentrations d'un métal lourd (Cu). Les données ont été ajustées à une fonction exponentielle décroissante et les constantes de premier ordre de chaque champ ont été comparées. Les résultats suggèrent que les systèmes agroforestiers avec cultures intercalaires augmentent la diversité microbienne du sol comparativement aux systèmes conventionnels, mais nous n'avons pu démontrer qu'il en résulte une plus grande tolérance microbienne face aux stress environnementaux.

Mots-clés : Agroforesterie, relation diversité-stabilité, bêta-diversité microbienne, PLFA, hétérogénéité spatiale.

INTRODUCTION

Soil microbial diversity is an important aspect of soil quality because it may ensure a higher redundancy and stability of ecological functions in soil ecosystems (Griffiths et al. 2004; Girvan et al. 2005). In tree-based intercropping (TBI) systems, soil properties such as organic matter content and nitrogen mineralization were shown to be spatially structured according to the distribution of the different plant species (Thevathasan and Gordon 2004). Consequently, we hypothesized that TBI systems increase the spatial heterogeneity (beta-diversity) of soil microbial communities compared to conventional cropping (CC) monoculture systems.

One way of characterizing soil microbial diversity is by analyzing soil extractable phospholipid fatty acids (PLFA). This is because different groups of microbes contain different proportions of specific PLFAs (Frostegård et al. 1993), and because these PLFAs do not persist in soil when microbial cells die. While PLFA profiles may vary over very small scales (< 1 cm) (Cavigelli et al. 1995), it may be presumed that these variations repeat themselves at larger scales in a homogeneous landscape such as conventional agricultural fields. In more complex plant communities, such as forests, microbial community structure may vary predictably at much larger scales according to the vegetation and other landscape features (Saetre and Bååth 2000; Lamarche et al. in press). Hence, compared to CC systems, we expect a greater beta-diversity of PLFA patterns in TBI systems where different tree species and annual crops alternate over scales of several metres.

Our study was also interested in testing the diversity-stability relationship that could exist in soil microbial communities of TBI and CC systems. For example, Orwin and Wardle (2005) showed a relationship between plant community composition and the resilience-tolerance of soil microbial communities to a drying disturbance. In the present study, we defined "microbial stability" as the tolerance of microbial communities to different levels of stress. Mixtures of within-site soils, which incorporated the inherent microbial beta-diversity of TBI and CC systems, were treated with different concentrations of a heavy metal (Cu) and microbial biomass was later assessed.

METHODS

Study sites and sampling

The study compared the spatial heterogeneity of soil microbial communities in a TBI and an adjacent CC field, at two study sites. The first study site is located near the town of Saint-Rémi (45° 16' N, 73° 36' W), Québec, Canada. Mean annual temperature is 6.2 °C and mean annual precipitation is 978.9 mm of which 22% falls as snow (Environment Canada). The TBI field was created in 2000 using alternating rows of hybrid poplar (*Populus trichocarpa* x *deltoides* TD-3230) and hardwood tree species (*Juglands nigra, Fraxinus americana*) with 8 m spacings between rows (Rivest et al. 2005). Soybean (*Glycine max*) was grown between tree rows since 2004. This field was paired with a CC field, situated 1500 m northeast, which had been planted with a soybean monoculture for the last 3 years.

The second study site is located near the City of Guelph (43° 32' N, 80° 12' W), Ontario, Canada. Mean annual temperature is 7.5 °C and mean annual precipitation is 792.7 mm of which 15% falls as snow (Environment Canada). The TBI field was created in 1987 using 10 tree species. The section sampled was bordered with rows of black walnut (*Juglans nigra*) and silver maple (*Acer saccharinum*) with 12.5 m spacings between rows (Thevathasan and Gordon 2004). This field was paired with a CC field, situated 300 m southwest, which had been planted with the same crop rotation of maize, soybean, winter wheat (*Triticum aestivum*) or barley (*Hordeum vulgare*) as the TBI field. Physico-chemical properties of the soil in each field are given in Table 1.

Table 1: Physico-chemical properties of soils and current year (2006) crops in each experimental field (CC = conventional cropping; TBI = tree-based intercropping).

	% clay	% silt	% sand	% organic matter	C/N ratio	pH KCl	2006 crop	Tree spacing (m)
St-Rémi								
CC	35	30	35	4.08	10.79	6.82	Soybean	-
TBI	35	30	35	5.97	10.13	6.05	Soybean	8
Guelph								
CC	20	30	50	4.51	13.36	7.14	Maize	-
TBI	20	30	50	4.61	15.57	7.10	Maize	12.5

In each field, a rectangular grid of 56 (7 x 8) sampling points was established between tree rows, with 1 m spacings between neighbouring sampling points. In late-August (St-Rémi) and early-September (Guelph) 2006, one 10 cm wide and 15 cm deep soil core was collected at each sampling point. The soil samples were immediately sieved (4 mm mesh), transported on ice in coolers to the University of Sherbrooke where they were kept at -20 °C until analyzed.

PLFA profiles

PLFAs were extracted from all 224 soil samples within three months of freezing following the method described by Hamel (2006). Briefly, lipids were extracted with dicholoromethane (DCM):Methanol (MeOH):citrate (1:2:0.8 v/v) buffer, and with DCM plus NaOH, and then again with DCM:MeOH (1:1 v/v). PLFAs were then collected by eluting with MeOH through a silica-gel column after discarding other fractions with DCM and acetone. The unlinked fatty acids (FAs) were methylated, and the extracts were injected in a HP 6890 gas chromatograph equipped with a flame ionization detector. They were carried by He gas in a 30 m Restek Rtx-1 Column. Known concentrations of FA 19:0 were added to each sample and used as internal standards to quantify concentrations of the 30 detected and identified indigenous FAs. Consequently, for each sample, a profile built from concentrations of 30 different FAs was created representing a signature of the microbial community.

Microbial tolerance to stress

To assess microbial tolerance, we developed a test that monitors changes in microbial biomass (MB) after bulk soil samples from the sample grids were treated with increasing concentrations of a heavy metal (Cu). Five soil mixtures, each comprising five randomly chosen soil samples, were created for each field (n=20). Each mixture was divided into 24 subsamples (24 g dry weight), and paired subsamples were then treated with 0.000, 0.006, 0.012, 0.018, 0.024, 0.036, 0.060, 0.090, 0.120, 0.150, 0.180 and 0.240 mg of $CuCl_2$. The treated soils were left to incubate 7 days after which microbial biomass was determined by substrate induced respirometry (SIR) (Anderson and Domsch 1978). From the resulting data, it was possible to derive an exponential equation (Fig. 1) describing the decrease in microbial biomass as a function of the Cu concentration. The first-order rate constant "k" defines the steepness of the decreasing exponential curve. A high "k" value denotes a fast drop in biomass, thus a low tolerance to stress.

Data analyses

PLFA data from Saint-Rémi and Guelph were analyzed separately by principal component analysis (PCA), and ordination biplots projecting the within-grid sampling locations on the first two principal components were used as a graphic measure of the degree of spatial heterogeneity within each field. Six FAs were removed from this analysis because of many zero values in the data matrix. In addition, the multivariate data set from each site was analyzed with PERMDISP software (Anderson 2004), a non-parametric and multivariate permutational extension of Levene's test for equality of variances. This test was performed on untransformed data using Euclidian distances. Finally, individual FAs within each sampling grid were analysed for equality of variance and dispersion using both Levene's test and Moses' test. The former is more robust than Bartlett's test for homogeneity of variance in the case of a departure from normality in the data and the latter is entirely non-parametric. First-order rate constants ("k" values), describing microbial tolerance to Cu stress, for TBI and CC systems were compared using a Student T-test.

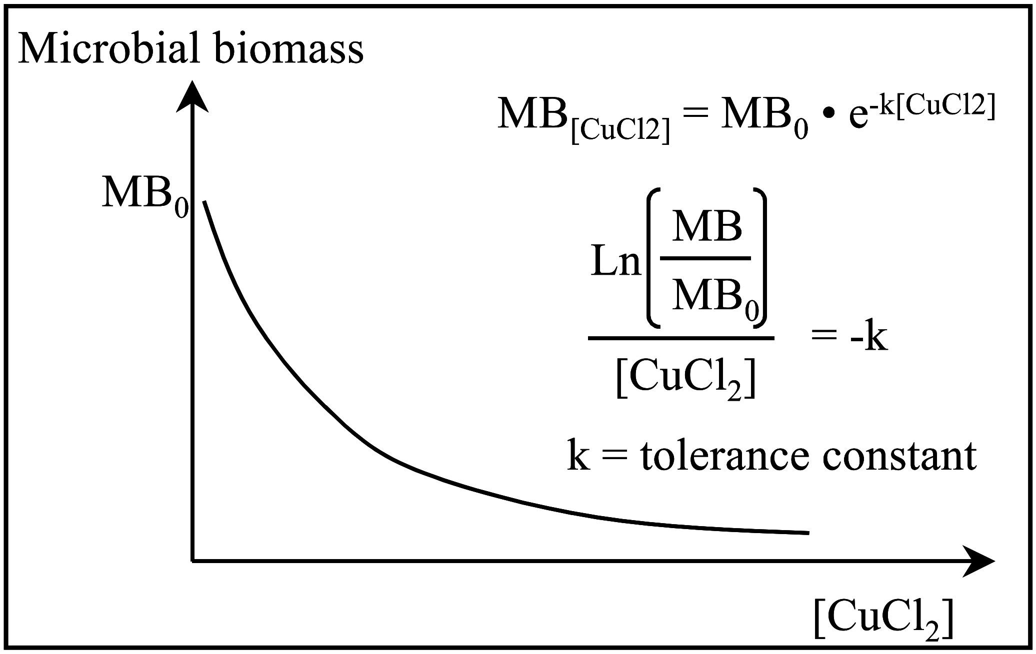

Fig. 1: Relationship between soil microbial biomass (MB) and $CuCl_2$ concentration.

RESULTS

The average total concentration of identified FAs of the 224 soil samples was 72 ng g^{-1}. Results from PCA showed TBI and CC samples from the St-Rémi site were segregated along the first principal component, and a wider distribution of TBI samples along the second principal component (Fig. 2A). At the Guelph site, TBI and CC sample scores along both principal components had similar means and standard deviations (Fig. 2B). The first two components at the St-Rémi and Guelph sites respectively explained 90% and 80% of the total variance in the data set.

The PERMDISP procedure confirmed a significantly higher dispersion of PLFA profiles in TBI than in CC samples at the St-Rémi site ($P<0.01$), but not at the Guelph site ($P=0.217$).

Tests for equality of variance performed on individual FAs concurred with the multivariate analyses. Results from Levene's test showed significantly higher ($P<0.05$) variance for 21 of the 24 FAs from TBI plots in Saint-Rémi. The test was significant for only one FA in Guelph. The Moses test gave similar results with TBI samples displaying a higher dispersion for 20 of the 24 FAs in Saint-Rémi and for none of the FAs in Guelph.

Microbial tolerance at the Guelph site could not be assessed because data failed to produce a significant fit to the decreasing exponential curve necessary to derive "k" values. In Saint-Rémi, "k" values were derived but did not differ significantly between CC and TBI fields ($t=-0.334$, $P=0.747$).

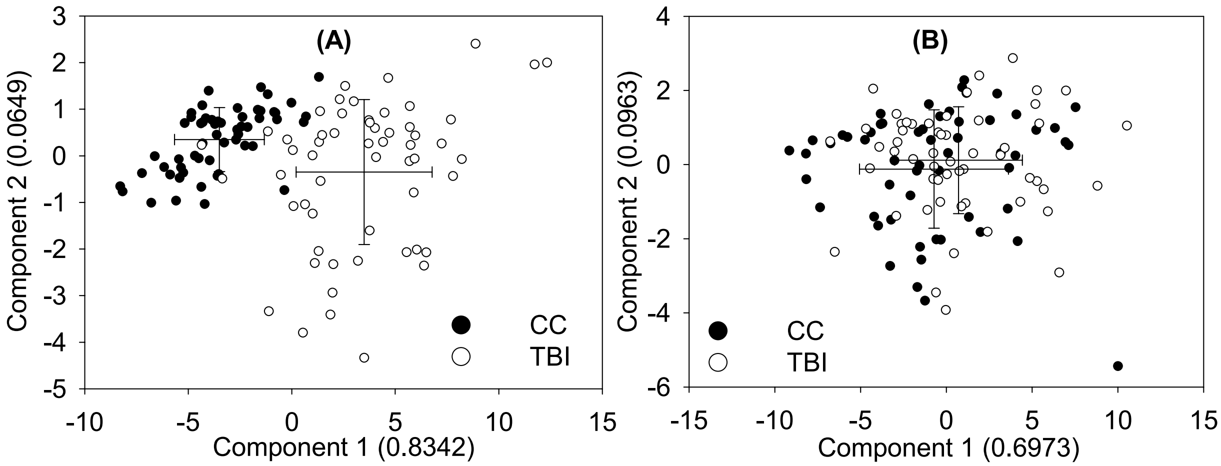

Fig. 2: Ordination biplots resulting from Principal Component Analysis (PCA) of 24 fatty acids found in TBI (white circles) and CC plots (black circles) in (A) St-Rémi and (B) Guelph. The proportion of the total variance explained by the first two principal components are shown in parentheses.

DISCUSSION

The combined results of PCA, PERMDISP, Levene and Moses tests indicate that the heterogeneity of the PLFA profiles at the St-Rémi site is higher in TBI than in CC systems. We can only speculate as to why this was not so at the Guelph site. The most obvious differences between both sites are the types of crops that were grown previous to, and during, the summer of 2006, and the textural class of the soils. Further research should, therefore, strive to understand how these two factors may interact with field-grown trees to control the spatial heterogeneity of soil microbial communities. For example, soybean is a crop that requires much less nitrogen fertilizer (30 kg N ha^{-1}) than corn (120-170 kg N ha^{-1}) (CRAAQ 2003). The effect of high fertilization rates may perhaps be greater than the effect of plant diversity on microbial communities. Hence, there may be a threshold fertilization rate over which plant effects are masked. For example, Ruppel et al. (2007) found a lower microbial metabolic quotient, a higher prokaryotic phylogenetic diversity and a higher diversity of substrate utilisation in soils receiving low rates of nitrogen fertilizers than in heavily fertilized soils. They hypothesized that fertilization resulted in the selection of specialized microbial communities, hence in fewer functional groups.

As for the possible effect of soil texture on microbial diversity, there is growing evidence that soil parent material may overshadow the effects of management practices (Yao et al. 2006; Lamarche et al. in press). For instance, Bossio et al. (1998) found that FAs associated to anaerobic bacteria were more present in agricultural soils with high clay content whereas FAs associated to aerobic bacteria and fungi were more likely to be found in sandier soils. We can surmise that a clay loam, such as found at the St-Rémi site, provides a wider range of soil particle sizes than a sandy loam, such as found at the Guelph site and, by implication, provides a wider array of microsites able to accommodate a wider range of bacterial niches. The textural class at the St-Rémi site is also apt to provide a better structured soil profile, again resulting in more diverse microsites for microbes. The higher clay content at the St-Rémi site is no doubt responsible for the higher organic matter content in TBI plots. Higher organic C provides more energy yielding substrates to the microbial community, and it has long been assumed that more energy cycling within a system allows more species to persist (Hutchinson 1959). Higher organic C and a higher diversity of litter inputs in the TBI plots at St-Rémi are likely to increase catabolic diversity of microbial communities (Degens et al. 2000). Consequently, TBI as a means of enhancing microbial heterogeneity may be valid on heavier soils only.

At the St-Rémi site, we were unable to observe a difference between the tolerance of soil communities in TBI and CC systems. Data suggests a higher sampling effort may be required.

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CROISSANCE ET BILAN NUTRITIF DE PEUPLIERS HYBRIDES DANS DES SYSTÈMES DE CULTURES INTERCALAIRES ÉTABLIS DANS LE SUD DU QUÉBEC

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Résumé : L'un des principaux objectifs du système de culture intercalaire (SCI) est la production de bois de qualité. Les connaissances actuelles concernant l'impact du SCI sur la croissance des arbres sont toutefois limitées, en particulier dans le contexte nord-américain. Afin d'analyser les effets de différentes modalités d'association arbre-culture et de l'itinéraire technique sur la performance de peupliers hybrides (PH), trois sites expérimentaux ont été établis en 2004 dans le sud du Québec. Sur les deux premiers sites, les PH (DN-3333 et DN-3570) ont été combinés à diverses successions de cultures annuelles de printemps (St-Paulin) ou d'hiver (St-Édouard), alors que sur le troisième site (St-Rémi), une culture de soya a été intégrée à des PH (DN-3308, NM-3729 et TD-3230) plantés en 2000. Les sites ont été établis suivant un modèle de plantation mixte de feuillus nobles et de PH disposés en rangées alternées. Le traitement de culture intercalaire (présence, absence) a été appliqué en parcelle principale, alors que le traitement de type de clone de PH a été appliqué en sous-parcelle selon un plan factoriel à blocs complets. Au terme de la deuxième saison de croissance, la hauteur, le diamètre et le volume des PH en SCI étaient significativement supérieurs à ceux des PH du traitement témoin. Le contenu en azote foliaire était quant à lui de 1,3 (St-Paulin) à 2,3 (St-Édouard) fois plus élevé chez les PH plantés en SCI. Les résultats de la troisième saison de croissance, ainsi que les effets du type de clone et d'un traitement d'élagage sont aussi présentés. Les résultats indiquent que les SCI présentent un potentiel de production de bois de qualité comparable, voire même supérieur, aux modèles classiques de plantation.

Mots-clés : Système de culture intercalaire, peupliers hybrides, nutrition, sylviculture.

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THE ECOLOGY AND ECONOMICS OF INSECT PEST MANAGEMENT AND BIODIVERSITY IN NUT TREE ALLEY CROPPING SYSTEMS IN THE MIDWESTERN U.S.

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Abstract: Our research involves examining the effects of alley cropping on insect biodiversity, crop yields, and small farm economics. We have investigated arthropod dynamics in a black walnut-alfalfa practice and a heartnut-canola-wheat practice compared to conventionally grown crops. We gathered data on the influence of trees on natural enemy effectiveness against alfalfa weevil in alley cropped alfalfa, the influence of tree-row spacing on arthropod populations, the influence of alley cropping on crop yield, and the overall economics of the system. We found that alfalfa weevil mortality was significantly higher in alley cropped alfalfa compared to monocropped alfalfa, and that arthropod diversity was greater in alley cropped crops compared to conventionally grown crops. Alfalfa yield from wider alleyways was not significantly different from monocropped alfalfa. The economic models indicated alfalfa in wider alleyways would be a profitable option for walnut growers. Alley cropping winter crops such as canola and wheat provide less competition with trees for water, nutrients and light while providing many of the same benefits found in the alfalfa-walnut system.

Key Words: Biodiversity, *Juglans nigra*, *Medicago sativa*, shade tolerance.

INTRODUCTION

The potential ecological benefits of an agroforestry practice such as alley cropping are numerous, but of little use unless the practice is economically viable. Alley cropping may increase biodiversity, reduce runoff, and improve carbon sequestration, but if growers cannot make money from the practice, it will not be adopted. The practical as well as the basic science of agroforestry must be explored to provide a complete picture.

The ecological basis for alley cropping arises from the theories found in agricultural polyculture. Many of the potential benefits of agroforestry are derived from increased diversity compared to traditional agricultural management practices (Stamps and Linit 1998). Increasing plant diversity through polyculture has been explored as a means to increase insect diversity and lower insect herbivore damage (Baliddawa 1985). Several mechanisms have been proposed for reduced herbivory by pest insects in diverse systems: (1) decreased host plant apparency; (2) increased interspecific competition among pest and non-pest species; and (3) improved natural enemy communities (Root 1973; Risch et al; 1983, Baliddawa 1985; Andow 1991).

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Insect natural enemies can regulate the population densities of many leaf-feeding insects. Agroecosystems can be modified to enhance the impact of beneficial insects, particularly parasitoids. Enhancements may include an increase in sources of adult parasitoid food (e.g., flowers or aphid honeydew), resting sites and places for mating (Altieri 1992; Idrus and Grafius 1995; Dyer and Landis 1996; Murphy et al. 1996). Trees grown in association with agricultural crops have the potential to increase parasitization of some important agricultural insect pests.

Ecological factors such as enhanced pest management are only one area to take into account when considering alley cropping. Crop-tree interactions, crop yield, nut yield, and overall management issues all play a role in this agroforestry practice. Appropriate crops that add positively to the economics of the small farm need to be considered.

Alfalfa is the most important and popular forage grown in the United States and can be readily sold as a hay crop. It is one of the few crops grown in every state, and there is an interest in growing alfalfa in an alley crop configuration (Barnes and Sheaffer 1995). However, little information is available on how alfalfa responds to shade environments that exist under trees, or how alfalfa pests respond to alley cropped alfalfa.

Economics is the driving force behind acceptance of an agroforestry practice. Alley cropping has the potential to diversify and stabilize income streams over short- and long-term time frames. Growing hardwood trees, especially for timber, is inherently a long-term enterprise with highly variable economic returns. The presence of a yearly crop could potentially provide an alternative income stream, provided the crop is compatible with alley cropping.

In this study, we examined numerous aspects of alley cropping. Our objectives were: (1) to determine the effect of black walnut alley cropping at wide and narrow alley spacings on field grown alfalfa forage yield and quality; (2) to examine arthropod pests and communities between forage grown in an alley cropped system and in a traditional monoculture system; and (3) to evaluate and compare the economics of conventional monocrop practices with alley crop practices.

METHODS AND MATERIALS

We established 2.5 ha of alfalfa in 12 m and 24 m wide alleyways among 17 year old black walnut trees in 2002. A similar sized plot of alfalfa was established in an adjacent open field. Alley cropped and conventional alfalfa plots were divided into 4 replications each. Four replications in each of the three areas (12 & 24 m wide alleyways and open field) were sweep sampled for arthropods throughout the growing season. The alfalfa was cut at 10% bloom three times during the growing season. We determined alfalfa yield from ½ m^2 samples collected immediately prior to cutting

.

Alfalfa weevil larvae were collected twice during the beginning of the growing season, ca. 2 weeks apart, over two years. The larvae were placed in individual rearing cups and were supplied with fresh alfalfa stems and leaves to complete their development. Mortality was monitored and the causes of mortality were noted to determine parasitism and disease rates.

Financial models were used to estimate the economic viability of alley cropping. We used the Black Walnut Financial Model Ver. 2.0 from the University of Missouri Center for Agroforestry web site to calculate the financials for the black walnut part of the plantation (Godsey 2007). We used the alfalfa budgets found in the Farm Business Management Guide FBM 3101 for alfalfa establishment and production in Southern Missouri to determine the alfalfa financials (Brees and Carpenter 2006). The financial performance of black walnut was determined at two tree row spacings (12 m and 24 m) and two tree type/nut harvest scenarios; (1) unimproved trees and nuts sold to a local sheller at $0.13/lb, and (2) improved and/or grafted trees and nuts directly sold to the processor at $0.50/lb. The alfalfa financials were determined for traditionally grown alfalfa and alfalfa grown in narrow (12 m) and wide (24 m) alley ways. Actual alfalfa yields from our experimental plots were used in the calculations.

RESULTS AND DISCUSSION

We found no difference in yield between 24 m alleyways and monocropped alfalfa on the first cutting date (Table 1). Yield from the 12 m alleyways was significantly lower than the other two treatments for both cutting dates. Yield decreased in the alleyways compared to the monoculture over the next two cutting dates because yields decreased in a linear fashion from the center of the alley ways to the driplines of the tree rows. Because growth is reduced when grown near black walnut trees, alfalfa would be more productive when wide alleys are used or during the early stages of plantations when tree growth has little influence on the alley environment.

Table 1: Dry-matter yield of alfalfa grown for three harvest cycles over two years in conventional plots and under trees spaced 12 and 24 m apart. Yields are kg/ha.

		21 May	24 June	7 August	Total
Establishment year	Monoculture	4017a	3834a	949a	8800a
	12 m alley	2778b	2033b	295a	5106b
	24 m alley	3566a	2641b	564a	6771c
		19 May	23 June	22 July	Total
Production year	Monoculture	2809a	3538a	2876a	9223a
	12 m alley	1314b	1816b	972b	4102b
	24 m alley	2133a	2512b	1786c	6431c

In 2004, the same percentage of alfalfa weevil larvae collected on 30 March from all treatments survived to adulthood, although *Zoophthora* infection was significantly higher in weevil larvae from alfalfa intercropped with trees compared to larvae from monocropped alfalfa (Table 2). The higher fungal-caused mortality was offset by lower parasitoid activity under the trees. For the 18 April collection, percent total mortality was significantly higher for weevil larvae from intercropped alfalfa compared to monocropped alfalfa, because of higher fungal mortality.

Fewer alfalfa weevils survived to adulthood from the monocropped alfalfa than from either of the alley cropped alfalfa treatments for the first collection date in 2005 (Table 2). The higher mortality of alfalfa weevil larvae from intercropped alfalfa can be attributed mainly to *Bathyplectes* parasitism. For the 15 April collection, both *Bathyplectes* parasitism and *Zoophthora* infection was significantly greater for weevil larvae from the 12.2 m alleyways compared to the other two treatments. An fungal epizootic was in progress during the last collection date, and the majority of the larvae died of fungal infection. Total mortality was very high for all three treatments and total mortality of weevil larvae was not significantly different among the treatments, although the trend towards higher mortality in larvae from the alley cropped alfalfa was still present. The presence of walnut trees appeared to increase natural enemy numbers, and significantly increased parasitism of alfalfa weevil over time.

Table 2: Mortality of alfalfa weevil larvae over four sampling dates among alfalfa fields grown in monoculture, in 12 M alleyways and in 24 M alleyways. Columns within a date with the same superscripts were not significantly different.

Date	Treatment	Adult weevil survivorship	Parasitoid mortality	Fungal infection
30 March 2004	Monoculture	47.5a	37.5a	15.0a
	12 M alley	43.8a	25.0a	31.3b
	24 M alley	45.0a	22.5a	32.5b
18 April 2004	Monoculture	41.3a	28.8a	30.0a
	12 M alley	18.8b	30.0a	51.3b
	24 M alley	26.3b	16.3a	57.5b
4 April 2005	Monoculture	73.2a	9.8a	17.1a
	12 M alley	52.5b	33.3b	14.2a
	24 M alley	58.4b	22.1a	17.3a
18 April 2005	Monoculture	12.1a	14.3a	73.6a
	12 M alley	4.5a	38.2b	57.0b
	24 M alley	4.6a	19.1a	74.1a

Readily available economic models and budgets were used to examine the economic feasibility of alley cropping alfalfa. The black walnut financial model indicated similar economics for 12 and 24 m tree row spacing without an intercrop (Table 3) using a discount rate of 4%. While wider tree row widths resulted in half as many trees, one less thinning was required, balancing the economics of wide and narrow alleyways. The "worst case scenario" of using unimproved trees and selling nuts to a local huller at $0.13/lb returned a net present value (NPV) of $240 (12 m spacing) and $270 (24 m spacing) and an average equivalent value (AEV) of around $10 and $11 for narrow and wide alley ways, respectively. Using improved or grafted trees and selling direct to the processor at $0.50/lb improved the economics dramatically; NPV rose to $1960 and $2050 and AEV rose to $80 and $83 for narrow and wide alley ways, respectively.

Table 3: Financial performance of black walnut at two tree row spacings and two tree type/nut harvest scenarios. Scenario 1: trees are unimproved and not grafted, and the nuts are sold to a local sheller at $0.13/lb – a "worst case scenario". Scenario 2: improved and/or grafted trees are planted and nuts are sold at a premium ($0.50/lb) directly to the processor. Discount rate of 4% was used in all models. Financial calculations from the Black Walnut Financial Model Ver. 2.0 from the University of Missouri Center for Agroforestry web site.

Model input scenario	Financial outputs	Tree row spacing	
		12 M alley 109 trees/acre	24 M alley 54 trees/acre
Unimproved trees	NPV[1]	$241.34	$268.57
$0.13/lb nuts	AEV[2]	$9.85	$10.96
Improved trees	NPV	$1964.51	$2050.83
$0.50/lb	AEV	$80.17	$83.69

[1]NPV, net present value: discounted value of all costs and revenues on a per acre basis.
[2]AEV, annual equivalent value: estimate of an equivalent annuity payment that would have the same NPV as the plantation.

The addition of alfalfa to the alleyways added to the positive economic outlook of the alley crop practice only for the wider alleyways (Table 4). While a grower would effectively break even during the establishment year ($2/acre cost), following production years would produce a profit of $20/acre in the 24 m alleyways based on the yield results from our study. Establishing alfalfa in narrower alleyways would cost $122/acre and production would not compensate for costs in the following years.

Costs and profits from black walnut vary greatly over the life of the plantation, and cashflows can be negative for decades. The addition of alfalfa in wide alleyways could provide a positive cashflow to offset the negative cashflow of tree establishment and help stabilize grower income year to year.

Our financial model did not take into account the potential non-market ecosystem values that may be gained from an agroforestry practice compared to a traditional crop practice, such as greater carbon sequestration, soil retention, increased biodiversity, improved aesthetics, and reduced pollution runoff (Farber et al. 2006).

Table 4: Financial performance of alfalfa grown traditionally and in wide and narrow alley ways between walnut tree rows. Tons per acre values based on research plot yields. Costs are based on alfalfa budgets found in the farm management guide for alfalfa establishment and production in Southern Missouri by Brees and Carpenter (2006).

		T/acre	Costs/acre	Returns/acre[1]	Profit/(loss)
	Monoculture	3.9	$302	$390	$88
Establishment	12 m alley	3.0	$302	$300	($2)
	24 m alley	2.0	$302	$200	($122)
	Monoculture	4.1	$260	$410	$150
Production	12 m alley	2.9	$260	$280	$20
	24 m alley	1.9	$260	$190	($70)

[1]Alfalfa price calculated at an average $100/ton or $3 per 60 lb bale.

The positive results in terms of higher pest mortality in alley cropped alfalfa compared to conventionally grown alfalfa, and the potential of alfalfa in wide alleyways to create positive and relatively stable yearly cashflows for growers suggest that an alfalfa/black walnut alley cropping practice could be promoted as an alternative to traditional plantation management.

We are engaged in further research investigating the suitability of winter crops as alley crops for nut trees. Alley cropping winter crops such as canola and wheat may provide less competition with trees for water, nutrients and light while providing many of the same benefits found in the alfalfa-walnut system but with narrower alleyways.

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SOIL AGGREGATE STABILITY AND ENZYME ACTIVITY IN AGROFORESTRY AND ROW-CROP SYSTEMS

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Abstract: The proportion of water-stable aggregates (WSA) influences soil quality, crop growth, nutrient retention, water infiltration, and surface runoff. Roots, fungi, and bacteria as well as numerous chemical substances secreted by these agents play important roles in soil aggregate formation, persistence, and turnover. The objective of the study was to test the hypothesis that permanent vegetative buffers will increase WSA and contribute to increased microbial diversity and enzyme activity. Soil samples (5 cm diam. and 10 cm long) from agroforestry (AG), grass buffer (GB), grass waterway (GWW) and crop (CS) areas were collected from summit, middle, and lower landscape positions at the Paired Watershed Study, near Novelty, MO. Water stable aggregates (> 250µm diam; wet-sieving method), soil carbon, soil nitrogen, and soil enzyme activity were determined and data were statistically analyzed. Soils under permanent vegetative buffers and GWW had significantly more WSA than the crop areas. Soil carbon and nitrogen were the highest in the GWW and the lowest in the CS treatments. Fluorescein diacetate (FDA) hydrolase, β-glucosidase and glucosaminadase enzyme activities were higher in AG, GB, and GWW soils than CS soils. Dehydrogenase activity was different between grass buffer or GWW and crop areas. The results of the study show that establishment of buffers with trees and grass as well as grass waterways increased WSA, soil carbon, soil nitrogen, microbial diversity, and enzyme activity. It could be speculated that improved soil physical properties and increased microbial diversity may help to reduce nonpoint source pollution from row crop agriculture watersheds thus improving environmental quality.

Key Words: Corn, agroforestry buffer, grass buffer, grass waterway, nonpoint source pollution, soil carbon; soil nitrogen, and soybean.

INTRODUCTION

The percentage of water stable aggregates (WSA) is a measure of resistance to breakdown by water and mechanical manipulation. Water stable aggregates improve soil water and air movement. Macroaggregates (diam. > 250 µm) are considered as a secondary soil structure associated with pores, microbial habitat, and physical protection of organic matter (Christensen 2001; Carter 2004). Aggregates provide spatially differentiated habitats for microorganisms and are important for biogeochemical soil processes (Park and Smucker 2005).

Enzyme assays provide quantitative information on microbial diversity, soil chemical processes, mineralization rates, and organic matter accumulation. Enzyme assays among different management practices may also indicate short-term differences in soil quality improvement, microbial diversity, rapid responses to changes in management, and sensitivity to environmental stresses (Dick 1997). Studies show that enzyme activity and microbial diversity are different in agroforestry alley cropping practices due to differences in litter quality and quantity, and root exudates (Gomez et al. 2000; Myers et al. 2001; Mungai et al. 2005).

Flourescein diacetate hydrolase represents a broad spectrum of enzymatic activities such as proteases, lipases, and esterases involved in decomposition of complex organic compounds (Dick et al. 1996). The activity of FDA can be found among a variety of primary decomposers and it has been correlated with soil organic carbon content (Dick et al. 1996; Gasper et al. 2001). β-glucosidase activity can be used as an indicator of soil carbon before other measurable properties can be evaluated (Dick 1994; Dick et al. 1996). This enzyme is involved in the degradation of cellulose, the main component of plant polysaccharides and carbohydrate polymers (Turner et al. 2002).

The substrate for glucosaminadase includes chitobiose and higher proteins (Parham and Deng 2000). Chitin hydrolyzing enzymes are widely distributed in nature and chitin degradation releases amino sugars – about 5-10% of organic N in soil (Stevenson 1994). The activity of this enzyme is highly correlated with fungal biomass and nitrogen assimilation (Sinsabaugh and Moorhead 1995; Miller et al. 1998).

Dehydrogenase activity is directly related to oxidation of organic matter (Dick et al. 1996). Research has shown that dehydrogenase activity is correlated with microbial biomass and other measures of biological activities and it can be used as an indicator of viable microbial populations (Stevenson 1959; Dick et al. 1996).

Although several environmental benefits of agroforestry practices are reported in the literature, Lovell and Sullivan (2006) stated that more research is needed for a comprehensive understanding of buffer effects on overall environmental quality. Studies of buffer influence on WSA, soil microbial diversity, and soil enzyme activity are limited in the literature. We hypothesized that adoption of grass and agroforestry buffer practices would improve soil properties, microbial diversity, and soil enzyme activity. The objective of this study was to compare differences in water stable aggregates, soil carbon, soil nitrogen, and enzyme activities in crop, grass buffer, agroforestry buffer, and grass waterway areas at three landscape positions in agroforestry and grass buffer alley cropping watersheds.

MATERIALS AND METHODS

Experimental site

Two north-facing experimental watersheds under corn (*Zea mays* L.)-soybean (*Glycine max* (L.) Merr.) rotation with no-till land preparation are located near Novelty, Missouri (40° 01' N, 92° 11' W; Fig. 1). The grass buffer (3.16 ha) and agroforestry buffer (4.44 ha) watersheds consist of 4.5 m wide buffer strips at 36.5 m apart. The grass-legume combination established in 1997 include redtop (*Agrostis gigantea* Roth), brome grass (*Bromus* spp.), and birdsfoot trefoil (*Lotus corniculatus* L.). Pin oak (*Quercus palustris* Muenchh.) trees were planted in the center of the buffer strips at 3-m spacing in the agroforestry watershed. Grass waterways on both watersheds consist of Kentucky 31 tall fescue (*Schedonorus phoenix* (Scop.) Holub). Details on watershed management, parent material, soils, experimental design, and climatic data can be found elsewhere (Udawatta et al. 2002; 2006).

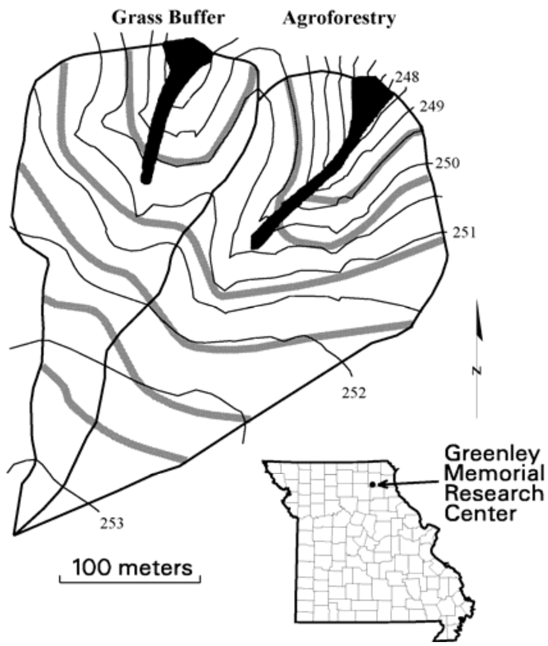

Fig. 1: Topographic map of the grass buffer and the agroforestry watersheds with 0.5 m elevation interval contour lines (black), grass (grass only), agroforestry (grass+trees) buffers (gray), and grass waterways (wide black). The inset map shows the location of watershed in Knox County, MO.

Sampling and analysis procedures

Soils from the row crop (CS), grass buffer (GB), agroforestry buffer (AG), and grass waterway (GWW) treatments were sampled in two transects extending from the summit to the lower backslope landscape positions in September 2006. GB and AG soils were sampled from buffers 1, 3 and 5 (counting from the south; Fig. 1) representing upper, middle, and lower landscape positions, respectively. Soil samples for the GB were taken from the center of the buffer. Soil for the AG treatment was sampled about 40 cm from the base of the tree trunk. For the CS treatment, soils were collected about 5 m south of the tree sample in the crop area. For the GWW treatment, soils were collected from three locations (south, middle, and north). Surface 0-10 cm soils were collected with a soil auger and soils were placed in a labeled ziplock bag. Sealed bags were transported to the laboratory in a cooler and stored at 4°C prior to measurements being conducted.

Water stable aggregates were determined using a 10 g soil sample with two replications using the wet-sieving method on aggregates >250µm diameter (Kemper and Rosenau 1986; Angers and Mehuys 1993). Total organic carbon and nitrogen concentrations were determined by combustion analysis at 950°C using a LECO TruSpec CN Analyzer.

The hydrolysis of FDA was colorimetrically quantified at 490 nm to indicate the broad-spectrum of soil biological enzyme activities and the concentration was expressed in µg fluorescein released g^{-1} dry soil h^{-1} (Dick et al. 1996). β-glucosidase enzyme activity was determined according to Dick et al. (1996). Soil was incubated with the *p*-nitrophenyl-β-D-glucoside substrate for one hour at pH 6.0 at 37°C. The concentration of *p*-nitrophenol was colorimetrically (410 nm) expressed in µg *p*-nitrophenol released g^{-1} dry soil h^{-1}. Glucosaminadase enzyme activity was determined as described by Parham and Deng (2000). Soil was incubated with the *p*-nitrophenyl-N- acetyl-β-D-glucosaminide substrate for one hour at 37°C. The concentration of *p*-nitrophenol was measured colorimetrically (405 nm) and the enzymatic activity was expressed in mg *p*-nitrophenol released kg^{-1} soil h^{-1}. Soil was incubated with 2,3,5-triphenyltetrazolium chloride substrate at 37°C for 24 hours to determine dehydrogenase enzyme activity (Pepper et al. 1995). The concentration of the triphenyl formazan (TPF) product was colorimetrically (485 nm) measured and the enzymatic activity was expressed in µg TPF released g^{-1} dry soil h^{-1}.

Analysis of variance was conducted with SAS using the GLM procedure to test differences between treatments and differences were declared significant at the $\alpha = 0.05$ level (SAS Institute 1999).

RESULTS

The percentage of WSA was significantly different between the buffer area and crop area soils (Fig. 2A). Among the four treatments, GWW had the highest percentage of WSA (19.97±1.75) and it was significantly different from the other three treatments. The GB and AG areas had almost two times more (1.94) stable aggregates as compared to crop areas (7.68±1.24). The percentage of WSA's was significantly different among all three landscape positions (Fig. 2B). The lower (17.3%±1.53%) and middle (13.03%±1.53%) positions contained higher percentages of WSA as compared to the upper landscape position (8.76%±1.54%).

Soil carbon concentrations in the surface soil were significantly higher for GB, AG, and GWW treatments compared with CS (Fig. 3A). The carbon percentage in the CS soil was less than 2% while the average percentage for the other three treatments was greater than 2.25%. Among the four treatments, the GWW had the highest carbon concentration. The difference was not significant among the permanent vegetative practices. Nitrogen distribution also followed a trend similar to carbon. The CS treatments were lowest in nitrogen content, which was significantly different from the other three treatments. The landscape position effect on carbon concentration was significant for the CS treatment (Fig. 3B); however, the landscape effect was not significant for the GB treatment. Among the three landscape positions sampled, the lower position within the AG system had the highest carbon content.

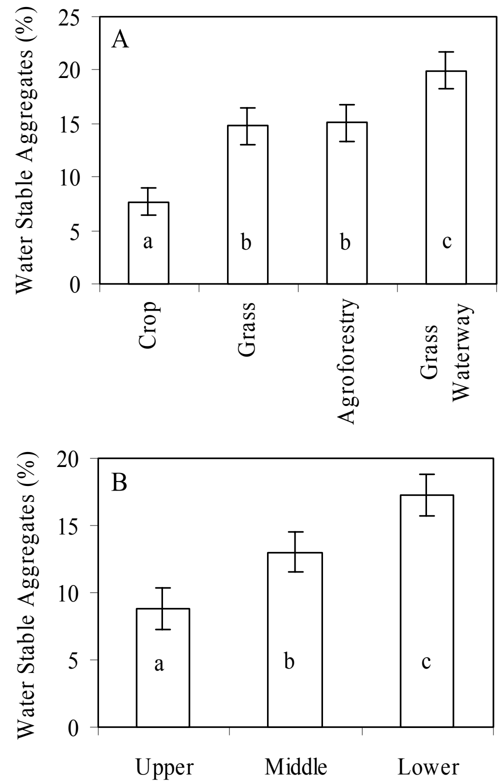

Fig. 2: Water stable aggregates by treatment (A) and landscape position (B). Bars with the same lower case letters were not significant at $p < 0.05$.

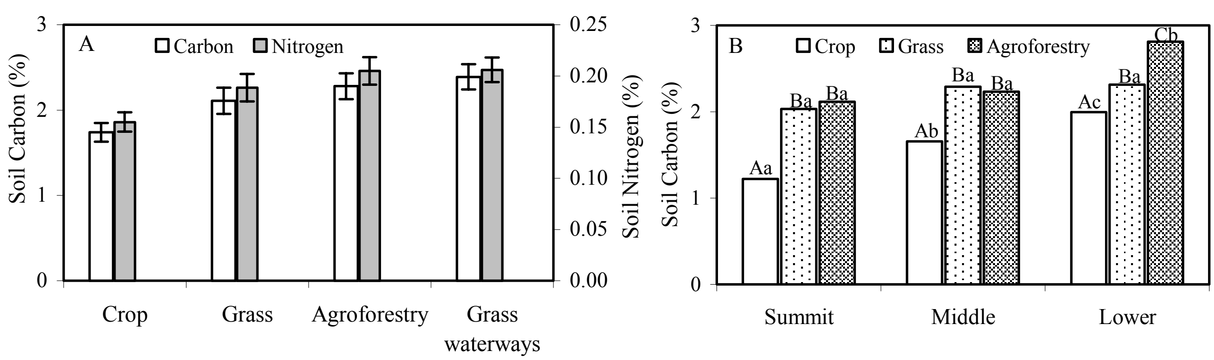

Fig. 3: Total soil carbon and nitrogen by treatment (A) and landscape position for row crop, grass buffer, and agroforestry buffer treatments (B). Bars with upper- and lower-case letters denote significant differences within a landscape position among treatments and among landscape positions within a treatment, respectively, at $p < 0.05$.

The FDA activity was significantly different between CS areas and the remaining three treatment areas (Fig. 4A). It was the lowest in CS area (8±0.61 µg fluorescein g^{-1} dry soil h^{-1}) and the highest in the GB area (13±0.86 µg fluorescein g^{-1} dry soil h^{-1}) under assay conditions. The AG and GWW treatments contained similar amounts of enzyme activity releasing an average of 11±0.86 and 10±0.86 µg fluorescein g^{-1} dry soil h^{-1}, respectively.

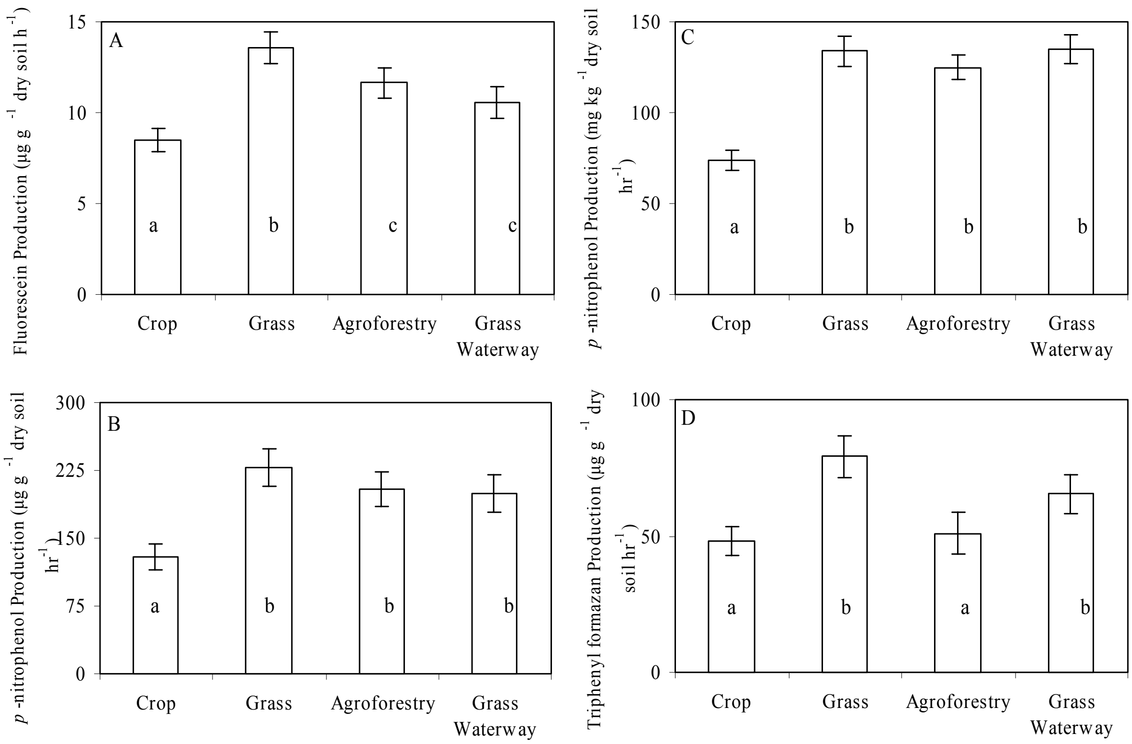

Fig. 4: FDA enzyme activity (µg fluorescein released g-1 dry soil h-1; A), β-glucosidase enzyme activity (µg *p*-nitrophenol released g-1 dry soil h-1; B), glucosaminadase enzyme activity (mg *p*-nitrophenol released kg-1 soil h-1; C), and dehydrogenase enzyme activity (µg triphenyl formazan g-1 dry soil h-1; D) for the four treatments. Bars with the same letter were not significant at $p < 0.05$.

Similar to FDA, the CS area (129±14.82 µg *p*-nitrophenol released g^{-1} dry soil h^{-1}) showed significantly lower levels of β-glucosidase activity compared to the GB, AG, and Similar to FDA hydrolase, β-glucosidase activity (129±14.82 µg *p*-nitrophenol released g^{-1} dry soil h^{-1}) was significantly lower in the CS are compared to GB, AG, and GWW treatment areas (Fig. 4B). The GB area had the highest level of enzyme activity with 228±20.59 µg *p*-nitrophenol released g^{-1} dry soil h^{-1}. With only slight differences, the AG and GWW treatments contained 204±19.26 and 199±20.59 µg *p*-nitrophenol released g^{-1} dry soil h^{-1}, respectively.

Analysis of glucosaminadase activity revealed significant differences between CS areas (73±5.12 mg *p*-nitrophenol released kg^{-1} dry soil h^{-1}) and the remaining treatment areas (Fig. 4C). Grass areas (GB and GWW) contained the highest levels of glucosaminidase activity with GWW and GB yielding 135±7.80 and 133±8.34 mg *p*-nitrophenol released kg^{-1} dry soil h^{-1}, respectively. Dehydrogenase activity was higher in grassed areas as compared to crop treatments (Fig. 4D). Grass buffers and grassed waterways exhibited an average production of 79±7.52 and 65±7.23 µg TPF g^{-1} dry soil h^{-1}, respectively. The lower levels of dehydrogenase activity within cropped areas were discovered to differ slightly between AG and CS treatments which contained an average TPF production of 50±7.52 and 48±5.21 μg TPF g^{-1} dry soil h^{-1}, respectively. However, the difference was not significant.

DISCUSSION

The WSA percentages within soils under CS management were lower compared with the GB, AG, and GWW treatments and these findings closely parallel previous findings. For example, Kremer and Li (2003) found higher percentage (18%) of WSA under various cool season grasses and legumes at sites managed under the "conservation reserve program" as compared to conventional tilled corn (10%) in Missouri. WSA in this study was also affected by the type of management, as soil under GWW management with fescue had significantly higher WSA as opposed to AG and GB treatments. Studies, on the same watersheds, showed increased soil porosity and reduced soil bulk density under the buffer areas as compared to the crop areas (Seobi et al. 2005; Udawatta et al. 2006; 2007). This may suggest that the organic matter added from fibrous root systems, leaves, twigs, and branches may have increased the WSA percentages and improved other physical soil properties at a much greater rate than can be achieved with conventional cropping practices.

Landscape position significantly affected WSA which increased from the summit to the lower landscape positions. This could be attributed to organic matter buildup, displacement, and deposition. This could also be due to higher water content at the lower landscape positions which promote more organic matter buildup and thus more soil aggregate development.

The proportion of water stable aggregates closely followed the distribution of soil organic matter, soil nitrogen, and soil enzyme activity. A good correlation between organic matter and increased WSA was also reported by Kremer and Li (2003) who found that soils under grass vegetation held greater amounts of organic matter along with higher WSA levels when compared with traditionally cropped areas. A higher percentage of WSA improves soil air and water movement and increases surface area as well as smaller aggregates as a secondary soil structure for microbial populations (Carter 2004).

The patterns of enzyme activities observed in this study support the hypothesis that permanent vegetative cover provides favorable conditions for microbial diversity and greater enzyme activities compared with soils under row crop management. Previous research indicates that different tillage systems, residue management practices, and cropping practices influence microbial population and enzyme activity due to changes in substrate supply, soil moisture, and temperature (Doran et al. 1998; Mungai et al. 2005). Similar to our results, Dick et al. (1996) observed reductions in enzyme activity under frequently disturbed soils. The cessation of intensive tillage could have positively affected enzyme activities in the permanent vegetation areas.

Soils managed to enhance organic matter production provide a healthy environment for diverse and competitive microbial populations and greater enzyme activity (Doran 1980). Other studies have shown that cover crops, crop rotation and organic matter addition increase microbial population and diversity (Kirchner et al. 1993). In this study, soil carbon originated from three different sources: crop, grass and trees. Therefore, the quantity and biochemical characteristics of the organic material available for decomposition varied among the management practices, which may have contributed to differences in enzyme activities. Furthermore, diverse plant communities in AG and GB likely support functionally distinct microbial communities through production of root exudates that differ from row crops in monoculture or short rotation systems (Lupwayi et al. 1998).

Our results show a strong correlation between high enzyme activity and increased levels of organic matter similar to other published research (Myers et al. 2001; Kremer and Li 2003; Mungai et al. 2005). In a mature agroforestry site in northeast Missouri, Mungai et al. (2005) observed greater enzyme activities under trees and less activity in crop areas. They attributed these differences to organic matter quality and quantity. Similar findings reported by Kremer and Li (2003) in Missouri showed greater FDA hydrolase and dehydrogenase activities under soils receiving organic matter compared with conventionally tilled areas. In forested ecosystems, Myers et al. (2001) found that microbial communities correlated with litter quality and quantity. The results of the current study indicate that establishment of AG buffers, GB buffers, and GWW in row crop watersheds may help increase degradation of agrichemicals due to increased enzyme activities. The increase in enzyme activity may also increase nutrient availability, which favors root growth, promotes microbial activities, and eventually increases the total soil carbon pool.

The effect of landscape position was not significant on enzyme activities. This suggests that factors influencing enzyme activity, such as organic matter quality and litter quantity, were not significantly influenced at various landscape positions within a management system. Decker et al. (1999) observed similar findings in which no significant change was apparent across various landscape positions in a soil enzyme study conducted in Ohio.

CONCLUSIONS

The purpose of the study was to examine influences of permanent vegetative buffers on water stable soil aggregates, soil carbon, soil nitrogen, microbial diversity, and enzyme activity. The top 10 cm soil was sampled which contains the highest biological activity and most likely exhibits short-term changes in response to plant communities. Based on measured properties, it is obvious that continuous disturbance has significantly reduced soil quality in the crop areas. The study showed that establishment of agroforestry buffers on previously cultivated agricultural areas has a significant effect on the measured soil quality indicators. The buffers were established in 1997 and therefore, the changes reported here occurred in less than 10 years. The extent of the improvement is partially determined by the vegetation type. These improved properties and other associated changes due to establishment of buffers may help to reduce NPSP from row crop agricultural lands.

Further studies are needed to understand the temporal variations and to quantify the influence of buffer age on these parameters. This will help to determine how long it would take to reach a steady state under these management systems. Additional research is also needed to understand substrate composition and its chemical quality on soil enzyme activity and microbial diversity in relation to agroforestry and grass buffer conservation management practices. Future research goals should be to identify the most suitable indicator/s as influenced by buffers that can be used to rapidly and efficiently estimate soil quality.

ACKNOWLEDGEMENTS

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COMPETITION FOR NITROGEN IN A LOBLOLLY PINE (*PINUS TAEDA*) – COTTON (*GOSSYPIUM HIRSUTUM*) ALLEY CROPPING SYSTEM IN THE SOUTHEASTERN UNITED STATES

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Abstract: The degree of tree-crop competition for nitrogen (N) and its effect on fertilizer-use efficiency and N movement were examined in a loblolly pine (*Pinus taeda*) – cotton (*Gossypium hirsutum*) alley cropping system in southern US established in 1999. Two pine-cotton alley cropping systems were studied: narrow and wide alleys. Pine trees were planted in triple rows with tree-row spacing of two meters. Cotton plants were grown eight rows per alley in the narrow alleys and sixteen rows in the wide alleys, with rows being one meter apart. Assessment of competition was accomplished via the installation of a belowground polyethylene root barrier in half of the number of the plots in order to provide two treatments – barrier and non-barrier. Soil samples were taken at three depths and at four stages of crop growth throughout the 2003 and 2004 growing seasons to examine nitrate nitrogen content and soil moisture. Aboveground biomass was sampled and N content and concentration were determined in the individual plant components (stem, leaf and seed cotton). The percentage of N derived from fertilizer (NDF) and fertilizer-use efficiency (UFN) were determined using 15N-enriched ammonium sulfate to twenty-four subplots in order to quantify nitrogen uptake by cotton plants and leaching loss in the soil profile at different distances from the trees. Data will be presented and discussed to show that competition for nitrogen is minimal in this system and tree roots function as safety net to reduce nitrate leaching in the soil through increase N interception and uptake.

Key Words: Competition, fertilizer use efficiency, safety-net hypothesis, tree-crop interaction, 15N recovery.

DOIG RIVER FIRST NATION HYBRID POPLAR INTERCROPPING ALLEY-CROPPING DEMONSTRATION

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Abstract: The Doig River First Nation (DRFN) with funding assistance from the BC Agroforestry Development Initiative, is creating an agroforestry demonstration where current and potential practitioners can develop and share 'on the ground' agroforestry information and expertise specific to the Peace River Region of British Columbia. The goal is to demonstrate the feasibility of alley cropping eight varieties of hybrid poplar including Walker, Okanese, Northwest, Green Giant, Hill, Assiniboine, and Katepwa with two varieties of native grass compared with pure stands of both trees and grasses. Two alley widths will be tested with each two varieties of native grass seed: 35 and 55 ft. Each tree belt located between the crop alleys will consist of 5 rows of trees spaced at 15 ft between rows and 10 ft between trees within a row. Each tree belt will incorporate four hybrid poplar selections. Each varietal block will be 5 trees wide x 15 trees long for a total of 75 trees. Comparisons will be made of the annual yield of native grass varieties in the alley crop verses the conventional field crop system, as well as comparisons of tree growth, damage and survival in the agroforestry system verses the plantation system. An economic assessment will also be conducted.

Key Words: Alley-cropping, hybrid poplars, First Nations, native grass.

SEASONAL OCCURRENCE OF THE LESSER CHESTNUT WEEVIL, *CURCULIO SAYI* (COLEOPTERA: CURCULIONIDAE) IN MID-MISSOURI

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Abstract: As the commercial growth of chestnuts in plantation and agroforestry systems increases in the Midwestern United States, it becomes necessary to understand a key threat to profitable nut production, the lesser chestnut weevil, *Curculio sayi*. There are relatively few scientific publications reporting on the basic biology and ecology of *C. sayi*. Consequently, the seasonal occurrence of C. sayi in mid-Missouri was investigated during the 2005 and 2006 seasons at a farm near Glasgow, Missouri. Wire-mesh cone emergence traps were placed on the ground under the canopy of several chestnut trees, and circle-trunk and pyramid-trunk traps were positioned on and around the trees, respectively. The former trap type was utilized to ascertain the adult emergence periods, and the latter trap types measured adult activity within and around the trees. All traps were checked weekly beginning in May and ending through October. Trap data revealed two distinct adult emergence and activity periods, with emergence peaks occurring in late-May and then again in early-September. Very few adults were trapped between these two periods, suggesting that the weevils leave the trees in the spring and then return in late-summer. Data on soil distribution and mortality of chestnut weevil larvae will also be presented.

Key Words: Lesser chestnut weevil, phenology.

EFFETS DE PEUPLIERS HYBRIDES, AVANT ET APRÈS ÉCLAIRCIE, SUR LA DISPONIBILITÉ DE LA LUMIÈRE ET LA PRODUCTIVITÉ DU SOYA DANS UN SYSTÈME DE CULTURE INTERCALAIRE ÉTABLI DANS LE SUD-OUEST DU QUÉBEC, AU CANADA

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Résumé : Dans les systèmes de cultures intercalaires (SCI), les arbres, et en particulier les peupliers hybrides (PH), peuvent entrer rapidement en concurrence avec les cultures pour la lumière, diminuant la productivité agricole. Certains éléments de l'itinéraire technique propre aux SCI, dont le choix des espèces et clones d'arbre, la densité de plantation et l'éclaircie permettent toutefois de maîtriser en partie cette compétition. Une étude a donc été entreprise pour analyser différents paramètres de productivité d'une culture intercalaire de soya en fonction de la variation de la proportion de la lumière totale transmise (PLTT) pendant deux saisons de croissance (2005 et 2006). Le soya a été intégré à une plantation mélangée, établie en 2000, de feuillus nobles et de PH disposés en rangées alternées espacées de 6 (pièce A) ou 8 m (pièce B). Le dispositif expérimental a permis de comparer les effets combinés de trois clones de PH (DN-3308, NM-3729 et TD-3230), ainsi que de l'orientation et de la distance par rapport à la rangée de PH. Une éclaircie a été réalisée au cours de l'hiver 2006 de façon à augmenter l'espacement des PH de 2 à 6 m sur les rangées. Les résultats obtenus avant éclaircie, en 2005, ont révélé que les paramètres de productivité du soya étaient généralement affectés significativement par le clone de PH associé et l'orientation. Le rendement du soya était le plus faible à proximité de la rangée de PH (2 m) et était positivement corrélé avec la PLTT. En 2006, après éclaircie, le rendement ne différait toutefois pas selon la distance, bien qu'il fût corrélé avec la PLTT. En général, les paramètres de productivité du soya étaient similaires à ceux observés dans des parcelles de référence (hors de l'influence des arbres) lorsque la PLTT était supérieure au seuil critique de 75-80 %. Durant les deux années de l'étude, le rendement était davantage corrélé avec le nombre de plants par m² et le nombre de gousses par m² qu'avec le poids de 100 grains. Les résultats suggèrent qu'il est possible de contrôler les effets négatifs de la compétition pour la lumière en portant une attention particulière à la sélection du clone de PH, à l'écartement et à l'arrangement spatial des rangées d'arbres, ainsi qu'à certains traitements sylvicoles comme l'éclaircie et l'élagage.

Mots-clés : Compétition pour la lumière, itinéraire technique, paramètres de productivité du soya, peupliers hybrides, système de culture intercalaire.

Abstract: In tree-based intercropping (TBI) systems, trees, especially hybrid poplars (HP), can compete quickly with crops for light, causing a decrease in crop productivity. Some components of the technical itinerary specific to TBI systems, including tree species selection, plantation density and thinning, allow for the control of at least part of this competition. Thus, a study was conducted in order to analyze different productivity parameters of a soybean intercrop in relation

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to the variation in percent total light transmittance (PTLT) during two growing seasons (2005 and 2006). Soybean was added to a hardwood-HP mixed plantation, established in 2000, and compose of alternate rows spaced 6 (parcel A) or 8 m (parcel B) apart. The experimental design allowed the comparison of the combined effects of three HP clones (DN-3308, NM-3729 and TD-3230), as well as of orientation and distance with respect to HP row. A thinning was carried out in the winter 2006 in order to increase spacing between the HP on a same row from 2 to 6 m. Results obtained before thinning, in 2005, revealed that the soybean productivity parameters were significantly affected by the HP clone and orientation. Soybean yield was the lowest near the HP row (2 m) and was positively correlated with PTLT. However, after the thinning, in 2006, yield did not differ according to distance from HP row, even if a correlation between yield and PTLT was observed. In general, the soybean productivity parameters were similar to the ones observed in reference parcels (without tree influence) when PTLT was higher than a threshold of 75-80 %. During both years of the study, the yield was correlated rather with the number of plants and pods per m² than with 100-grain weight. Results suggest that it is possible to control the negative effects of light competition if a particular attention is given to HP clone selection, spacing and spatial arrangement of tree rows, as well as some silvicultural treatments like thinning and pruning.

Key Words: Hybrid poplar, light competition, soybean productivity parameters, technical itinerary, tree-based intercropping system.

INTRODUCTION

Le système de culture intercalaire (SCI) est une technologie agroforestière qui consiste en la plantation de rangées d'arbres largement espacées les unes des autres de façon à pouvoir allouer les bandes intercalaires à des plantes cultivées. Bien que la plupart des essais expérimentaux soient encore récents sous climat tempéré, des résultats issus de modèles de simulation novateurs indiquent que certains SCI intégrant des peupliers hybrides (PH) ou des feuillus nobles s'avèrent plus rentables et productifs que les systèmes conventionnels agricoles ou forestiers (Graves et al. 2007), tout en présentant de multiples bénéfices environnementaux comme la réduction de l'érosion des sols et du lessivage de l'azote, ainsi que l'augmentation de la séquestration du carbone et de la diversité biologique des paysages (Palma et al. 2007). La prédiction de ces bénéfices environnementaux corrobore des observations issues de recherches menées en Ontario sur des parcelles expérimentales avec des arbres à maturité (Thevathasan et al. 2004).

La présente étude, réalisée dans le sud-ouest du Québec, s'insère dans le cadre d'un projet expérimental qui vise à caractériser les interactions écologiques dans un SCI associant des PH et des feuillus nobles à une culture de soya. La structure particulière des SCI, intermédiaire entre celles des monocultures intensives et des écosystèmes naturels, fait effectivement intervenir un large éventail d'interactions complexes qui contrôlent la productivité des arbres et des plantes agricoles. Une meilleure compréhension de ces interactions devrait permettre de cibler les critères prépondérants à la conception et à la régie de SCI novateurs applicables au contexte du nord-est de l'Amérique du Nord, tout en consolidant une base scientifique en pleine émergence dans plusieurs régions tempérées (Gordon et Newman 1997).

L'ombrage des arbres et la concurrence qu'ils exercent pour l'approvisionnement en eau représentent deux types d'interactions qui peuvent particulièrement limiter la productivité de la culture intercalaire associée (Jose et al. 2004). Dans l'est du Canada, les rares recherches ayant abordé le SCI associant des PH au soya suggèrent que la compétition pour la lumière serait le principal facteur limitant (Reynolds et al. 2007). Plusieurs essais utilisant des ombrières artificielles ont effectivement mis en évidence la sensibilité du soya à la disponibilité de la lumière, particulièrement au dessus d'un seuil critique de 20 à 30 % d'ombrage et lorsque le traitement est appliqué au cours de la phase reproductive (Wahua et Miller 1978; Eriksen et Whitney 1984; Egli et Yu 1991). Ces travaux sont cependant délicats à extrapoler aux SCI, les arbres présentant la possibilité d'entrer en compétition avec la culture intercalaire non seulement pour la lumière, mais aussi pour l'eau et les ressources édaphiques.

Bien que la productivité du soya soit appelé à décliner assez rapidement sous l'influence des PH (Puri et al. 2002), certains éléments de l'itinéraire technique propre aux SCI, dont la sélection des espèces d'arbre, l'espacement et l'arrangement spatial des rangées d'arbres, l'élagage et l'éclaircie, peuvent toutefois contribuer à atténuer la compétition interspécifique, ce qui permettrait d'augmenter le nombre d'années où la culture intercalaire est envisageable (Dupraz et al. 2005; Reynolds et al. 2007). Les effets combinés de ces éléments de l'itinéraire technique sur la disponibilité de la lumière et la productivité du soya demeurent toutefois peu connus. Les objectifs de la présente étude consistaient à : 1) comparer les effets de deux espacements entre les rangées d'arbres (6 ou 8 m), de trois clones de PH (TD-3230, DN-3308 et NM-3729) et de deux orientations de la culture par rapport aux rangées de PH (est et ouest), avant et après éclaircie des PH, sur la PLTT et différents paramètres de productivité du soya, à diverses distances de la rangée de PH; et 2) déterminer les relations entre la PLTT et les paramètres de productivité du soya.

MATÉRIEL ET MÉTHODES

Site

L'étude a été menée à St-Rémi (45°14′ N., 73°40′ O.), dans la Municipalité régionale de comté (MRC) des Jardins de Napierville. Le sol est un loam contenant approximativement 20 % d'argile et 50 % de sable, avec une bonne capacité d'échange cationique (20,6 meq/100 g), une faible teneur en phosphore (27 kg/ha), un drainage modéré à imparfait et un pH neutre (6,9). De 2004 à 2006, une culture intercalaire de soya a été intégrée à une plantation mélangée, établie en 2000, de feuillus nobles et de PH disposés en rangées alternées. Avant l'établissement de la plantation, des cultures de soya (1999) et de maïs (1998) occupaient le site.

Traitements et dispositif expérimental

Le dispositif est composé de 2 pièces (A et B) qui diffèrent selon l'espacement entre les rangées de feuillus nobles et de PH (A = 6 m, B = 8 m). Chacune des pièces est divisée en 4 blocs aléatoires complets, comprenant chacun 5 rangées de PH et 4 rangées de feuillus nobles, de façon à ce que tous les rangs de feuillus nobles soient accompagnés des 2 côtés par un rang de PH. Les PH ont été plantés à tous les 2 m sur le rang, à raison de 9 plants contigus pour chacun des clones (*Populus nigra x maximowiczii* NM-3729, *Populus deltoides x nigra* DN-3308, *Populus trichocarpa x deltoides* TD-3230) distribués de façon aléatoire. Les clones de PH choisis et les feuillus nobles permettent de viser une production de bois de grande qualité, à des fins de production de bois de déroulage, à haute valeur ajoutée. Les feuillus nobles (noyer noir (Juglans *nigra*) et frêne d'Amérique (*Fraxinus americana*) sont plantés aux 3 m sur le rang, par groupe de 3 plants par espèce. Les rangées d'arbres sont orientées à 310°, ce qui correspond approximativement à l'orientation des terres dans la région de l'étude.

Le soya (cultivar S03-W4) a été semé le 11 juin en 2005 et le 3 juillet en 2006. Il a été ensemencé par semis direct en visant une densité de 50 plants par m² et selon un espacement entre les rangs de 38 cm. Afin de répondre à des objectifs de recherche différents de la présente étude, le soya n'a été implanté que sur la moitié du dispositif, l'autre moitié étant sans culture. Le soya a reçu une application conventionnelle d'herbicides (mélange de FirstRate®, Pinnacle ® et Assure® II) au stade trifolié. La répression des herbacées à proximité des arbres est assurée par un paillis de plastique installé en bande continue. Les bandes d'herbacées colonisant l'interface paillis-soya ont été éliminées annuellement grâce à l'application localisée de glyphosate (Round Up®). En pré-semis, le sol a été amendé avec un fertilisant N-P_2O_5-K_2O à raison de 300 kg/ha de 5-27-24 en 2005 et de 275 kg/ha de 9-24-21 en 2006. Une éclaircie réalisée au cours de l'hiver 2006 a permis d'augmenter l'espacement entre les PH de 2 à 6 m sur les rangées, faisant passer leur densité de 417 à 139 tiges/ha dans la pièce A et de 313 à 104 tiges/ha dans la pièce B. Les PH ont été élagués en 2003 et en 2005 en visant à dégager, dans l'ordre, le tiers et la demie de leur fût.

Paramètres échantillonnés

Afin d'éliminer l'effet de bordure, les mesures du soya n'ont été effectuées qu'à partir d'une seule rangée de PH située au centre de chacune des deux pièces. Le Tableau 1 présente les caractéristiques des arbres dans les parcelles échantillonnées. En général, les PH de la pièce A avaient une taille légèrement plus grande que ceux de la pièce B. La taille des PH était similaire d'un clone à l'autre. Comme les feuillus nobles, de taille beaucoup plus petite, ont sans doute exercé une influence négligeable sur la productivité du soya au cours de cette étude, l'échantillonnage a été réalisé de façon à isoler les effets du clone, ainsi que de l'orientation (est et ouest) et de diverses distances par rapport à la rangée de PH sur différents paramètres de productivité du soya. Chaque parcelle de PH couvrait une superficie de 216 (pièce A) ou 288 m² (pièce B), avec une suite de 9 (en 2005) ou 3 (en 2006, à la suite de l'éclaircie) PH d'un clone donné en son centre. Dans chacune des pièces et pour chacun des paramètres de productivité, 8 quadrats (2 par parcelle x 4 blocs) de chaque combinaison clone x orientation x distance (2, 3 et 4 m dans la pièce A; 2, 3, 4, 5 et 6 m (2005) ou 2 et 5 m (2006) dans la pièce B) ont été échantillonnés (N = 384 en 2005 et N = 240 en 2006). Pour les mesures du rendement par m² et du poids de 100 grains, les plants de soya ont été récoltés manuellement dans des quadrats de 4 m² (1,14 x 3,51 m) en 2005 ou de 3 m² en 2006 (1,14 x 2,63 m). Le nombre de plants par m² et le nombre de gousses par m² ont été dénombrés dans des sous-parcelles de 1 m² (1,14 x 0,88 m). Afin d'avoir des valeurs de référence (hors de l'influence des arbres) pour chacun des paramètres de productivité du soya, 12 (2005) ou 8 (2006) quadrats ont également été échantillonnés, au nord et au sud de la pièce A, ainsi qu'au sud de la pièce B.

Tableau 1 : Caractéristiques des arbres au début des saisons de croissance 2005 et 2006 dans un système de culture intercalaire établi dans le sud-ouest du Québec, au Canada.

Mesure	TD-3230		DN-3308		NM-3729		Feuillus nobles	
	2005	2006	2005	2006	2005	2006	2005	2006
Pièce A : espacement = 6 m								
Hauteur (m)	8,2	11,0	6,9	9,8	7,0	10,1	2,1	3,2
Diamètre (cm)	8,3	11,4	7,0	10,7	6,9	9,6	3,6	5,5
Pièce B : espacement = 8 m								
Hauteur (m)	7,0	8,9	6,3	8,6	6,8	8,6	1,8	2,6
Diamètre (cm)	7,0	10,1	6,2	9,6	6,4	8,9	3,3	5,2

Note : le diamètre des peupliers hybrides a été mesuré à 1,3 m du sol (DHP) et celui des feuillus nobles au niveau du sol.

Des photos hémisphériques ont été prises en août 2005 et 2006, à l'aide d'une caméra numérique (*Nikkor Coolpix* 990) équipée d'une lentille *fisheye* à projection orthographique (*Nikon fisheye converter* FC-E8) qui était montée sur un trépied à 1 m du sol. Les photos couleurs ont d'abord été converties en mode binaire à l'aide du logiciel de traitement d'image Photoshop®. Elles ont ensuite été analysées à l'aide du logiciel *Gap Light Analyser* (Frazer et al. 1999). Une correction magnétique de 50^o ouest a été appliquée afin de corriger l'orientation des rangées d'arbres (310^o). La proportion de lumière totale (directe et diffuse) transmise a été mesurée pour la période comprise entre le 15 juin et le 31 septembre. Les photos ont été prises le long de transects croisant perpendiculairement le centre de la rangée de PH de chacune des 12 parcelles de la pièce B (3 clones x 4 blocs). Le long de chacun de ces transects, une photo a été réalisée à 5 distances (2, 3, 4, 5 et 6 m) de la rangée de PH, dans chacune des deux orientations (N = 120).

Analyses statistiques

Les pièces (A et B) et les deux années de l'étude ont été évaluées de façon indépendante. Le plan d'expérience a été considéré comme un plan factoriel à blocs complets aléatoires. L'analyse de variance (ANOVA) et la comparaison multiple des moyennes ont été réalisées à l'aide de la procédure MIXED de SAS. Dans les cas où la normalité et l'homogénéité de la variance n'étaient pas respectées, une transformation non paramétrique (rang) a été utilisée. Le test de comparaison multiple des moyennes de Tukey a été utilisé pour faire ressortir les différences significatives entre les différentes combinaisons de traitement. Le seuil de signification retenu lors des analyses a été de 5 %. Les relations entre la PLTT et les différents paramètres de productivité du soya ont été évaluées à l'aide d'analyses de corrélation.

RÉSULTATS

Au cours des deux années de l'étude, le type de clone de PH n'a pas affecté la PLTT. À la première année de l'étude (2005), une interaction entre la distance et l'orientation par rapport à la rangée de PH a toutefois affecté significativement la PLTT (Fig. 1). La PLTT du côté ouest de la rangée de PH était supérieure de 24 % à celle du côté est. D'un côté comme de l'autre, entre 2 et 5 m, la PLTT augmentait de façon significative d'une distance à l'autre, puis se stabilisait entre 5 et 6 m, ce qui suggère que l'interception de la lumière par les feuillus nobles était marginale par rapport à celle des PH. Suite à l'éclaircie réalisée à l'hiver 2006, la PLTT mesurée à 2 m de la rangée de PH, dans la pièce B, s'est accrue de 30 % par rapport à l'année précédente. Par ailleurs, une interaction significative entre le clone de PH, la distance et l'orientation a été mesurée (Fig. 2). Comme c'était le cas en 2005, la PLTT mesurée à l'est de la rangée de PH était inférieure à celle mesurée à l'ouest. En revanche, elle variait de façon beaucoup moins prononcée d'une distance à l'autre, particulièrement chez le clone NM-3729 (côté est) et le TD-3230 (côté ouest). L'écart entre la PLTT à 2 m et celle à 5 m était de 26 et 8 % en 2005 et 2006, respectivement.

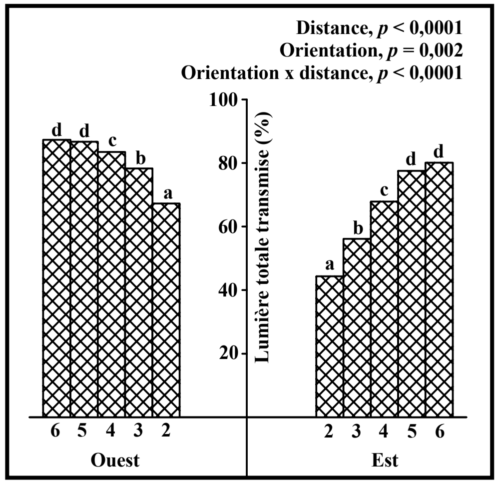
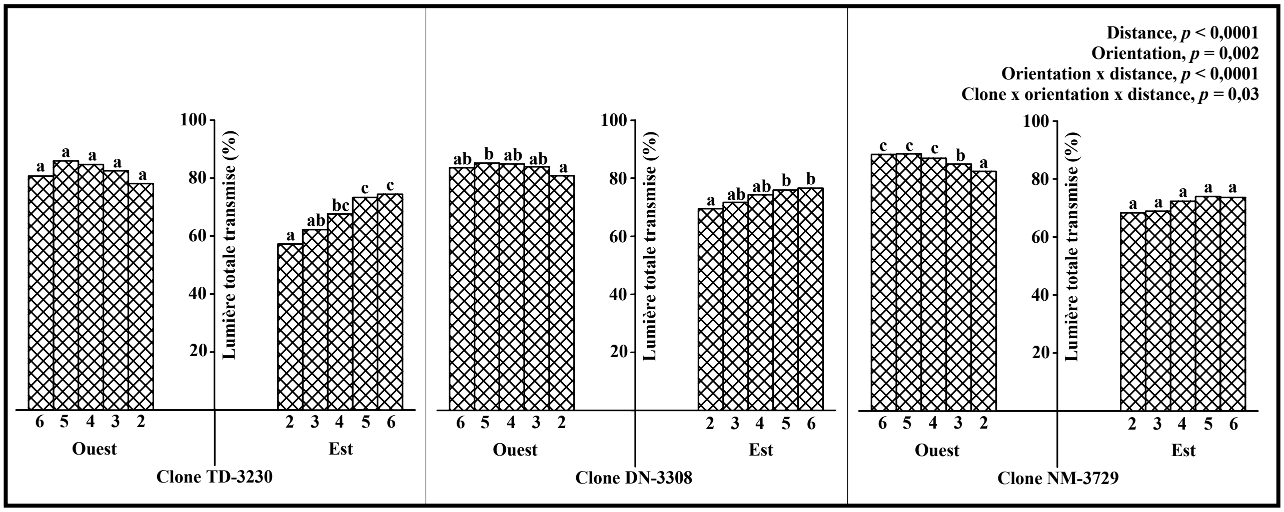


Fig. 1 : Lumière totale transmise avant éclaircie (2005) en fonction de l'orientation et de la distance (m) par rapport à la rangée de peupliers hybrides, dans un système de culture intercalaire établi dans le sud-ouest du Québec, au Canada. Les moyennes ont été calculés sur la base des observations réalisées dans la pièce B (espacement = 8 m). Les valeurs de probabilité (p) significatives de l'ANOVA sont indiquées dans le coin supérieur droit. Pour une combinaison d'orientation et de distance, les moyennes auxquelles ont été attribuées des lettres différentes sont différentes à $p < 0,05$ (test de Tukey).

Le type de clone de PH a affecté significativement les paramètres de productivité du soya mesurés en 2005. Dans la pièce A, le rendement du soya sous l'influence du clone NM-3729 était de 15 et 21 % supérieur à celui des clones DN-3308 et TD-3230 respectivement ($P = 0,02$) (Tableau 2). Dans la pièce B, bien que le rendement du soya avec le NM-3729 ait été plus élevé qu'avec le DN-3308 (3 %) et le TD-3230 (14 %), aucune différence significative n'a cependant été mesurée entre les trois clones ($P = 0,11$).

Bien qu'aucune différence concernant le nombre de plants par m² n'ait été observée dans la pièce A, ce nombre était plus faible avec le clone TD-3230 qu'avec les clones NM-3729 et DN-3308 ($P = 0,002$) dans la pièce B (Tableau 2). Le nombre de gousses par m², quant à lui, était supérieur avec le NM-3729, intermédiaire avec le DN-3308 et inférieur avec le TD-3230, autant dans la pièce A ($P = 0,05$) que dans la pièce B ($P = 0,04$). Le poids de 100 grains suivait, dans la pièce B, la tendance inverse de celle observée pour le nombre de gousses par m² : il était le plus élevé avec le TD-3230 et le plus faible avec le NM-3729 ($P = 0,05$). Suite à l'éclaircie des PH en 2006, aucun effet du clone de PH n'a été observé.



Fig, 2 : Lumière totale transmise après éclaircie (2006) en fonction du clone de peuplier hybride, de l'orientation et de la distance (m) par rapport à la rangée de peupliers hybrides, dans un système de culture intercalaire établi dans le sud-ouest du Québec, au Canada. Les moyennes ont été calculés sur la base des observations réalisées dans la pièce B (espacement = 8 m). Les valeurs de probabilité (p) significatives de l'ANOVA sont indiquées dans le coin supérieur droit. Pour une combinaison de clone, d'orientation et de distance, les moyennes auxquelles ont été attribuées des lettres différentes sont différentes à $p < 0,05$ (test de Tukey).

L'orientation a influencé significativement le rendement du soya, autant en 2005 ($P = 0,005$) qu'en 2006 ($P = 0,02$), mais seulement dans la pièce A (Tableau 2). Du côté ouest de la rangée de PH, le rendement du soya était de 9 et 7 % supérieur à celui du côté est, en 2005 et 2006 respectivement. De plus, un effet du clone de PH en interaction avec l'orientation ($P = 0,02$) a été observé en 2005 : le rendement était plus faible du côté est avec les clones TD-3230 et NN-3729, alors qu'il ne différait pas d'une orientation à l'autre avec le DN-3308.

En 2005, tous les paramètres de productivité du soya variaient significativement en fonction de la distance par rapport à la rangée de PH ($P < 0,01$). Les valeurs étaient généralement les plus faibles à 2 m et les plus élevées à 4 (pièce A) ou 5-6 m (pièce B ; Fig. 3). Aucun paramètre de productivité du soya n'a toutefois été affecté par la distance en 2006, après éclaircie. Néanmoins, une interaction entre l'orientation et la distance a influencé le rendement du soya dans la pièce A ($P = 0,002$; résultat non présenté). À 2 m de la rangée de PH, il était inférieur du côté est, tandis qu'il ne différait pas entre les deux orientations à 3 et 4 m. En outre, une interaction observée en 2006 entre le clone de PH et la distance, dans la pièce B, a mis en évidence que le rendement du soya avec le NM-3729 était plus faible à 2 m qu'à 5m, ce qui n'était pas le cas pour les deux autres clones ($P = 0,02$; résultat non présenté).

Tableau 2 : Comparaison des paramètres de productivité du soya en fonction de trois clones de peuplier hybride et deux orientations par rapport à la rangée de peupliers hybrides, avant (2005) et après éclaircie (2006), dans un système de culture intercalaire établi dans le sud-ouest du Québec, au Canada.

			Rendement (g/m²)			Plants par m² (nb)			Gousses par m² (nb)			Poids de 100 grains (g)		
Pièce	Année	Clone	Ouest	Est	Moyenne	Ouest	Est	Moyenne	Ouest	Est	Moyenne	Ouest	Est	Moyenne
A	2005	TD-3230	132 a X	108 a Y	120 a	38	36	37	311	250	281 a	22,1	23,1	22,6
		DN-3308	125 a X	126 b X	126 a	44	39	42	330	290	310 ab	21,8	22,7	22,2
		NM-3729	148 a X	138 b Y	143 b	43	40	41	345	319	332 b	21,8	22,4	22,1
		Moyenne	135 X	124 Y	129	42	38	40	329	286	308	21,9	22,7	22,3
	2006	TD-3230	150	135	143	38	36	37	400	308	354	17,2	17,1	17,1
		DN-3308	148	140	144	41	37	39	372	313	343	16,9	16,8	16,9
		NM-3729	142	138	140	40	37	38	372	321	345	16,8	17,1	17,0
		Moyenne	147 X	138 Y	142	40	36	38	381 X	314 Y	347	17,0	17,0	17,0
B	2005	TD-3230	173	174	173	41	39	40a	352	369	361 a	22,2	22,7	22,4 a
		DN-3308	188	194	191	46	45	46b	403	409	406 ab	21,5	22,2	21,8 ab
		NM-3729	201	194	197	42	39	41b	418	415	417 b	20,9	22,3	21,6 b
		Moyenne	184	189	187	43	41	42	390	398	394	21,5 X	22,4 Y	22,0
	2006	TD-3230	166	167	166	32	33	33	437	397	417	16,6	16,8	16,7
		DN-3308	157	151	154	31	33	32	409	400	404	16,8	17,0	16,9
		NM-3729	180	177	179	34	30	32	481	335	408	16,9	16,9	16,9
		Moyenne	168	165	166	33	32	32	443	377	410	16,8	16,9	16,8

Note : Les moyennes d'une même colonne pour chaque combinaison de pièce, d'année et d'orientation (ouest, est et moyenne) auxquelles ont été attribuées des lettres différentes sont différentes à $p < 0,05$ (test de Tukey). Les pièces A et B correspondent, dans l'ordre, à un espacement de 6 et 8 m entre les rangées d'arbres. Les moyennes d'une même ligne pour chaque combinaison de pièce, d'année et de clone (TD-3230, DN-3308, NM-3729 et moyenne) auxquelles ont été attribuées des lettres différentes sont différentes à $p < 0,05$ (test de Tukey).

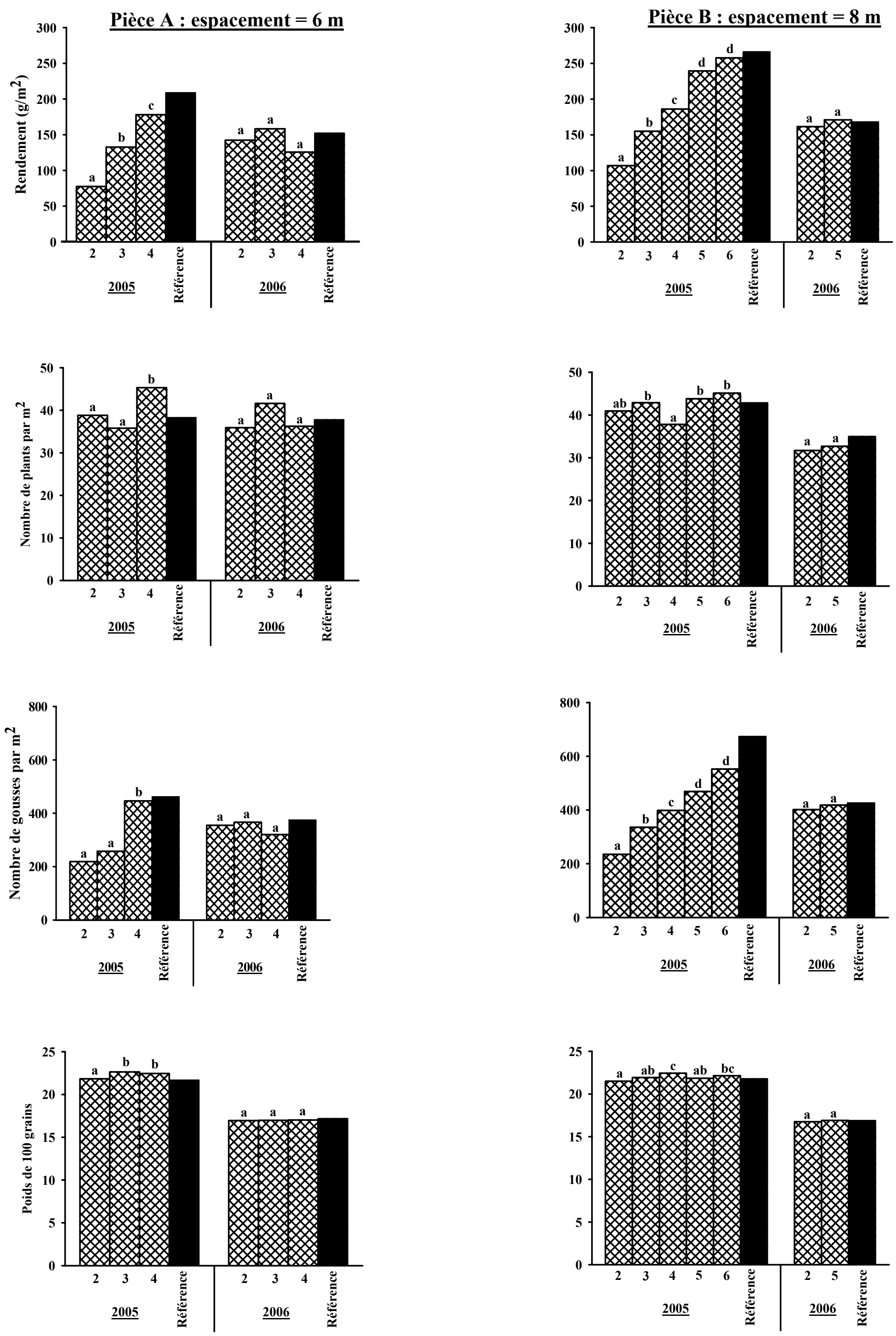


Fig. 3 : Comparaison des paramètres de productivité du soya mesurés à diverses distances (m) par rapport à la rangée de peupliers hybrides et hors de son influence (référence), avant (2005) et après éclaircie (2006), dans un système de culture intercalaire établi dans le sud-ouest du Québec, au Canada. Pour une combinaison de pièce, d'année et de distance, les moyennes auxquelles ont été attribuées des lettres différentes sont différentes à $p < 0{,}05$ (test de Tukey).

La mesure des différents paramètres de productivité du soya dans des parcelles de référence, effectuée à titre indicatif, a fait ressortir notamment que le rendement moyen en 2005 y était supérieur de 61 et 42 % à celui du SCI pour les pièces A et B, respectivement (Fig. 3). Après l'éclaircie de 2006, cet écart important de rendement s'est cependant largement amoindri : hors de l'influence des arbres, il n'était supérieur que de 7 et 1 % par rapport à celui des pièces A et B, respectivement. En général, les paramètres de productivité du soya étaient similaires à ceux observés dans des parcelles de référence lorsque la PLTT était supérieure au seuil critique de 75-80 %. Wahua et Miller (1978) rapportent qu'une diminution de la lumière de 20 %, obtenue grâce à l'utilisation d'ombrières artificielles, n'avait affecté ni le rendement du soya ni le nombre de gousses par m². Sous un tel niveau d'ombrage, les auteurs mentionnent toutefois que le poids de 100 grains y était plus élevé que celui mesuré en pleine lumière, ce qui est en accord avec ce qui a été observé dans la présente étude.

Au cours des deux années de l'étude, le rendement du soya était corrélé significativement avec la PLTT, excepté en 2005, à 5 m de la rangée de PH (Tableau 3). Le poids de 100 grains était lui aussi généralement corrélé avec la PLTT, mais de façon négative. Le nombre de gousses par m² n'était significativement corrélé avec la PLTT qu'en 2005, à 2 m, là où les plus faibles valeurs de PLTT ont été mesurées. À l'opposé, là où les plus hautes valeurs de PLTT ont été mesurées, soit lors de la saison de croissance 2006, à 5 m, une corrélation significative entre le nombre de plants par m² et la PLTT a été mesurée. En 2005, tout comme en 2006, le rendement du soya, en particulier à 2 m, était davantage corrélé avec le nombre de plants par m² et le nombre de gousses par m² qu'avec le poids de 100 grains, ce qui a également été observé par Ball et al. (2001) dans le cadre d'une étude sur la culture conventionnelle du soya.

DISCUSSION

Un effet significatif du clone de PH sur la plupart des paramètres de productivité du soya a été observé. Dans le contexte de l'optimisation de la productivité de la culture intercalaire, ce résultat souligne l'importance d'une sélection appropriée des espèces et des clones d'arbre, comme le suggèrent d'autres études sur des SCI associant des arbres à croissance rapide au soya (Dhyani et Tripathi 1999; Reynolds et al. 2007). En 2005, à l'exception du poids de 100 grains, les paramètres de productivité du soya étaient généralement les plus élevés avec le NM-3729 et les plus faibles avec le TD-3230. Ces contrastes entre clones n'ont cependant pas été observés en 2006, probablement en raison de l'éclaircie qui s'est traduite par une augmentation notable de la PLTT. Bien que les analyses statistiques ne l'aient pas mis en évidence, parmi les trois clones de l'étude, le TD-3230 est celui qui tendait à intercepter le plus de lumière totale transmise, probablement en raison du fait qu'il a développé une cime plus large que celle des deux autres clones (résultat non présenté). La modélisation (e.g. SORTIE), au cours des années futures, de la PLTT en fonction de différents paramètres de l'arbre (hauteur, DHP, largeur et porosité de la cime), pourrait permettre de préciser davantage les tendances observées en ce qui concerne les différences entre les clones de PH. Par ailleurs, dans l'hypothèse où les PH entrent en concurrence avec le soya pour les ressources édaphiques du sol, il faut considérer également que l'utilisation de ces ressources puisse varier en fonction du clone comme l'ont démontré Berthelot et al. (2000).

Tableau 3 : Coefficients de corrélation entre la proportion de lumière totale transmise et différents paramètres de productivité du soya à 2 et 5 m de la rangée de peupliers hybrides, avant

(2005) et après éclaircie (2006), dans un système de culture intercalaire établi dans le sud-ouest du Québec, au Canada.

	Distance par rapport à la rangée de peupliers hybrides									
	2 m					5 m				
Variables	1	2	3	4	5	1	2	3	4	5
2005, avant éclaircie										
(1) Lumière totale transmise (%)	1,00					1,00				
(2) Rendement (g/m^2)	0,66***	1,00				-0,10	1,00			
(3) Nombre de plants par m^2	0,31	0,42*	1,00			0,40	0,19	1,00		
(4) Nombre de gousses par m^2	0,57**	0,86***	0,61**	1,00		-0,17	0,51*	0,08	1,00	
(5) Poids de 100 grains (g)	-0,42*	-0,28	-0,18	-0,28	1,00	-0,79***	0,05	-0,30	0,00	1,00
2006, après éclaircie										
(1) Lumière totale transmise (%)	1,00					1,00				
(2) Rendement (g/m^2)	0,45*	1,00				0,51*	1,00			
(3) Nombre de plants par m^2	0,39	0,60**	1,00			0,59**	0,59**	1,00		
(4) Nombre de gousses par m^2	0,29	0,72***	0,24	1,00		0,18	0,18	-0,14	1,00	
(5) Poids de 100 grains (g)	-0,48*	-0,18	0,00	-0,29	1,00	-0,25	-0,25	-0,10	-0,36	1,00

Note : les coefficients de corrélation ont été calculés sur la base des observations (N = 24) réalisées dans la pièce B (espacement = 8 m). *$P < 0,05$; **$P < 0,01$; ***$P < 0,001$

Dans le SCI à l'étude, les rangées d'arbres étaient orientées à 310^o, ce qui est intermédiaire entre une orientation nord-sud et une orientation est-ouest. L'écart entre la PLTT du côté est de la rangée de PH et celle du côté ouest s'est avéré important, en particulier à proximité des PH. Bien que ce n'ait pas été le cas dans la pièce B, le rendement du soya était lui aussi le plus faible du côté est des PH dans la pièce A. Ces résultats sont en accord avec ceux obtenus lors d'une étude portant sur un SCI avec le PH, dans laquelle on a observé que, à 2 m de la rangée de PH, la disponibilité de la lumière et le rendement d'une culture de blé d'hiver étaient plus faibles du côté est et du côté nord, pour une orientation des rangées d'arbres nord-sud et est-ouest, respectivement (Dupraz et al. 2005). Les auteurs soulignent que le fait d'observer une réaction comparable de la PLTT et du rendement de la culture à l'effet de l'orientation des rangées d'arbres, porte à croire que la lumière était probablement le facteur limitant. Les auteurs mentionnent cependant que la concurrence pour la lumière peut être minimisée en optant pour une orientation nord-sud des rangées d'arbres. Comme c'était le cas dans la présente étude, l'orientation des terres et du réseau de drainage peuvent cependant représenter des contraintes importantes à l'adoption d'une orientation nord-sud.

Le plan d'expérience du présent essai n'autorise pas les comparaisons formelles entre la pièce A et la pièce B, ni entre les parcelles de référence (sans arbres) et celles du SCI. Les différences observées dans la réaction aux traitements peuvent cependant être considérées comme des indicateurs de tendances plus générales. Au cours des deux années de l'étude, il se dégage notamment que le rendement moyen du soya de la pièce B, comportant une plus faible densité d'arbres, était supérieur à celui du soya de la pièce A, tout en étant plus près de celui des parcelles de référence. Ces résultats appuient ceux obtenus par Shanker et al. (2005) qui ont observé que le rendement du soya en culture pure était supérieur de 2 et 9 % à celui de jeunes SCI avec *Hardwickia binata* comportant 200 et 800 tiges/ha, respectivement. Dans leur synthèse sur les SCI en Chine, Wu et Zhu (1997) ont insisté sur le fait que l'espacement entre les rangées d'arbres est un critère important à considérer dans un contexte où la lumière est le principal facteur limitant la productivité de la culture intercalaire. Dans le cas où les cultures agricoles et les arbres présentent une valeur économique similaire, ces auteurs recommandent d'opter pour un espacement de 15 à 20 m entre les rangées d'arbres, ce qui est bien en deçà de ceux utilisés dans la présente étude (6 ou 8 m), le dispositif ayant été conçu à l'origine pour des fins de recherche forestière. Néanmoins, la disposition des feuillus nobles et des PH en rangées alternées constitue, pour sa part, un système tout à fait novateur (Thevathasan et Gordon 2004) qui offre l'avantage de maintenir le site ouvert, ce qui est favorable aux cultures intercalaires. Cela a été clairement démontré en 2005 alors que la PLTT et le rendement du soya à proximité (2 m) des feuillus nobles étaient supérieurs à ceux à proximité des PH. En outre, un tel système permet l'obtention d'une récolte de bois à moyen terme (15-20 ans) grâce aux PH, ce qui n'est pas le cas des SCI intégrant uniquement des feuillus nobles.

En ce qui a trait à la validité du traitement d'éclaircie, il aurait été hasardeux de morceler davantage le dispositif expérimental en y ajoutant un témoin sans éclaircie, compte tenu de la taille restreinte de l'aire de l'étude. Néanmoins, la comparaison entre l'année avant (2005) et l'année après (2006) l'éclaircie peut être considérée comme un bon indicateur de l'effet du traitement. En 2005, face à des réductions importantes de la PLTT, en particulier à proximité des PH, les paramètres de productivité du soya étaient fortement réduits. Par contre, suite à l'éclaircie qui s'est traduite par une augmentation importante de la PLTT à proximité des PH, les différents paramètres de productivité du soya présentaient une distribution uniforme d'une distance à l'autre de la rangée de PH. En augmentent de façon notable la PLTT grâce à l'élagage des PH, Dupraz et al. (2005) ont constaté, eux aussi, une atténuation importante du gradient de productivité de la culture intercalaire en relation avec la distance de la rangée d'arbres.

Bien que davantage de recherche soit nécessaire afin de préciser l'importance des effets de concurrence pour la lumière par rapport aux interactions souterraines (compétition pour l'eau et les éléments minéraux), les corrélations significatives mesurées entre la PLTT et le rendement du soya, ainsi que leur réponse similaire à l'effet de l'orientation, indiquent que la lumière est probablement le facteur limitant du SCI à l'étude. Cette conclusion est tout à fait en accord avec celle qu'ont tirée Reynolds et al. (2007) d'un SCI similaire à la présente étude, ainsi que Jurik et Van (2004) d'un système associant le soya au maïs et à l'avoine. Les résultats suggèrent qu'il est possible de contrôler les effets négatifs de la compétition pour la lumière si une attention particulière est portée à la sélection des espèces et des clones d'arbre, à l'écartement et à l'arrangement spatial des rangées d'arbres, ainsi qu'à certains traitements sylvicoles comme l'éclaircie et l'élagage.

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PRODUCTIVITY AND CHARACTERISTICS OF SIX BLACK WALNUT CULTIVARS IN MISSOURI

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Abstract: Commercial nut production offers an alternative to the traditional agronomic crops grown in the Midwest, USA. Black walnut (*Juglans nigra*) appears to have good potential, but commercial production based on improved cultivars has yet to be documented. Numerous superior cultivars have been identified, yet little data is available on their potential productivity. A black walnut orchard of 135 trees was established in southwest Missouri in 1993 in order to compare yields and other characteristics among six of the most promising cultivars. Seedling trees were field-grafted to 'Emma K', 'Football', 'Kwik-Krop', 'Sparrow', 'Surprise', and 'Tomboy' in a completely-randomized study. Significant nut production began in 2003, with the fourth and largest harvest conducted in 2006. During these four initial years, cumulative nut yields from producing trees were highest in 'Tomboy' with mean yields of 21.2 kg/tree, and lowest in 'Surprise' with 1.5 kg/tree. During the 2006 harvest, which was the largest to date, yield patterns mirrored cumulative yields. 'Tomboy' produced a mean of 863 nuts per tree with a mean dry weight of 15.2 kg, whereas 'Surprise' produced only 121 nuts per tree weighing 2.1 kg. 'Football' fruits had the highest percent hull at 80.2%, whereas 'Tomboy' had the lowest at 62.8%. At harvest, 'Surprise' hulled nuts had significantly higher percent water (27.5%) above ambient moisture compared with the other cultivars that ranged from 21.0% ('Emma K') to 19.0% ('Football'). At this early stage of production, 'Tomboy', 'Emma K', and 'Sparrow' appear to be especially promising nut-producing cultivars at this location.

Key Words: *Juglans nigra*, nut, yield, grafted, cultivar.

MODELS TO QUANTIFY THE ENVIRONMENTAL AND ECONOMIC BENEFITS OF TREE-BASED INTERCROPPING SYSTEMS IN CANADA

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Abstract: Canada has more than 50 million hectares of agricultural land that is classified as "marginal". If this land was afforested, the carbon stored in soils and woody tree components would count as a carbon sink in our National Inventory. Our project focuses on tree-based intercropping (TBI), in which agricultural crops are grown in the alleys between tree rows, as a system that can reduce the environmental impacts of climate change and intensive agriculture. Yet, there are only a few TBI research sites in Canada, which makes it difficult to predict the trajectory and magnitude of environmental responses (i.e., rates of C sequestration) that could be expected from such a system. Incorporating more trees in the rural landscape requires investment and a reduction in annual crop yields but is expected to provide higher economic returns when mature trees are harvested for bioenergy and bioproducts. The tradeoffs between short- and long-term profitability in TBI systems must be quantified before a commercial enterprise can be developed in Canada. We will test robust ecological and economic models with datasets from short- (3-5 year old), medium- (8-10 year old) and long-term (20-22 year old) TBI systems. The validated models will be used to examine the range of environmental and economic benefits that may accrue from TBI systems under various scenarios, such as in different Canadian ecozones, with climate change and with changing market factors. Model output could suggest policies and incentive programs that would make TBI systems a feasible option for landowners across Canada.

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SECTION 4

Systèmes sylvopastoraux / Silvopastoral Systems

THE USE OF SHEEP AND GOATS FOR THE MANAGEMENT OF COMPETING VEGETATION IN BC FORESTS

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Abstract: Sheep grazing has been an accepted forest vegetation management technique in British Columbia (BC) since 1990, and operational use of goats is now also being investigated. This presentation includes information on development of the grazing program in BC, activity trends, operational accomplishments, environmental issues, and concerns associated with using domestic animals in the forest. It also discusses the contributions that the provincial government, the sheep producers industry, sheep grazing contractors, program monitors, and field foresters have made towards the creation of a successful program. These include the development of policies, guidelines, and field monitoring criteria to address issues and concerns relating to animal health, wildlife–carnivore interactions, and the environment.

Key Words: Forest, vegetation management, sheep, grazing, British Columbia program.

INTRODUCTION

In British Columbia (BC), areas that are harvested on Crown land must be reforested and tended to a free-growing state where the young trees are healthy, free from the influence of competing vegetation, and are predicted to grow unimpeded through to maturity. This is a legal requirement of the BC government. To this end, an extensive integrated vegetation management program is in place that encourages appropriate application of a range of approved vegetation management methods. Suitable vegetation management techniques must be chosen on a site-specific basis to favour crop tree species survival and growth and desired target vegetation control, with no negative impact on other resource management interests — no single method can be used in all situations.

The main vegetation management methods that are utilized in BC include biological techniques (the use of living organisms such as sheep and goats), chemical techniques (using registered forest herbicides), and manual techniques such as cutting or girdling. These can be applied as either site preparation or brushing treatments. Mechanical site preparation and controlled burning techniques are applied to prepare sites for natural regeneration or planting, and are also effective methods of controlling vegetation. In addition to considering the effectiveness of a technique for meeting silviculture objectives and its economic cost, the integrated vegetation management approach also specifies that impacts on workers and local inhabitants, and on environmental factors must also be considered. Experience in BC has shown that sheep grazing, either by itself or in combination with other treatments, is an effective option for managing competing vegetation on some forest regeneration sites.

HISTORY AND TRENDS OF SHEEP USE IN BRITISH COLUMBIA

Operational use of sheep for vegetation management in BC began in early 1990, after experimental forest grazing projects showed that sheep could effectively control competing vegetation in forest plantations with a minimum of damage to crop seedling species such as spruce (Newsome et al. 1995; Newsome 1996). Controlling competing vegetation with sheep was regarded as an example of successful integrated resource management, and as a biological and an "environmentally friendly" forestry activity with high public acceptance (Newsome 1996; Kabzems et al. 1998). Since 2004, brushing with goats is also being applied operationally and seems to hold some promise.

Sheep grazing generated great interest in many Forest Districts and communities of British Columbia in the 1990s. The program peaked in 1994 with about 45,000 sheep grazing on nearly 9,500 ha of young forest plantations (Fig.1). Since then, however, the program has declined steadily, mainly due to decreasing availability of area that is suitable for this treatment. By 2005, grazing was applied to only 1,950 ha, and involved only 7,475 sheep and 725 goats. Preliminary figures for 2006 suggest even further reductions, with treatments continuing to be applied only in the northern interior region of BC. Grazing has nonetheless played an important role in the British Columbia vegetation management program. From 1991 to 2006, approximately 77,500 ha were brushed with sheep or goats, representing 7.4% of the overall program for that period.

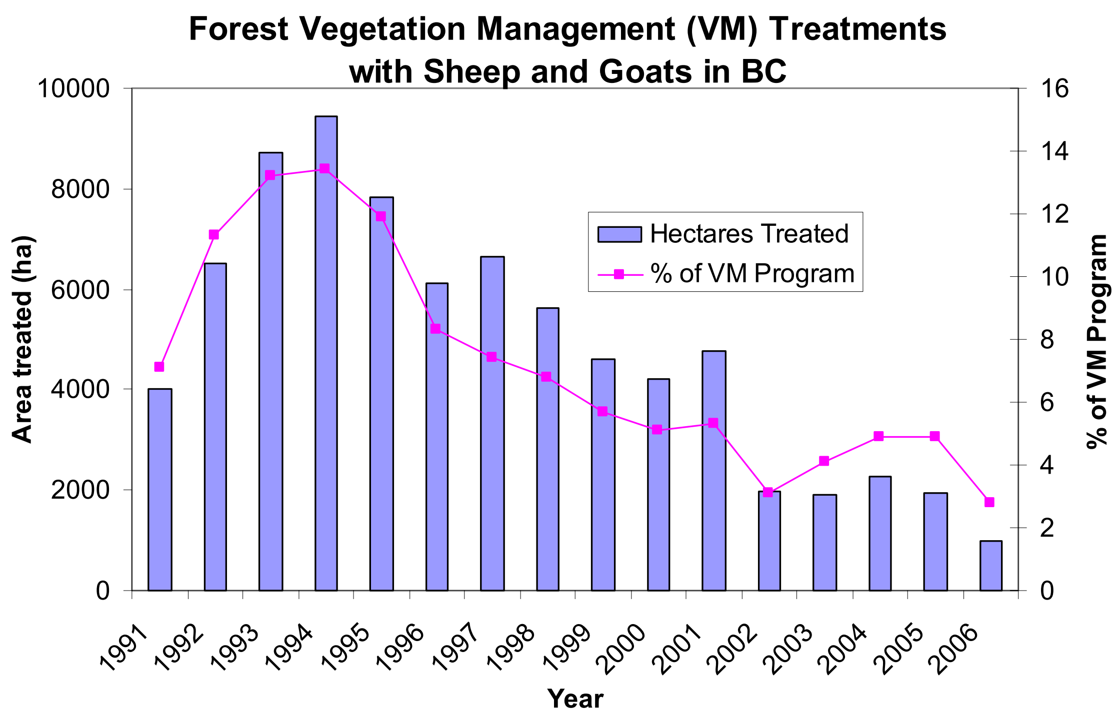

Fig. 1: Hectares treated by sheep or goat grazing to control competing vegetation in British Columbia from 1991 - 2006, and proportions of the annual vegetation management (VM) program that these values represent[1].

[1] Based on data from individual BC Ministry of Forests and Range Annual Reports (1991/92 to 2006/2007).

OPERATIONAL CONSIDERATIONS REGARDING SHEEP USE

Site selection

Practical observations regarding appropriate site conditions for successful sheep grazing are reported in various publications (Newsome et al. 1995; Kabzems et al. 1998; BC Ministry of Forests 2000; BC Ministry of Forests and Range 2001; 2002). Sites with heavy slash loading (over 50 cm high), with broken topography (gullies with slopes greater than 50%), or areas prepared with linear site preparation equipment such as plow or disk trenching (Kabzems et al. 1998) are unsuitable. Areas with critical wildlife habitat issues and community watersheds are also avoided.

Successful selection of sites also involves considering sheep forage preference. Preferred species include fireweed (*Epilobium angustifolium*), cow parsnip (*Heracleum lanatum*), forest wheatgrasses (*Agropyron* spp.), peavine (*Lathyrus* spp.), showy aster (*Aster conspicuous*), sitka valerian (*Valeriana sitchensis*), western fescue (*Festuca occidentalis*), bigleaf maple (*Acer macrophyllum*), Douglas maple (*Acer glabrum*), trembling aspen (*Populus tremuloides*), and rose (*Rosa* spp.). When succulent, blue joint (*Calamagrostis canadensis*) and pinegrass (*Calamagrostis rubescens*) are also preferred (Ministry of Forests and Range 2001).

Grazing productivity and treatment costs

Length of the grazing season varies because of factors such as herd size, site conditions, and weather. A herd may spend 80 - 100 days on a single large cutblocks where two grazing passes are required, whereas they may be moved every 10 days or so between smaller cutblocks. With average livestock herd sizes ranging from 1230 - 1500, the BC provincial average productivity during the last 5 years has been approximately 5.1 ha/day (Table 1).

Table 1: Recent sheep grazing productivity rates on BC forest plantations

Year	Size of livestock herd		Productivity rate (ha/day)	
	Range	Average	Range	Average
2001	900-3600	1470	3.1-10.7	5.3
2002	600-2900	1230	3.2- 7.2	5.5
2003	900-2900	1430	2.2- 6.3	5.2
2004	560-1550	1250	1.6- 6.5	4.6
2005	725-2150	1500	1.6- 8.3	5.1

Grazing treatments for vegetation management are carried out by contract, and are paid for by the proponent (e.g., BC Ministry of Forest or forest licensees) in exactly the same manner as other brushing treatments involving herbicide, manual, or mechanical techniques. Unlike cattle grazing on forest range, which is conducted under the BC Forest and Range Act, sheep grazing for the purpose of forest vegetation management does not require payment for forage use or a grazing license. The average price paid to grazing contractors for one season of grazing varied little from 1991-2006 (average of \$350 - \$390/ha, with a range of \$230 - \$640/ha). One licensee reported paying between \$300 - \$500/ha in recent years (2001-2006) and spent a total of nearly

$1.1million to treat about 2,800 ha during the period (P. Forsythe[2], pers. comm., 2007). It is estimated that a total of about $28 M has been paid to sheep brushing contractors operating in BC since 1991. At the peak of the program (1994), over $3.5 million was paid to sheep contractors in a single year.

The average single-entry cost for sheep grazing slightly exceeds that of herbicide application, but is less than for manual treatment. With proper planning, site selection, timing of treatment after harvest, and treatment implementation, free growing status has been achieved after only one season of grazing. However, as with manual treatments, two or three seasons of grazing are generally required to achieve free growing, compared with only a single application for herbicide treatments. In general, the cost to reach free growing is 2 - 3 times higher for sheep grazing, manual, or mechanical methods than for herbicide (Table 2).

Table 2: Comparison of average costs[3] for single brushing treatments and to achieve free growing in BC forest plantations

Method	Average cost per hectare	
	Single entry treatment	Estimate to free growing
Biological	$350	$875
Herbicide	$375	$410
Manual	$540	$1350
Mechanical	$570	$1425

Brushing quality, crop seedling damage, and shepherd training

To achieve 100% brushing quality, contractors must achieve 75 - 85% removal of target (edible) vegetation, with no damage to crop tree seedlings. From 2001 - 2005, crop seedling damage (mainly nipping of leaders and trampling) has averaged only 1.3 - 3.9%, which is attributed primarily to the use of experienced shepherds**.** Shepherding on reforestation sites requires conscientious, hardworking and resourceful persons with a variety of skills including vegetation assessment, dog training and handling, sheep husbandry, veterinary first aid, and mechanical skills. The current crop of shepherds managing sheep in the forest is well trained and experienced, mainly due to a training program that was initiated in 1992 by the BC Sheep Federation. The training was specifically designed to meet the requirements of the BC provincial government.

Livestock, herd and guardian dogs, and livestock losses

Most of the sheep used on reforestation sites in BC are mixed breeds, with the majority of herds (90 - 90%) coming from Hutterite colonies in Alberta, Saskatchewan, and BC. A herd of sheep grazing on a forest site is likely to be comprised of three or more constituent flocks, but the fewer the sources, the lower the likelihood that disease problems will emerge. Herds are composed of sheep weighing from 77 - 114 kg (minimum 23 kg for lambs), with a preference for large ewes having the ability to negotiate slash. Grazing success depends in great measure on using

[2] Peter Forsythe, Silviculture Officer, Winton Global, Prince George, BC.
[3] Calculated from Ministry of Forests and Range Annual Reports (1994/95-1997/98). Free growing cost is calculated using risk for re-treatment; provincial averages: Herbicide 1.1X and 2.5X for biological, manual and mechanical.

experienced sheep because they flock together and disperse less. It is considered that a relatively inexperienced shepherd with a flock of experienced sheep will have more success than an experienced shepherd with inexperienced sheep.

Dogs are important members of the shepherding team, and are employed to both herd and guard the sheep. The most common breeds of herd dogs are the border collie and Huntaway from New Zealand and the Kelpie from Australia. Crossbreeds are occasionally used to herd. The use of guardian dogs for forest grazing became compulsory in 1993, and since that time, losses to predators have been negligible. Common guardian dog breeds are the Maremma, Pyrenees, Akbash, Anatolian, Kuvash and Komondor. Regulations require there to be two guard dogs for the first 1,000 sheep and one more for each additional 500 head. The main predators are coyotes and bears, but where wolves are present it is recommended that the number of dogs be increased to match the number of wolves.

Losses of sheep during forest grazing operations are currently in the range of 0.20 - 0.44%, which is generally lower than losses of sheep that remain on the home farm. Losses to predators have been almost completely eliminated because of the use of guardian dogs. Most livestock losses are attributed to toxic plant poisoning, death and injury from trucking, “pile-ups” (sheep smother themselves by piling on top of one another when the lead sheep panics and refuses to move), pneumonia, and fever. Plants considered by shepherds to be responsible for poisoning are water hemlock (*Cicuta douglasii*), false hellebore (*Veratrum viride*), monkshood (*Aconitum* spp.), and bracken fern (*Pteridium aquilinum*). These plants are associated with moist grounds and it is believed that sheep eat them when browse is in low supply in drier areas of the cutblock.

ADDRESSING CONCERNS RAISED BY THE GRAZING PROGRAM

The success of the forest sheep grazing program has been due to cooperation between the BC provincial Ministry of Forests and Range, the Ministry of Environment, the Ministry of Agriculture and Land, sheep producers, sheep grazing contractors, consultants, vegetation management foresters and researchers, and veterinarians. In the early years of the program, many difficulties were encountered, including outbreaks of disease among sheep, sheep welfare problems due to inadequate nutrition or transportation for great distances, losses due to predation, inexperienced shepherds, and inexperienced sheep. These issues created enormous concern, and prompted the formation of an interministry committee (Interministry Committee for the Use of Domestic Sheep for Vegetation Management 1995). The particular concerns of the three Ministries fall into three categories.

Forest management concerns

Ministry of Forests and Range (MOFR) and forest licensee staff were mainly concerned with developing guidelines to identify areas and conditions under which sheep could be used. They also wanted information regarding the efficacy of grazing as a vegetation management tool, and were searching for ways of working within the restrictions that were imposed by other resource agencies. Operational and research staff working with the sheep grazing contractors provided the necessary information and guidelines to assist field foresters and contractors (Newsome et al. 1995; Kabzems et al. 1998; Ministry of Forests 2000; Ministry of Forests and Range 2001; 2002).

Environmental concerns

The Ministry of Environment (MOE) had three major concerns with regards to the use of sheep for forest vegetation control: (1) the effects that domestic sheep might have on wildlife habitat, (2) diseases they might possibly transmit to wildlife, and (3) the effects on predator populations and predator individuals. Based on observations from Oregon, it was determined that sheep grazing provides high quality foliage for big game 2 - 3 weeks after treatment, but that browse availability may be limited if sheep grazing is conducted two or more times in a single year. The risk of disease transfer from domestic ungulates to wild ungulates is greatest between similar species and least between species that are not related. Thus, wild sheep are at greatest risk, and it was decided that domestic sheep would not be permitted to graze forest sites that were within 15 km of wild sheep habitat, and that the domestic sheep would also have to be certified as healthy and clinically free of common sheep diseases.

Concerns about domestic animal health

Duties of the Ministry of Agriculture and Land included ensuring that sheep being used for forest vegetation management work were healthy, free from diseases, properly fed, and well-treated. In the early years of the program, when disease problems were on the increase, the sheep producers and brushing contractors undertook to retain any sheep that appeared to have any signs of illness at the home farm and to send only healthy animals. The results of this approach were mixed, but the disease problem was eventually resolved through a program of certification that was instituted and monitored by veterinarians in private practice or who were working for the provinces of British Columbia or Alberta. A protocol for goats was also prepared between 2005 and 2007.

Government support of the program

The MOFR provides funds for field monitoring of grazing experiments and programs, and also for the promotion of the sheep grazing program at silviculture workshops and conferences. Each year the grazing program successes and problems are reviewed by the various participants (government staff, forest licencees producers contractors, First Nations and all other players) at a meeting in Prince George that is hosted by the MOFR. These meetings are well attended, lively, and effective. Topics of discussion include policies and guidelines, field monitoring by the province to address the issues and concerns relating to animal health, wildlife–carnivore interactions, and the environment.

DECREASING USE OF THE GRAZING PROGRAM

As described above, most of the forest management, environmental, and animal health and welfare concerns relating to the grazing program have been addressed. The major problem currently facing the program is the overall reduction in the use of grazing as a vegetation management tool during recent years (Fig. 1). A survey was made by MOFR staff to find out why foresters are not using the tool as in the past, and the most common response was a lack of areas where sheep could be used. Ironically, most of the loss of area is related to improved forestry practice in BC — backlog openings have been treated, clearcut opening sizes have been reduced, selection harvesting systems are being employed, and the use of genetically improved seedling stock and prompt regeneration has eliminated the need for brushing on many sites. Additionally, reduced use of prescribed burning in recent years has left many blocks unsuitable for sheep due to the slash load. Nonetheless, sheep contractors indicate that they are willing to alter their practices to work within smaller openings, and they encourage foresters to continue to consider sheep a viable option.

SUMMARY AND CONCLUSIONS

- Sheep grazing is an effective method for controlling competing vegetation and achieving the silviculture objective of free growing in an economically and ecologically sound manner.
- In terms of agroforestry, both highly nutritious food (lamb) and ecologically sound fibre (wool) are produced. The livestock (sheep) grazed on the forest sites are well-managed well because of the stringent health requirements. They have good bone structure, appropriate fat content, and are very fit and well, which raises the overall integrity of the flock on the farm. They are used as breeding stock.
- Nevertheless, there are limitations to the sheep grazing program due to the high risk of transfer of disease to wild ungulates, the complexity of the health certification preparation process, and the application of monitoring procedures.
- The maintenance of a knowledgeable and skilled workforce of contractors, shepherds, producers, truckers and licensees, foresters and public servants is essential to the program.
- If the biological option for vegetation management is to remain viable in BC, sheep management practices must conform to smaller opening sizes and more frequent movement of herds between sites.
- Sound management methods for forestry, agriculture and environmental health are necessary for developing sustainable systems. Sheep grazing for vegetation management of reforestation sites can be regarded as one such sustainable solution.

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FORAGE EVAPOTRANSPIRATION IN AN APPALACHIAN HARDWOOD SILVOPASTURE

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Abstract: There is a lack of good information on how the characteristics of specific silvopasture systems affects water partitioning between forage and trees. Practically all of the extensive body of research on evapotranspiration (ET) in agricultural systems has been done for open fields. Small 26 cm diameter, 23 cm deep lysimeters planted with either orchardgrass (*Dactylis glomerata* L.) or tall fescue (*Lolium arundinaceusm* (Schreb.) S.J. Darbyshire) were placed in the ground along the north and south edge of two 15 m wide by 50 m deep notches cleared into a mature second growth hardwood forest. One notch opened to pasture on the east receiving more early day solar radiation and one to pasture on the west receiving more wind and late day solar radiation. There was no significant difference in ET between orchardgrass and tall fescue. North edges, receiving more direct beam radiation, had significantly higher ET (39%) than south edges which received a higher percentage of diffuse radiation. The west notch had significantly higher ET (11%) than the east notch. At the sunniest sites, advection provided 20% of the energy used for ET while at the shadiest sites it provided more than half (56%) with the rest provided by net radiation (R_n). The Penman equation for calculating reference ET as a function of weather conditions did an adequate job of predicting ET in response to tree modification of microclimate. These results indicate tree modification of microclimate does not decrease forage ET to the extent that photosynthetically active radiation (PAR) is decreased.

Key Words: Net radiation, Penman, wind.

INTRODUCTION

It is common knowledge that water use by forages is strongly influenced by incoming solar radiation. Evapotranspiration decreases as incoming solar radiation decreases due to increasing cloud cover or decreasing day length and solar angle (Allen et al. 1994). Shading by trees also decreases forage ET (Eastham and Rose 1988).

Soil moisture, which is depleted by ET, in temperate hardwood silvopastures was not statistically different compared to soil moisture in adjacent pastures in several studies (Belsky et al. 1993; De Montard et al. 1999; Feldhake 2001). However, soil moisture was higher under a tree configuration similar to a silvopasture without a forage understory (De Montard et al. 1999). This suggests that ET by the combination of trees and forage in silvopastures differs little from ET by treeless pasture.

We don't have a good understanding of how soil water is partitioned between forage and trees in a temperate hardwood silvopasture, in part because we don't have a good understanding of the spatial relationships between forages and tree induced microclimate modification.

Since it is not feasible to measure ET at all places at all times, methods have been developed to allow estimation of ET from ambient weather conditions using equations such as the Penman equation (Allen et al. 1994). This is widely used since it accounts for energy available to evaporate water both from R_n and from advection. Advection is related to the dryness of the air and how fast the wind is moving it. However, equations for estimating ET have been developed for open field conditions and need evaluation for applicability in silvopastures where microclimate conditions vary widely.

The objective of this research was to examine the relationship between forage ET and site, relative to amount and daily timing of incident solar radiation and wind due to spatial relationship to forest edge.

MATERIALS AND METHODS

Two notches were cut into a mature second growth hardwood forest dominated by scarlet oak (*Quercus coccinea* Muenchh), white oak (*Quercus alba* L.) and red maple (*Acer rubrum* L.). One notch opened into a pasture to the east and one to the west. The one facing east had more early day sun exposure and the one facing west had more wind and late day sun exposure. The 15 by 50 m cleared notches were planted to orchardgrass, perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). Forage canopies within and around the lysimeters were trimmed to maintain a height between 8 and 16 cm.

Lysimeters were constructed from 25 cm inside diameter PVC pipe with an inside depth of 23 cm. The lysimeters were filled with a mix of 50% sand, 25% peat moss, and 25% of a Dekalb soil (fine sandy loam, mixed, mesic Typic Hapludult). Twenty four lysimeters were planted to tall fescue and twenty four were planted to orchardgrass. The grass was established in a glass house during the spring of 2006. The lysimeters were moved to the notches in early June. Holes for placing the lysimeters in the ground were dug on the north and south edges of both notches. Four holes were dug in a cluster at the open edge, midway into, and at the back forest edge of both notches (Fig. 1). Holes were lined with 26 cm diameter PVC and filed with several cm of pea gravel to keep the outside bottom of the lysimeters soil free and to allow adjustment to keep lysimeter top edges even with ground level. The lysimeters had a removable plug in the bottom to allow drainage after major rainfall events. Two lysimeters with tall fescue and two with orchardgrass were placed at each location.

The lysimeters were pulled from the ground and weighed using an Ohaus Twenty Kilogram capacity heavy duty triple beam solution balance (Ohaus Corp., Pine Brook, N.J.). Weights were measured for either two or three day intervals. Weights were measured starting at 9:00AM in the east facing notch first. It took about 45 minutes to weigh the lysimeters in each notch. Weights were measured to the nearest gram which gave an evapotranspiration sensitivity of .02 mm per weighing period which was less than 1% of the weight of water typically used.

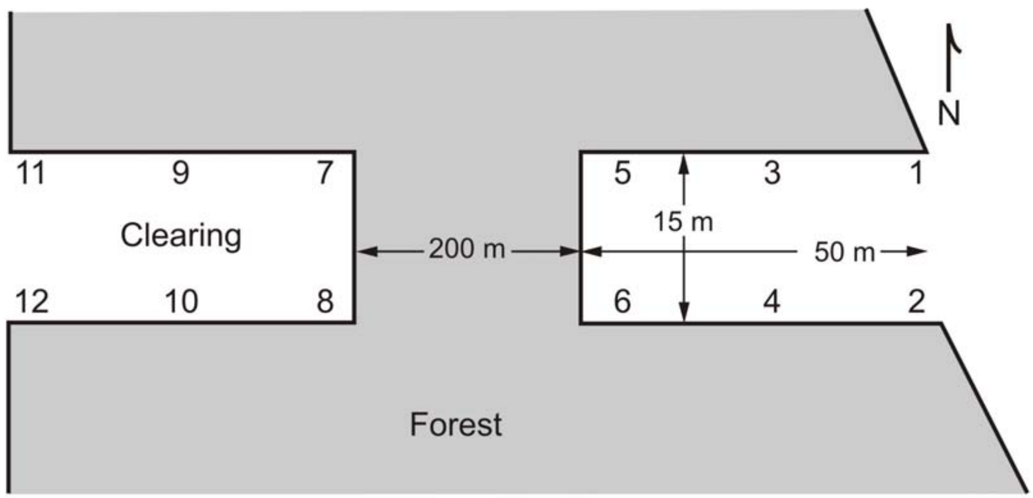

Fig. 1: Schematic of research site showing location of 12 lysimeter clusters for measuring forage evapotranspiration relative to mature second-growth hardwood forest.

Measurements of PAR was measured directly over each cluster of 4 lysimeters during three periods , the fourth week of June, the first week of July, and the first week in August using a system of LI-COR LI-191-SB line quantum sensors (LI-COR, Lincoln, NE). Measurements were made every 10 s and averaged hourly using Campbell Scientific 21X (Campbell Scientific, Inc., Logan UT) data loggers. Regression equations were developed to predict PAR at each lysimeter site from PAR data at the weather station in the adjacent pasture for periods when the line quantum sensors were in use for other experiments. Net radiation (R_n) was estimated from PAR using the conversion:

$$R_n = (PAR)*0.375 \text{ MJ mol}^{-1} \quad (1)$$

During an overcast summer day with full tree foliage expansion, upward hemispherical images were photographed in the center of each lysimeter cluster using a Nikon Coolpix 995 digital camiera with a Nikon FC-E* Fisheye Converter and a self-leveling mount. Images were analyzed for open sky Percent field-of-view and potential direct-beam transmitted solar radiation through the tree canopy as a function of day-of-year (DOY) using WinSCANOPY software (Regent Instruments Inc., Quebec Canada).

Wind was measured at the open end, midpoint and forest end of both notches using 6 Belfort totalizing atmometers (Belfort Instrument Co., Baltimore, MD). They were mounted at the standard 2m reference height.

Measured ET values were compared to reference ET calculated using the Penman equation and weather data from a weather station in the adjacent pasture (Allen et al. 1994). Analysis of variance was used to test for differences between grass species and for differences between lysimeter locations. Regression analysis was used to determine how well R_n and Penman reference ET predicted measured ET.

RESULTS AND DISCUSSION

Average ET varied by a factor of three between sites (Table 1) ranging from 12.3 MJ m^{-2} d^{-1} at site 11 to 3.9 MJ m^{-2} d^{-1} at site 4. Other sites exhibited a fairly even gradient of values between these extremes. Percent open sky to which lysimeters were exposed was related to position within the notches with those at the open end having the greatest amount. Open sky alone, however, was not a primary driver of ET.

Table 1: Average daily evapotranspiration for the 12 lysimeter cluster locations and percent open sky in the field of view. Each value is the average of 4 lysimeters from 21 days between June 13 and July 31, 2006. Evapotranspiration values followed by the same letter are not statistically different by Tukey's (HSD) comparison of means.

Site	Average ET (MJ m^{-2} d^{-1})	Open Sky (%)
11	12.3 a	33.2
3	11.1 ab	24.8
1	11.0 ab	42.4
9	9.6 b	22.1
12	7.6 c	33.5
7	7.3 c	17.2
5	6.9 cd	16.5
8	6.5 cd	17.7
10	6.2 cd	21.4
2	5.8 cde	35.3
6	5.2 de	17.6
4	3.9 e	19.9

There was no significant difference in ET by tall fescue compared to orchardgrass across the entire site (Table 2). The 39% difference in ET between the north edge and south edge across both notches was highly significant as was the 55% difference in net radiation. The 5% difference in net radiation between the east notch and the west notch was not significant, however, the 11% difference in ET between the two notches was highly significant (Table 2).

Table 2: Average evapotranspiration and net radiation for lysimeter sites as a function of grass species, notch edge, and notch location.

Evapotranspiration (MJ m^{-2} d^{-1})		
Orchardgrass	Tall Fescue	P
7.58	7.98	0.24
North (Sunny)	South (Shaded)	
9.69	5.87	0.00
East (AM Sun)	West (PM Sun)	
7.32	8.24	<0.01
Net Radiation (MJ m^{-2} d^{-1})		

North (Sunny)	South (Shaded)	
8.22	3.73	0.00
East (AM Sun)	West (PM Sun)	
5.83	6.12	0.64

The difference in ET between the two notches can probably be attributed to two factors. The first is that wind speed was usually higher in the west notch since prevailing winds are from the west (Table 3). The second is that the east notch receives more solar radiation in the morning when there is a small vapor pressure deficit, while the west receives more solar radiation in the afternoon when the vapor pressure deficit is usually at a daily maximum.

Table 3: Average wind speed within the cleared notches for the evapotranspiration measurement period of June 13 through July 31, 2006.

	Average wind ($km\ hr^{-1}$)	
Within Notch Location	East Notch	West Notch
Open Edge	1.70 (Sites 1 & 2)	2.96 (Sites 11 & 12)
Mid Region	1.81 (Sites 3 & 4)	3.04 (Sites 9 & 10)
Forest End	1.20 (Sites 5 & 6)	2.60 (Sites 7 & 8)

The primary driver of ET in humid environments is R_n (Merva and Fernandez 1985). In this study the slope of the relationship between ET and R_n for all sites and measurements periods pooled was nearly one (Fig. 2). However, there was a 2.46 MJ m^{-2} d^{-1} increase in energy utilized by ET over that provided by R_n. At the highest R_n levels ET consumed 1.25 times as much energy as provided by R_n. At the lowest R_n levels ET consumed 2.25 times as much energy as provide by R_n meaning that in highly shaded environments advection dominated as the driver of ET. It should be noted though that on the sunniest days the air us usually driest therefore R_n and advective energy are highly correlated over time.

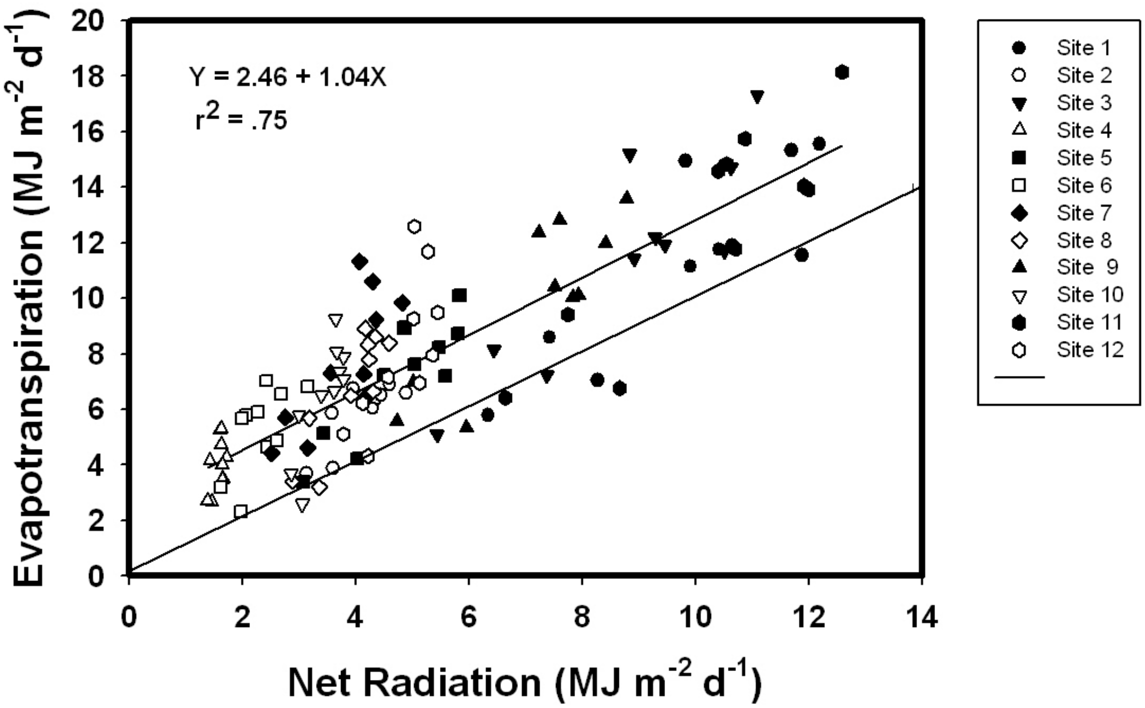

Fig. 2: Measured ET as a function of R_n for all lysimeter sites for each measurement period. The line extending to the axis is where ET = R_n.

The Penman equation did a better job of predicting lysimeter ET than R_n alone (Fig. 3). At low ET values it did very well (they were equal at 2.6 MJ m^{-2} d^{-1}) but at high values it tended to predict higher values than were measured (about 14% higher at 14 MJ m^{-2} d^{-1}). This discrepancy at high R_n needs further study to determine if it is due to climate differences compared to drier regions where ET predictive equations are calibrated or whether it was due to the modification of advective energy by the proximity to trees.

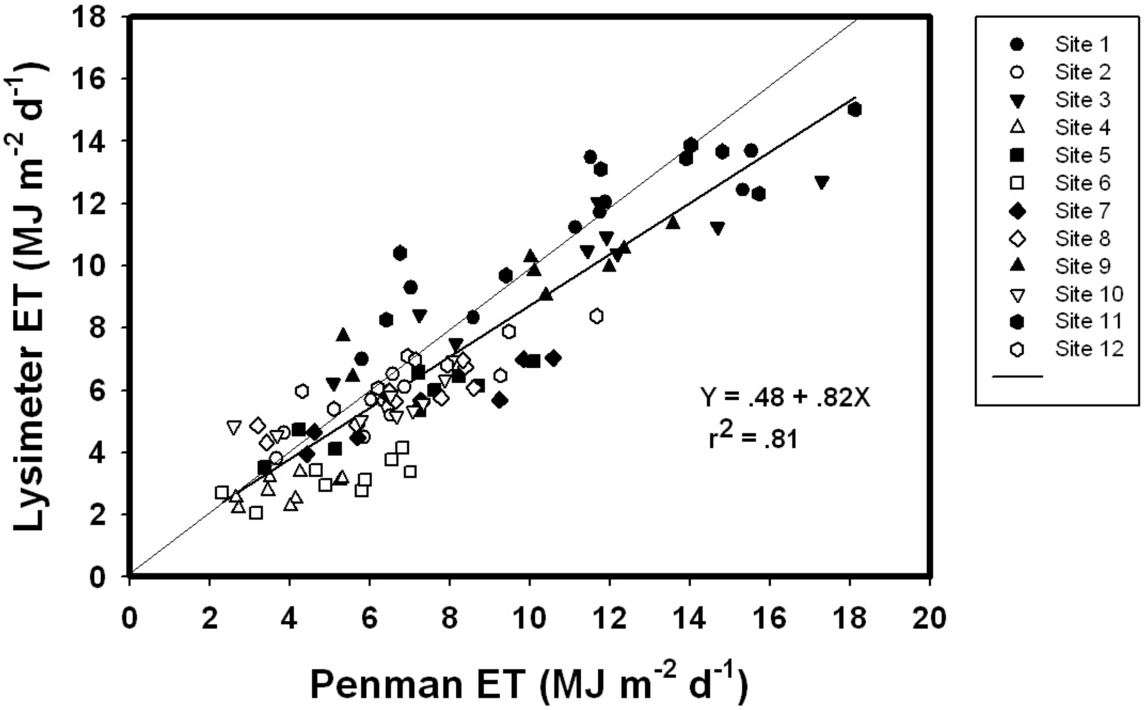

Fig. 3: Measured ET using lysimeters as a function of calculated Penman reference ET using weather data. The line extending to the axis is where Lysimeter ET = Penman ET.

CONCLUSIONS

Within silvopasture systems the interception of PAR by forages and the accompanying evapotranspiration of water resources vary spatially as a result of microclimate modification by trees. This study showed that for an average of 21 summer days, ET increased linearly with PAR (assuming it is a constant fraction of R_n). At high PAR ET is regulated primarily by incoming radiation, however, at low PAR ET is more than twice as high as incoming radiation due to the increased relative importance of advection.

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ADOPTION AND ECONOMICS OF SILVOPASTURE SYSTEMS BY FARM SIZE IN NORTHEASTERN ARGENTINA

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Abstract: Differences between the theoretical benefits and the actual adoption of silvopasture systems among farmers have prompted researchers and extension agents to learn more about the adoption mechanisms for silvopasture systems. In the past decade, farmers in northeast Argentina's Misiones and northern Corrientes provinces have begun adopting silvopasture systems to a moderate extent. Interestingly, adoption has occurred among small-, medium- and large-scale farmers, either through individual decisions, or spurred by extension education and financial subsidy payments. This unique situation allows us to explore potential differences and similarities between the adoption and implementation of silvopasture between farmers of different scales. A survey of managers of the three farm scales in Misiones and northern Corrientes was used to determine advantages and disadvantages of the system, as perceived by managers. In addition, farmers were asked to describe economic costs incurred and benefits received from the silvopasture parcels. These data were used to compare the perceived merits, likelihood of continuance and production levels for silvopasture systems among the different farm-scale levels.

Key Words: Adopter perceptions, productivity, farm scale, silvopasture**.**

INTRODUCTION

Silvopasture systems have been shown to have potential profitability in many parts of the world (Dangerfield and Harwell 1990; Clason 1999; Clason and Sharrow 2000; Grado et al. 2001; Colcombet et al. 2004; Esquivel et al. 2004; Fassola et al. 2004a), yet are not commonly adopted (Garrett et al. 2000; Rapey et al. 2001; Dagang and Nair 2003; Stainback and Alavalapati 2004).

Where silvopasture is practiced in the Americas, it is most often practiced by large landholders. Even in countries where small landholders own livestock, it is relativly rare to see pastures integrated with forestry systems. There are several possible barriers to adoption of silvopasture systems for small-scale farmers with limited resources (Dagang and Nair 2003; Pagiola et al. 2004). If we are to expect good adoption of silvopasture systems among small farmers, we should properly understand their motivations and expectations (Dagang and Nair 2003; Shrestha et al. 2004).

One possible explanation for the differential in adoption between small and large landholders is that silvopasture systems exhibit increasing returns to scale. Under this hypothesis, increasing all of the inputs would increase output more than proportionally. Small farmers would not be able to access these efficiencies. We are unaware of any research that has estimated the production efficiencies of silvopasture of varying scales. All financial analyses to date have assumed constant costs and benefits per hectare (i.e. a linear relationship between land area and yield; constant returns to scale). This may be a naïve approach to modeling silvopasture.

This study uses direct survey methods to qualitatively investigate the motivations behind silvopasture adoption among farmers of different scales in northeastern Argentina, and whether adopters are likely to continue use of the system. Then, we use farmers' estimates of past and future costs and benefits to approximate economic returns for different farm scales. Our study is not designed to answer definitively all these questions, but rather to be a starting point for future research in the area.

MATERIALS AND METHODS

Description of the study area

The northeastern provinces of Misiones and northern Corrientes, Argentina, have experienced moderate adoption of silvopasture systems in recent years among farms of all scales. Esquivel et al. (2004) estimated that, assuming constant returns to scale at a 7% discount rate, silvopasture yielded an equivalent annual income of 441 Argentine pesos (US$ 1 = Ar$ 3.085 in June 2006) per hectare, higher than alternative agriculture, cattle-ranching or forestry systems. Silvopasture implementation had reached an extent of approximately 10,000 hectares by 2004 (Esquivel et al. 2004). In general, these systems integrate a tree component of *Pinus spp.*, *Eucalyptus spp.* or the native *Araucaria angustifolia* with native (e.g. *Axonopus compressus*) or exotic (e.g. *Brachiaria brizantha*) forage species and cattle.

A diversity of farm types exit in Misiones and Corrientes. Northern Corrientes and southwestern Misiones are flat prairie-land, which has been traditionally used for cattle grazing. Central and northern Misiones consists of a forest zone, which has been settled for agriculture, with some of the more remote areas still relatively undisturbed (Fassola et al. 2004b). This area is utilized by semi-subsistence and cash-crop farmers, including forest-product firms (who primarily plant *Pinus spp.*).

Adoption of silvopasture was spurred on when the national government of Argentina began offering cost-share payments to offset a portion of the costs of site preparation and planting trees starting in 1999 (Congreso 1998). This program functioned fairly well until the Argentine economic crisis of 2001. A number of large-scale cattle ranchers as well as medium- to large-scale forest plantation firms have adopted silvopasture systems. We should note that forest-product firms would have received the cost-share payments anyway; the decision to adopt silvopasture was made independent of this policy. Also, special extension programs, including in-kind provision of necessary capital for starting silvopasture parcels, have convinced a relatively few small-scale farmers to adopt the system.

Farm survey

A farm survey of silvopasture adopters was conducted in the Misiones and northern Corrientes provinces of northeastern Argentina during June and July of 2006. A purposive sample of adopters of varying farm scales was selected throughout the region to participate in the survey. These were identified by researchers and extension agents at the Instituto Nacional de Tecnología Agropecuaria (INTA), who were familiar with the region. Personal interviews about opinions of silvopasture systems, farm inputs and budgets, and producer success were conducted.

In total, 38 silvopasture practitioners of varying scales were interviewed, producing 35 usable responses. Farm size (including all properties of the same owner in relatively close proximity) ranged from 20 to 14,000 hectares with a mean of 1536 ha and a median of 280 ha. Surveyed farmers were classified into three groups using natural clusters: small-scale (20-50 hectares), medium-scale (90-800 ha) and large-scale (>1100 ha). There were 13 small-, 10 medium- and 12 large-scale farmers in the sample.

Farmers were asked qualitatively about the advantages and disadvantages that they perceived in the silvopasture system at two points in time, at the time of the adoption decision and in the present (i.e. during implementation of the system). They were asked whether they would be likely to continue practicing silvopasture systems given the current prices and incentive policies. Each of these questions was open-ended, that is, no list of possible responses was given. Farmers were permitted to give as many responses as they felt appropriate.

Farmers were also asked in detail about the inputs and outputs received from silvopasture. They were asked to state, whenever possible, actual costs and benefits incurred up to 2006 for a specific silvopasture plot, based on recall. For future inputs and outputs, farmers were asked to give realistic estimates based on their knowledge.

Inputs included capital and labor for site preparation and planting, thinning and pruning, annual weeding and control of insects, daily livestock management, etc. Outputs included sale or household consumption of timber, sale or household consumption of livestock and milk, etc. Most farmers could recall fairly detailed information over a long period about relatively infrequent events (pruning, sale of timber, etc.) but could not report with certainty about long-term information regarding frequent events (livestock management). Therefore, farmers were asked to estimate costs and benefits from livestock management in silvopasture systems only over a one-year period (June 2005-May 2006).

Farmers were asked to estimate the 2006 height and diameter at breast height (DBH) of the trees in the silvopasture system. When possible, sample measurements of height and DBH of trees in the silvopasture plot were taken using a random plot design.

Data analysis

Responses for perceived (qualitative) advantages and disadvantages, and for the perceived likelihood of continuance of silvopasture were pooled into similar responses. Responses were compiled into the three farm-scale groups.

Data on the economic (quantitative) costs and benefits were compiled into spreadsheets to calculate the equivalent annual income (EAI) for silvopasture on each farm (Jacobson 1998), using a 7% discount rate. Because of the multiple-input, multiple-output nature of silvopasture, and varying rotation lengths, EAI in monetary terms was used as a measure to compare productivity. While prices were necessary in order to put inputs and outputs into common units, the actual peso amounts may not have meaning in real terms. Prices from region to region may vary somewhat, so a set of common prices in were used for inputs (e.g. labor, chemical treatments) and outputs (e.g. pulp, timber, beef, milk) in order to measure actual production rather than spatial and temporal anomalies in the market. Incentive payments were not taken into account and in-kind support of supplies was treated as if the farmer had purchased the materials.

Based on past and present management and the current measurements, we used the SIMULADOR FORESTAL (Crechi et al. 1997) program to estimate future timber harvests. Inputs and outputs for livestock, based on the 2005-2006 data, were estimated from year 3 to rotation completion.

Because the land used for adoption of a silvopasture system in each case belonged to one of many possible starting scenarios, the costs of site preparation are inherently different in each case. Cases existed in which the silvopasture system was planted on clear-cut plantation forest, annual cropland, pasture and degraded native forest. In order to compare costs and benefits of the current management without being biased by the starting condition of the land, each EAI was adjusted (AEAI) to reflect a starting situation of clear-cut plantation forestland, using the difference in average costs for site preparation (Colcombet 2005) between the actual starting condition and clear-cut forest. This is consistent with the land being replanted to silvopasture after the current timber rotation is completed.

RESULTS AND DISCUSSION

Perceived advantages and disadvantages

In many cases, the perceived advantages and disadvantages of the system varied from the point in time before adopting the system to the present. Among the 35 farmers interviewed, the most common responses for advantages and disadvantages are listed in Tables 1 and 2, respectively.

In general, there were fewer negative responses about silvopasture systems than positive responses. It is important to note that, since the sample was only of adopters, there is a form of self-selection bias in the sample. Adopters most likely believed from the beginning that the system would offer something positive. However, the study does provide one of the first comparisons of perceptions of various advantages or disadvantages across farm-scale groups or across time frames.

Currently perceived advantages

When farmers were asked what advantages they see in silvopasture at the present, the most common response was that silvopasture systems provide microclimate benefits for livestock management (Fig. 1). Large- and medium-scale managers were more likely to give this response than small-scale farmers. The second most common response in general, and the most common response among small-scale farmers, was that silvopasture systems have good cash-flow qualities. In particular, sale of cattle and frequent forest thinnings can provide short- to medium-term income, while the growth of sawtimber acts as a long-term investment. The fact that cash flow benefits were the most common response among small-scale farmers corresponds well to the fact that in developing regions it is difficult for small-scale farmers to access credit (or savings accounts). In addition, because of the past instability of the Argentinean currency, real assets including land, livestock, and trees may have exceptional value still in the country.

Table 1: Most common perceived advantages of silvopasture systems. Responses with less than a 15% frequency among all groups were omitted for brevity.

Advantage	**Explanation**
Cash flow	The silvopasture system products (livestock, thinned timber and final sawtimber) operate on different time scales.
Practical	Silvopasture provides a low-cost way to combine two activities that farmers were practicing anyway.
Profitable	Silvopasture systems provide more profit than alternative production systems in the region.
Microclimate	In the summer, shade reduces heat stress on the livestock. Also, reduced heat stress on the forage helps keep it tender and palatable in the summer. In the winter, trees provide some shelter against frost.
Weed control	Livestock help combat shade-tolerant weeds which would otherwise need to be sprayed in forest plantations. Trees shade out some aggressive shade-intolerant weeds.
Fire control	Livestock reduce the amount of dry matter under the forest, and thus reduce the risk of catastrophic forest fires.
Erosion control	Compared to other production systems, silvopasture provides a high degree of soil cover.
Dual use	The system produces two products, timber and livestock, from the same parcel of land.
Timber quality	The silviculture implied by a silvopasture system (high intensity of pruning and thinning) leads to a high-quality end product (high grade sawtimber or veneer with few knots).

Table 2: Most common perceived disadvantages of silvopasture systems. Responses with less than a 15% frequency among all groups were omitted for brevity.

Disadvantage	**Explanation**
Uncertainty	There are two forms of uncertainty: 1) being a new technology, relatively few studies have been conducted, leaving farmers to trial and error, and 2) institutional instability in Argentina creates uncertainty in prices, export policy and the continuance of the cost-share program.
Capital	The investment required for the purchase of seedlings, herbicides, pesticides, etc. can be high.
Competition	Competition between the tree and forage components for light, water and nutrients can decrease the growth of both.
Complexity	The system requires a very intensive management regime and can be quite difficult for those uninitiated in the management of one of the components.
Health	Wooded areas provide habitat for an increased quantity of livestock pests, such as ticks.

High percentages of respondents also answered that silvopasture provided the benefits of two products from the same plot of land and weed control. Small farmers tended to respond that the “dual-use” of land was a benefit while medium and large farmers were more pleased with the benefit of weed control.

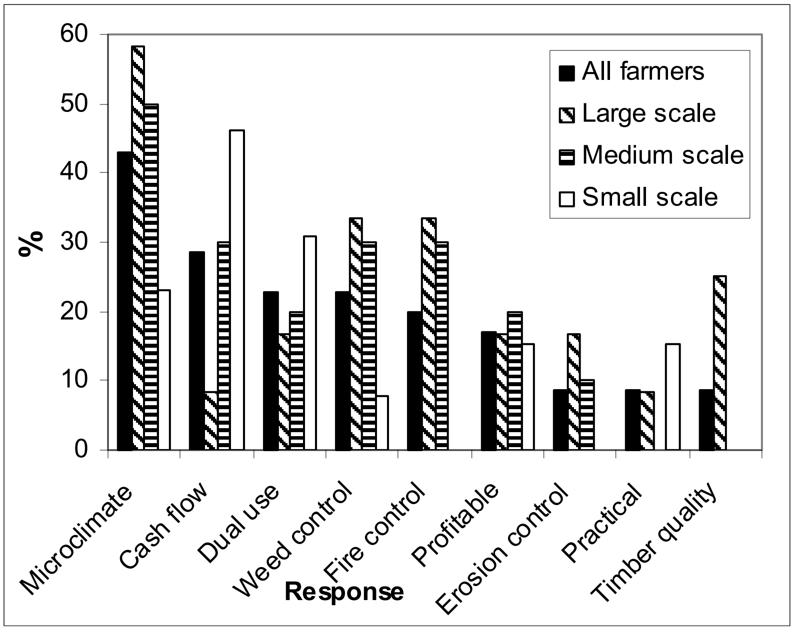

Fig. 1: Currently-perceived advantages of silvopasture. Frequency of response for various perceived advantages, by farm-scale groups. Responses with less than a 15% frequency among all groups were omitted for brevity.

Fire control was an important response for large- and medium-scale farmers. This may partially reflect the fact that the more fire-prone, savanna areas of the region are generally divided into much larger landholdings, while areas of native forest are less likely to have major difficulties with fire and have been colonized more recently by small-scale farm families.

There were substantial differences between the benefits farmers believed they would receive when they adopted the systems and the benefits they actually felt were the most important now that they have significant experience with the system. In particular, improved "microclimate" increased in perceived importance, surpassing "dual-use" of land, which decreased in frequency of response. In addition, "cash flow" became an increasingly important benefit, especially for small-scale farmers.

In general, it appears that small-scale farmers focused mostly on more direct financial benefits of the system, while large- and medium-scale farmers perceived the technical benefits of the system as more advantageous (although technical benefits such as microclimate and fire control do have a financial side).

Currently perceived disadvantages

The most common concerns among farmers at the present are competition between trees and forage plants for light, water, etc., and the complexity of system management (Fig. 2). Farmers have fewer concerns about silvopasture in the present, now that they have experience with the system, than before adoption. There is a decreased importance of concerns about plant competition relative to system complexity, indicating that farmers now realize that there are many ways of managing the competition among plants, although this management requires much planning.

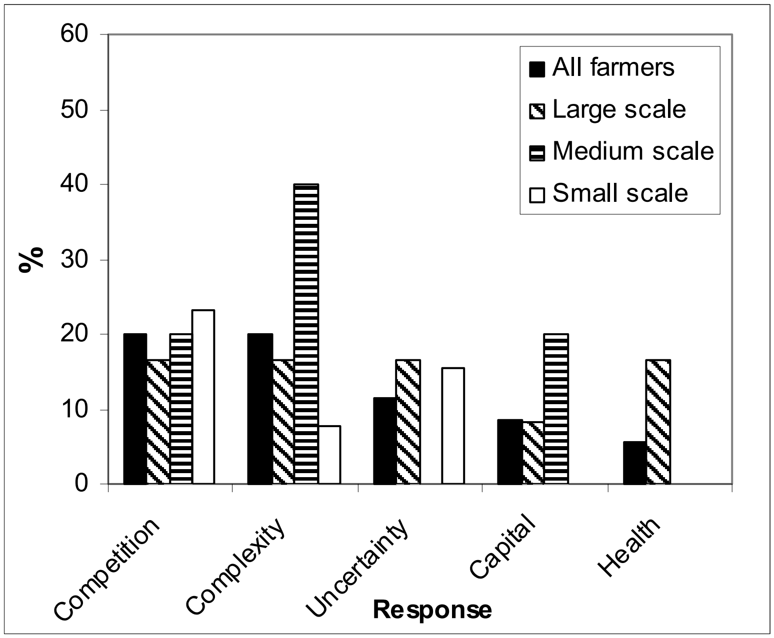

Fig. 2: Currently-perceived disadvantages of silvopasture. Frequency of response for various perceived disadvantages, by farm-scale groups. Responses with less than a 15% frequency among all groups were omitted for brevity.

The only disadvantage of silvopasture that was perceived to be more important currently than it was at the time of adoption is the requirement of investment capital to start the system. Normally, we would think that this would be a more important disadvantage when farmers are considering adoption, since this is when most of the investment would take place. However, most of these farmers initially adopted silvopasture before 2001, when cost-share and in-kind support programs were more easily accessible. It is likely that they did not view the capital requirement as a barrier at the time of adoption because of the availability of these programs, which may no longer be a feasible alternative. It is interesting that no small-scale farmers voiced this concern.

Likelihood of continuance

The majority of farmers indicated that they had received help starting the silvopasture system either through government cost-share programs or in-kind support. By a wide margin, farmers indicated that they would probably increase the area of land given to silvopasture if cost-share or in-kind support programs continued (Fig. 3). Small farmers seemed somewhat less likely to state that they would increase the area of their land dedicated to silvopasture, but this is at least in part due to the fact that small farmers are more land-constrained, and most high-productivity areas are used for annual subsistence or cash crops.

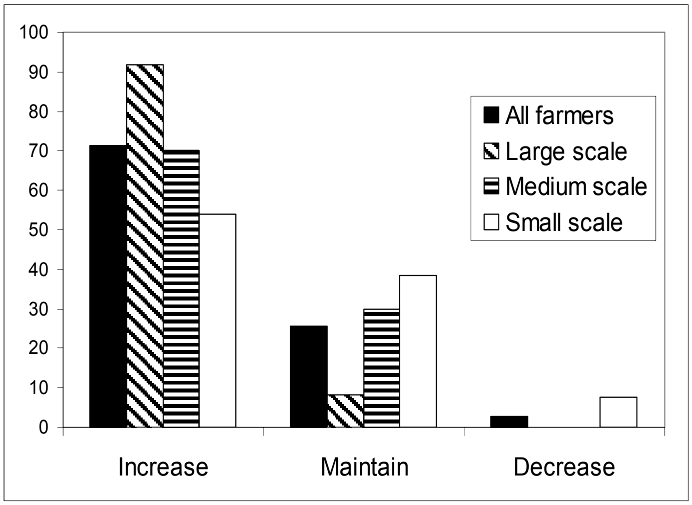

Fig. 3: Likelihood of continuance of silvopasture system area, with current prices and incentive policies.

In addition, the majority of farmers, particularly large- and medium-scale farmers, indicated that they would continue implementing silvopasture systems, even if no government support were provided (Fig. 4). This is a good indication that these farmers believe that silvopasture is beneficial to them. Furthermore, these data seem to indicate, to some degree, that the hurdle of convincing farmers to install silvopasture is a one-time barrier.

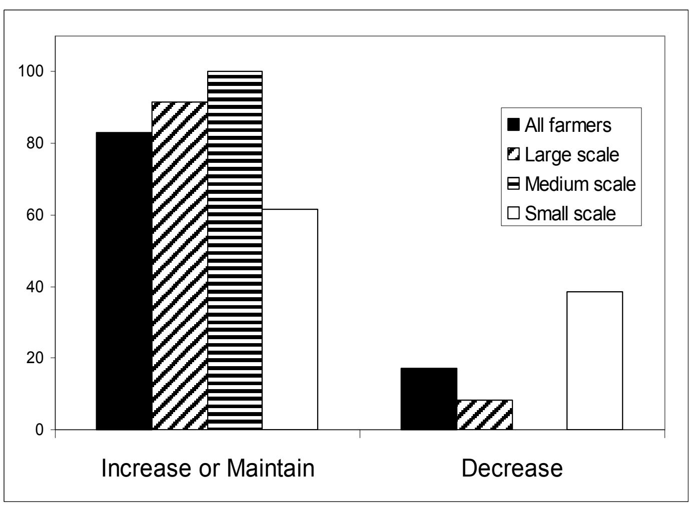

Fig. 4: Likelihood of continuance of silvopasture system area, with no incentive policies

Economic results

Adjusted equivalent annual income (AEAI) was highly sensitive to changes in the wage rate. This is significant because small-scale farmers substitute labor for capital. Small farms had a much higher AEAI when the wage rate of Ar$ 15 per day was used (often cited by small farmers as the cost of hiring a hand for a day), while large farms were more productive at a wage of Ar$ 58.41 per day (the official minimum wage for unskilled labor, including taxes and other costs for which a firm may be responsible, such as food and transportation; Fig. 5). At Ar$ 38.90 (the official minimum wage for unskilled labor, including taxes), the three farm scale groups had very similar AEAIs, with small farms slightly higher. At Ar$ 38.90, the rate most commonly used in cost-benefit financial analyses, the overall mean was Ar$ 406, which is close to the value estimated by Esquivel et al. (2004) (Ar$ 441). When considering only farms from north-central Misiones, the region considered by Esquivel et al. (2004), our mean total AEAI was Ar$ 442.

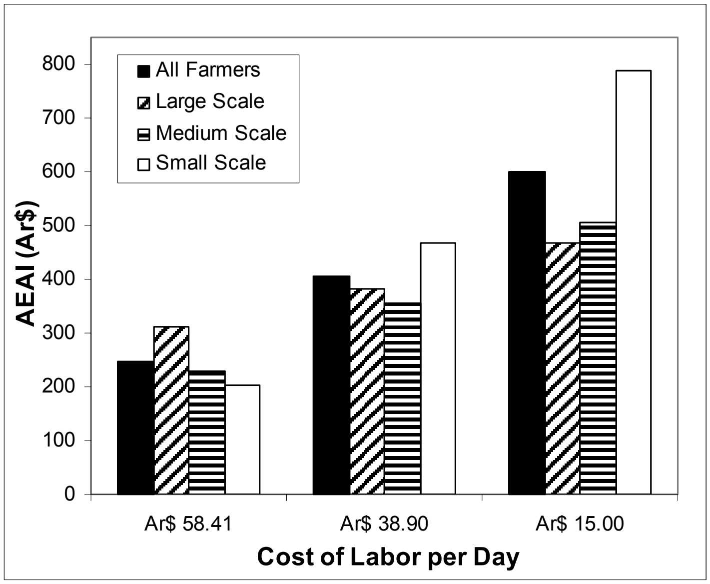

Fig. 5: Adjusted Equivalent Annual Income (AEAI) per hectare for farms of varying scales at varying wage rates.

The fact that small-scale farmers have equal or higher AEAI at low and intermediate wage rates means that we cannot reject the assumption of constant/decreasing returns to scale. Increasing returns to scale do not conform to the data, and would not appear to be an important factor in preventing small-scale farmers from adopting silvopasture systems.

CONCLUSIONS

Small, medium and large farmers in Northeastern Argentina demonstrated different perceptions of silvopasture systems. Small farmers are interested in the financial advantages of having short-, medium- and long-term cash flow, while larger-scale farmers seem to appreciate technical benefits such as improved microclimate, weed control and fire control. Extensionists and researchers should keep in mind the benefits farmers believe to be the most important when conversing with potential future adopters and when comparing production systems.

The question of whether or not the front-end investment in silvopasture is too much for farmers to overcome is still an interesting one and merits more precise research. The majority of all adopters surveyed indicated that they would continue implementation or even expand silvopasture on their lands, with or without cost-share or in-kind benefits. In addition, only a relatively few farmers believed that the high investment cost was a disadvantage of the system. However, it is questionable whether or not new farmers, particularly small farmers with limits on capital, are likely to adopt the system without some form of incentives. Small-scale farmers did not cite capital costs as major concern. These results indicate that adoption will probably continue.

The economic analysis of productivity for the different farm scales provided insight into the substitution of capital for labor under differing wages. The data do not support increasing returns to scale. However, a method that does not depend on input/output prices, such as data envelopment analysis, may help to illuminate further these results.

Overall, the results of this study do indicate that silvopasture systems have significant benefits to farmers who adopt them, of all scales. Further research in other countries in the Americas may help determine their applicability in other locations where good livestock and forest products markets exist. The results also can inform future research on economic analyses of silvopasture systems and differences by ownership size.

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N SOURCE INFLUENCES ON FORAGE AND SOIL IN SOUTHERN-PINE SILVOPASTURE VERSUS OPEN-PASTURE

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Abstract: Silvopasture is considered a sustainable agroforestry practice as a result of benefits the system offers for biodiversity, economic returns, and environmental quality. However, little is known about the temporal and spatial dynamics of forage productivity and soil quality in pastures being converted to silvopasture. The objectives of this research were: 1) to determine the impact of N source (fertilizer-N versus legume-N) on forage productivity and quality in silvo- versus open-pasture systems, and 2) to determine the impact of N source on soil aggregate stability, fungal hyphal density, and compaction in silvo- versus open-pasture systems. This research was conducted during 2005 and 2006 at Americus, Georgia, USA in 5- to 6-y old longleaf pine (*Pinus palustris* Mill.)-bahiagrass (*Paspalum notatum* Flugge) silvopasture and adjoining bahiagrass pasture without trees. Treatments included either fertilizer-N or overseeded crimson clover (*Trifolium incarnatum* L. 'Dixie'). May 2005 shoot dry matter was higher for the legume- than fertilizer-N treatment, and higher for open- than silvopasture. May 2006 shoot dry matter was different among alley positions relative to trees in silvopasture. May 2005 forage N concentration was higher for the legume- than fertilizer-N treatment. May 2006 water stable aggregates were higher for the legume- than fertilizer-N treatment. Initial soil compaction at 15 and 20 cm was higher for open- than silvopasture. Compaction at all depths was also higher for silvopasture soil positions furthermost from trees. N source was the major cause of differences in forage productivity and quality, while pasture type had the greatest impact on soil compaction.

Key Words: *Pinus palustris* Mill., *Paspalum notatum* Flugge.

INTRODUCTION

Silvopasture is an intensive land management system where forage and trees are grown together and integrated with grazing animals (Clason and Sharrow 2000). Silvopasture can be established by thinning an existing forest stand and adding or improving a forage component, or by adding low densities of trees to existing pasture. Several studies have highlighted the diversified economic, biological, and environmental benefits of silvopasture systems (Clason 1999; Clason and Sharrow 2000; Stainback and Alavalapati 2004). Some studies conducted in mature pine-silvopasture and open-pasture have estimated higher forage biomass production for open- than silvopasture (Clason 1999; Kallenbach et al. 2006) but better quality of forage from silvopasture (Kallenbach et al. 2006). However, information on the temporal and spatial dynamics of forage productivity and quality in southern pastures being converted to silvopasture is lacking. In addition, to fully understand the productivity dynamics of a developing silvopasture system, it is also important to consider impacts on soil quality as the conversion proceeds.

Aggregate stability and compaction are major physical indicators of soil quality (Singer and Ewing 2000). Soil aggregate stability is important to reduce erosion, maintain porous structure, enhance infiltration and microbial activity, and maintain productivity (Franzluebbers et al. 2000). Soil compaction is related to pore space, and therefore impacts infiltration, air and water movement, and root growth (Stephenson and Veigel 1987). Studies conducted on some forage and crop species have revealed that plant species can have a significant impact on aggregate stability (Haynes and Beare 1997; Reid and Goss 1981). Franzluebbers et al. (2000) highlighted the influence of pasture age and management practices on aggregate stability. The role of fungi on aggregate formation and stabilization has been highlighted in many studies (Kay and Angers 2000; Klironomos 2000). Few studies conducted with crop species have been concerned with the influence of fertilization or type of fertilizer on aggregate stability and hyphal length. Dapaah and Vyn (1998) reported that soil aggregate stability and corn growth and development were affected more by cover crops than applied nitrogen. Bittman et al. (2005) found significantly greater hyphal length in untreated soil than in manured and fertilized soil. Shannon et al. (2002) mentioned that total and active fungi were more abundant in organically-managed soils. However, there is no information on soil quality dynamics in developing silvopasture. Therefore, this research was conducted with the following objectives: 1) to determine the impact of N source (fertilizer-N versus legume-N) on forage productivity and quality in silvo- versus open-pasture systems, and 2) to determine the impact of N source on aggregate stability, fungal hyphal density, and soil compaction in silvo- versus open-pasture systems.

METHODS

Research site

This research was conducted during 2005 and 2006 in a developing 4-ha longleaf pine (*Pinus palustris* Mill.)-bahiagrass (*Paspalum notatum* Flugge) silvopasture and adjoining 4-ha bahiagrass pasture without trees (open-pasture) at Americus, Georgia, USA (32° 3' N, 84° 14' W). The bahiagrass pasture to be converted to silvopasture was prepared in the summer of 2000 by in-row subsoiling and application of glyphosate in the double-row set configuration to be used for planting the pine seedlings. In December 2000, longleaf pine seedlings were planted in double-row sets with a 1.82-m tree-to-tree-in-row spacing and 3.04-m spacing between the double-rows of trees. Alleys between double-row tree sets were 12.2-m wide. The soil at the site is an Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) with a particle size distribution of 850 g kg^{-1} sand, 125 g kg^{-1} silt, and 25 g kg^{-1} clay, 22 g kg^{-1} organic matter, and an estimated ion exchange capacity of 6.23 cmol kg^{-1}. Using annual Auburn University soil test recommendations, levels of plant available P and K were adjusted as needed with mixed commercial fertilizer in late spring, and soil pH was maintained at 6.0 with addition of dolomitic limestone in the fall.

Treatments

Silvopasture and open-pasture were each divided into three blocks and each block randomly assigned to two N source treatments: commercial N fertilizer or crimson clover (*Trifolium incarnatum* L. 'Dixie'). Each treatment plot measured 0.2 ha; silvopasture plots included four double-row tree sets and three 12.2-m alleys. N fertilizer was applied as a single application of 67 kg ha^{-1} N in late spring; this rate was based on current Auburn University soil test recommendations for bahiagrass pasture. Crimson clover was overseeded in October 2004 at a rate of 11.2 kg ha^{-1} within the legume-N treatment plots with a no-till native grass drill.

Sample collection

In 2005, permanent points for sample collection in each plot were located at 5 random locations within the three 12.2-m alleys included in each treatment plot per block. At each location, points were located to represent the alley center or alley side relative to trees. Points representing the alley center position were located 6.1 m from the center of the tree base; the alley side position was located 1.0 m from the center of the tree base. The result was 5 sub-samples from each alley center and alley-side position within each plot. A similar sampling scheme was applied to open-pasture. In 2006, an additional sample point for shoot biomass was added at 3.5 m from the center of the tree base (equidistant between the 1.0- and 6.1-m sample points) for all alley locations in the silvopasture.

To estimate shoot biomass, forage within a 0.25-m^2 quadrat was clipped to 5 cm from the ground. Immediately after sample collection, plots were mowed (2005) or grazed (2006) to 5 cm then allowed to regrow. Samples were collected three times a year: May, June or July, and August. Root samples were collected to 10 cm in August 2005 with a 5-cm diameter core sampler. Samples for water stable aggregates (WSA) were collected in May and August of 2005 and 2006. Samples for density of fungal hyphae (DFH) were collected in August 2005 and May and August 2006. In June 2005, soil compaction was measured in terms of penetration resistance in-situ with a dynamic cone penetrometer (Herrick and Jones 2002) at four depths: 0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm.

Sample analysis

Shoot biomass tissue samples were dried at 60^{o}C for 72 hours then weighed. Oven-dried samples were ground to pass a 2-mm sieve and used to estimate Kjeldahl-N and acid detergent fiber (ADF; Goering and Van Soest 1970). Samples for WSA were sieved through a 2 mm sieve in a field moist condition, allowed to air dry, then analyzed using a wet sieving apparatus (Eijkelkamp Agrisearch Equipment) equipped with 0.250-mm sieves. Samples for root biomass and DFH were kept cool (4^{o}C) until analysis which was completed within 14 days of collection. Root cores were washed over a sieve (500-μm), debris removed from the roots, then the root tissue dried at 60^{o}C for 72 hours and weighed. DFH was estimated using the membrane filter technique (Bardgett 1991) to prepare two membrane filtrate slides for each sample. These slides were examined at 200x magnification observing five fields of view for each slide and the total hyphal length for each slide estimated following method 4 of Olson (1950). Average hyphal length from two slides prepared for each sample was used to estimate DFH in m g^{-1} of wet soil, which was then converted to m g^{-1} of oven-dried soil based on the gravimetric water content of a subsample of the initial DFH sample.

Data analysis

Proc mixed was used in SAS 9.1 to analyze the data with block as a random factor and sampling date as a repeated factor where applicable. Main sources of variation included pasture type, N source, and sampling date. For compaction, depth was another source of variation used as a repeated factor. The interaction effects of pasture type and N source, pasture type and sampling date, and N source and sampling date were also analyzed. Moreover, interaction of depth and pasture type, and depth and N source were assessed. Data from silvopasture were analyzed separately to assess the alley position effect as a result of proximity to trees. Probability level for rejection of the H_0 was set at 0.05.

RESULTS

Climatic conditions

Except for May, precipitation remained above the 47-y average from March to July of 2005 but remained consistently below the 47-y average during the same period in 2006 (Fig. 1). Monthly average minimum and maximum temperature remained similar for both years (Fig. 2).

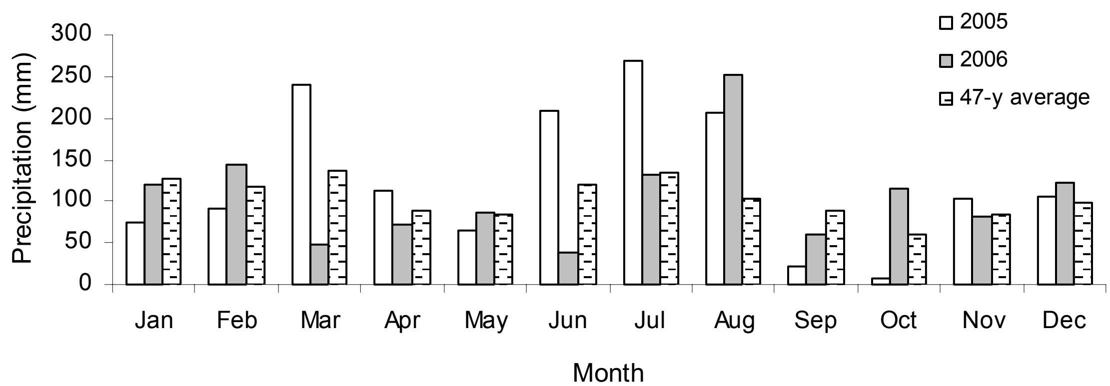

Fig. 7: Monthly total precipitation pattern for 2005, 2006, and 47-y average, Americus, GA, U.S.A.

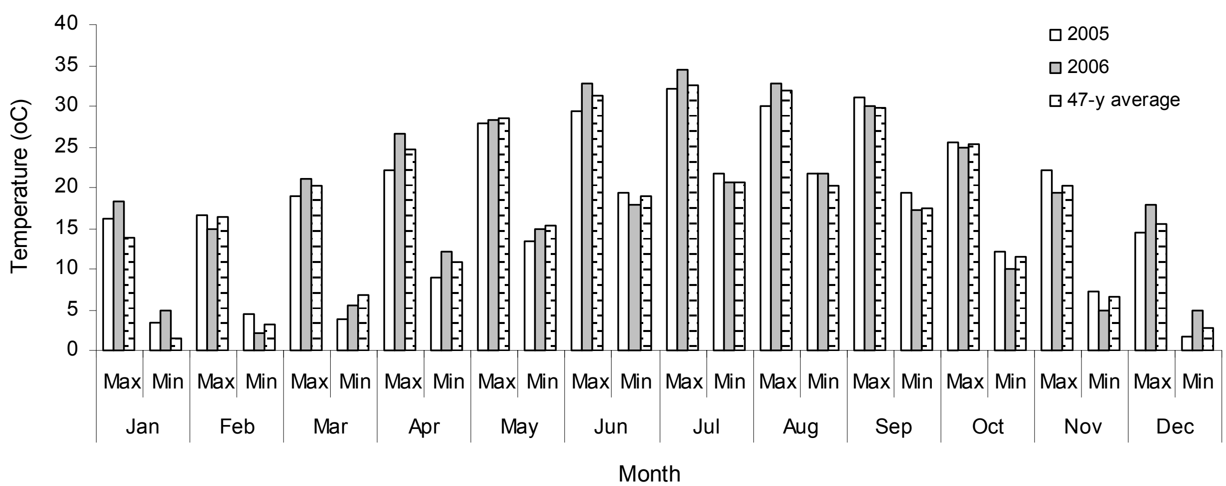

Fig. 8: Monthly average minimum and maximum temperature for 2005, 2006, and 47-y average, Americus, GA, U.S.A.

Shoot biomass

There was a successful stand of clover in May 2005 and, although the 2005 stand was managed to reseed, the 2006 stand was sparse to non-existent in most plots. A possible explanation for this failure was the dry soil conditions experienced at the site in September and October 2005. Overall, the shoot dry matter (SDM) production was not different between either legume-N and fertilizer-N treatments or open- and silvopasture. However, both N source and pasture type showed an interaction effect with sampling date. The SDM was higher for legume-N than fertilizer-N treatments (Fig. 3) and for open-pasture than silvopasture in May 2005 (Fig. 4).

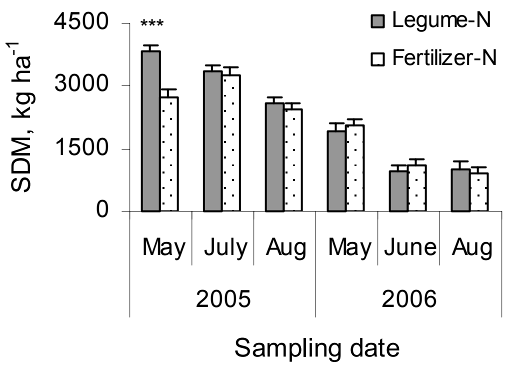

Fig. 9: Forage shoot dry matter (SDM) production (LSmean ± SE) at different sampling dates for legume- and fertilizer-N treatments, Americus, GA, USA (***P = 0.0001).

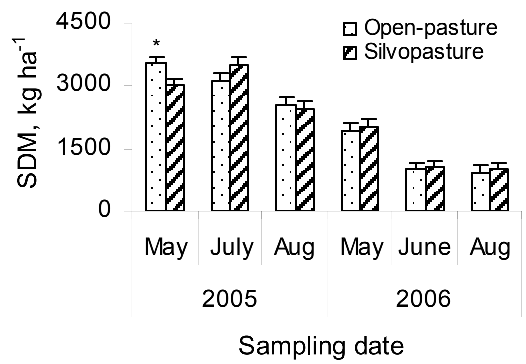

Fig. 10: Forage shoot dry matter (SDM) production (LSmean ± SE) at different sampling dates from open- and silvopasture, Americus, GA, USA (*P < 0.05).

In silvopasture, there was no alley position effect on SDM production in 2005. However, in 2006, this effect was manifested ($P < 0.01$) with the higher SDM production at the 3.5-m alley position (1525 ± 61.5 kg ha^{-1}) than at the 6.1-m (1279 ± 44.3 kg ha^{-1}) or 1.0-m (1272 ± 44.3 kg ha^{-1}) alley positions. When analyzed over 2006 sampling dates, an alley position effect was evident only in May (Table 1).

Table 6: Forage shoot dry matter production (LSmean ± SE) in silvopasture for different alley positions and sampling dates, 2006, Americus, GA, USA.

	Shoot dry matter production		
	Alley position relative to tree base		
Sampling date	6.1 m	3.5 m	1 m
	kg ha^{-1}		
May	1911 ± 75.8^{b}	2309 ± 101.4^{a}	1930 ± 74.4^{b}
June	1007 ± 75.4	1121 ± 100.1	941 ± 73.8
August	918 ± 75.4	1145 ± 100.2	946 ± 73.8

LSmeans in a row with different superscripts are different ($P < 0.01$).

Root biomass

Root biomass was not different between either legume-N and fertilizer-N treatments or open- and silvopasture. Also, no alley position effect was detected on root biomass from silvopasture.

Forage quality

Overall, forage N concentration was not different between either legume-N and fertilizer-N treatments or open- and silvopasture. However, there was an interaction effect between N source and sampling date with higher ($P < 0.0001$) N concentrations in forage from legume-N (18.6 ± 0.53 g kg^{-1}) than from fertilizer-N treatment (14.5 ± 0.53 g kg^{-1}) in May. Forage N concentration for open- (15.7 ± 0.62 g kg^{-1}) and silvopasture (17.3 ± 0.62 g kg^{-1}) approached the significant difference ($P = 0.051$) in May. Forage ADF concentration was not different between either legume-N and fertilizer-N or open- and silvopasture. No position effect was detected for forage N or ADF concentrations in samples collected from silvopasture.

Soil quality

Water stable aggregates (WSA)

Overall, differences in WSA for legume-N and fertilizer-N were not detected. However, when analyzed over sampling dates, higher WSA was observed for soils sampled from legume-N versus fertilizer-N treatments in May 2006 (Fig. 5). Pasture type did not have a significant effect on WSA concentration. In silvopasture, there was no position effect overall on WSA concentration. However, May 2006 WSA in soils at the 1.0-m alley position (648 ± 25.8 g kg^{-1}) remained higher ($P < 0.05$) than for soils at the 6.1-m alley position (616 ± 25.8 g kg^{-1}).

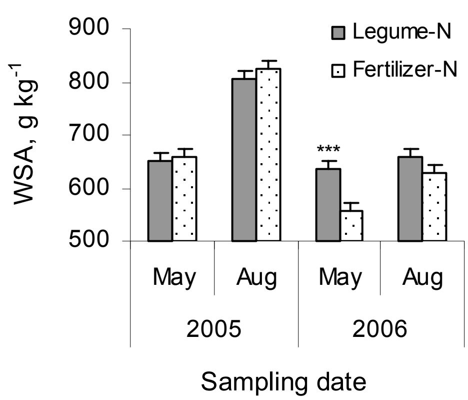

Fig. 5: Water stable aggregates (WSA) of soil (LSmean ± SE) for legume- and fertilizer-N treatments at different sampling dates, Americus, GA, USA (***$P < 0.001$).

Density of fungal hyphae (DFH)

Overall, DFH was not different between either legume-N and fertilizer-N or open- and silvopasture. However, when analyzed over sampling dates, DFH was higher for open- than silvopasture in August 2005 (Fig. 6). In silvopasture, higher DFH was found in soils at the 6.1-m alley position than at the 1.0-m alley position in August 2005. But, in May 2006, DFH was higher at the 1.0-m than 6.1-m alley position (Fig. 7). Positive correlation was found between DFH and gravimetric water content of soil sample ($r = 0.35$, $P < 0.0001$). Positive correlation was also present between DFH and WSA ($r = 0.33$, $P < 0.0001$).

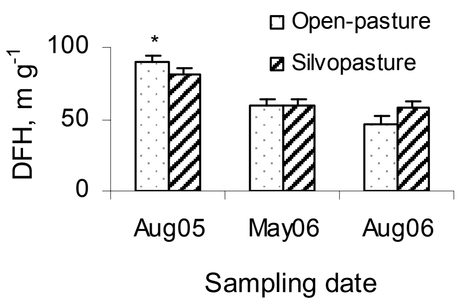

Fig. 11: Density of fungal hyphae (DFH) (LSmean ± SE) for soil from open- and silvopasture at different sampling dates, Americus, GA, USA (*P < 0.05).

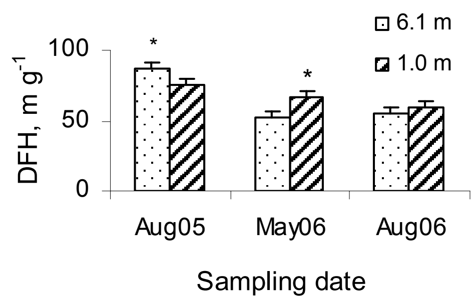

Fig. 12: Density of fungal hyphae (DFH) (LSmean ± SE) for soil at 6.1-m and 1.0-m alley positions relative to the base of trees in silvopasture at different sampling dates, Americus, GA, USA (*P<0.05).

Compaction

Soil compaction as measured in terms of soil penetration resistance (PR) was not different between legume-N and fertilizer-N treatments. However, soil PR was higher in open- than silvopasture at 10-15- and 15-20-cm depths (Fig. 8). In silvopasture, PR at all depths remained lower in soils at the 1.0-m alley position versus the 6.1-m alley position (Fig. 9).

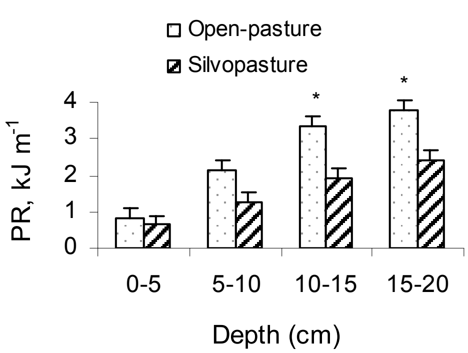

Fig. 13: Soil penetration resistance (PR) (LSmean ± SE) for open- and silvopasture at different depths, June 2005, Americus, GA, USA (*P < 0.05).

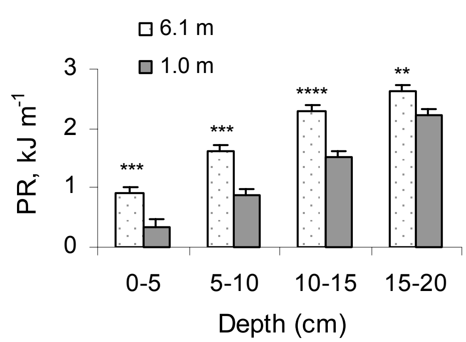

Fig. 14: Soil penetration resistance (PR) (LSmean ± SE) for 6.1-m and 1.0-m alley positions relative to the base of trees in silvopasture at different depths, June 2005, Americus, GA, USA (**P < 0.01, ***P < 0.001, ****P< 0.0001).

Sampling date

Sampling date had a significant effect on the forage biomass and quality, and soil quality. For all sampling dates, SDM production remained higher in 2005 than 2006. Differences in SDM production was also observed among months in the same year (Table 2). Highest forage N and lowest ADF concentrations were observed in May 2005 (Table 3). WSA (Table 4) and the DFH (Table 5) were highest in August 2005.

Table 7: Forage shoot dry matter production (LSmean ± SE) at different sampling dates, Americus, GA, USA.

Sampling date		Shoot dry matter, kg ha^{-1}
2005	May	3282 ± 104.5^{a}
	July	3311 ± 121.2^{a}
	Aug	2499 ± 121.0^{c}
2006	May	1984 ± 115.4^{d}
	June	1009 ± 115.1^{b}
	August	956 ± 115.2^{b}

LSmeans with different superscripts are different ($P < 0.0001$).

Table 8: Forage N and ADF concentrations (LSmean ± SE) at different dates, Americus, GA, USA.

Sampling date (2005)	N, g kg^{-1}	ADF, g kg^{-1}
May	16.5 ± .44^{a}	392 ± 4.1^{a}
August	12.3 ± .44^{b}	419 ± 4.0^{b}
September	12.7 ± .44^{b}	418 ± 4.1^{b}

LSmeans in a column with different superscripts are different ($P \leq 0.0001$).

Table 9: Water stable aggregates (WSA) (LSmean ± SE) at different dates, Americus, GA, USA

Sampling date		WSA, g kg^{-1}
2005	May	656 ± 13.8^{a}
	August	815 ±14.0^{b}
2006	May	596 ± 13.9^{c}
	August	642 ± 13.8^{a}

LSmeans with different superscripts are different (August 06 ≠ May 06: $P < 0.01$, other comparisons: $P < 0.0001$).

Table 10: Density of fungal hyphae (DFH) (LSmean ± SE) at different dates, Americus, GA, USA

Sampling date		Hyphal density, m g^{-1}
2005	August	85.1 ± 3.31^{a}
2006	May	59.4 ± 3.31^{b}
	August	52.3 ± 3.32^{c}

LSmeans with different superscripts are different (a ≠ b & c: $P < 0.0001$, b ≠ c: $P < 0.05$).

DISCUSSION

The May 2005 stand of clover explains the higher (39%) shoot dry matter (SDM) production for legume-N versus fertilizer-N treatment. This result is supported by the findings of Cuomo et al.

(2005) and Malhi et al. (2002). They reported that bromegrass-legume mixtures without N fertilizer produced more forage than bromegrass monoculture for different rates of N fertilizer application. Higher (16%) May 2005 SDM for open-pasture versus silvopasture could be the result of differences in microclimate, especially increased availability of radiation and soil moisture for clover growth in open-pasture versus silvopasture. Similar SDM production from both N treatments at the other sampling dates, even when clover was dormant, could be attributed to the total N fixation by legumes in the system. This indicates that shoot biomass production in this system can be maintained without applying N fertilizer if legumes are introduced. Overall, no difference in SDM production between the pasture types in this research contradicts the findings of Clason (1999) and Kallenbach et al. (2006). Differences in the forage species and tree stand age between this research and those of Clason and Kallenbach et al. could be the reason for this contradition. We found the difference in SDM production between the pasture types with higher SDM in open- than silvopasture only in May 2005, when clover was a major species in the legume-N treatment plots. This indicates that crimson clover may produce less biomass in silvopasture even when the pine stands are as young as 5-y. However, bahiagrass productivity appeared to be similar in both pasture types with presence of up to 6-y old longleaf pine in the silvopasture.

In May 2006, SDM production from 3.5-m alley position was 21% and 20% higher than from 6.1-m and 1.0-m positions, respectively. Higher SDM production from 3.5-m alley position than 6.1-m alley position could be a result of less compaction at the former versus the latter position. Though we did not measure compaction at 3.5-m, less compaction at the 1.0-m versus 6.1-m alley position indicated the possibility of less compaction at the 3.5-m versus the 6.1-m alley position. Also, forage in 3.5-m alley position might have received more protection against harsh climatic conditions by the nearby presence of trees. Less SDM production from 1.0-m versus 3.5-m alley position could be the result of microclimatic modifications, especially solar radiation or soil moisture.

Higher (28%) forage-N concentration in biomass from legume-N versus fertilizer-N treatments in May 2005 can be attributed to the large contribution of clover to the available forage. Work of Malhi et al. (2002) supports this finding. They found higher protein content of forage from bromegrass-legume mixture than from bromegrass monoculture.

Some treatment differences also occurred in terms of water stable aggregates (WSA). In May 2006, WSA were the lowest among the sampling dates, but N treatment differences occurred with higher (14%) WSA for the legume-N than the fertilizer-N treatment. The interaction between climatic conditions and plant species might have played a role in this difference. Further research is required to understand this interaction. Unlike WSA, differences between pasture types were observed in August 2005 with 10% higher density of fungal hyphae (DFH) in open-pasture versus silvopasture. One of the causes for this difference could be soil moisture content. However, the cause of differences in DFH between positions in silvopasture observed in August 2005 and May 2006 could be the result of other causes including possible differences in microclimate and root systems between the two positions at the given sampling dates. Differences in root systems and microclimatic conditions brought about by the trees could also be responsible for the difference in soil penetration resistance (PR) between pasture types, and alley positions in silvopasture. Soil PR at 10-15-cm and 15-20-cm in open-pasture was 76% and

57% higher, respectively, than silvopasture. Similarly, soil PR at 0-5-, 5-10-, 10-15-, and 15-20-cm was 155%, 88%, 80%, and 18% higher, respectively at the 6.1-m versus the 1.0-m alley position in silvopasture.

To date, this research indicates that N source was a major cause of differences in forage productivity and quality, and WSA, a soil quality indicator. Moreover, pasture type and position relative to trees in silvopasture caused differences in soil compaction and density of fungal hyphae. The effect of sampling date on all the variables measured was most likely the result of seasonal variation in climatic conditions and plant species. An additional year of data collection will be completed in the fall of 2007 and final data analysis conducted before final conclusions are drawn from this stage of study in this system.

ACKNOWLEDGEMENTS

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STOCKING RATE FOR A GOAT SILVOPASTORAL SYSTEM IN NORTH FLORIDA

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Abstract: The use of goats in silvopastoral systems under temperate agroforestry has received limited evaluation. In 2005, 16 – 18 months old Boer X Spanish goat crossbreeds were introduced into a Tifton-9 bahia grass pasture established under widely spaced loblolly pine trees and in an adjacent open space with no trees for comparison. A different set of 24 – 30 months old Boer and Spanish goat breeds were utilized for the same experiment in 2006. Grazing in 2005 was conducted between September and November, while that for 2006 was done between August and November. The experiment design was a split plot design with treatments randomly assigned to blocks in two replications. The stocking rates for animals in both years were 10 and 17 goats per hectare in shaded and un-shaded areas respectively. Life weights (LW) of goats were determined every 14 days before grazing (BG) and after grazing (AG) prior to being rotated within and across fenced paddocks. Herbage yield for Tifton-9 bahia grass in each paddock was determined BG and AG for 2005 and 2006. Life weights (LW) of goats were higher for 10 animals per hectare (APH) compared to 17 APH. For the higher stocking rate LW declined or remained the same while for the lower stocking rate, LW increased until they became constant and then declined.

Paddocks containing more goats had higher herbage yield compared to those with fewer goats contrary to expectation. Mean herbage yield for each paddock was higher BG than immediately AG.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together*. Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

AGROFORESTRY AND SILVOPASTORAL DEVELOPMENT PROCESS IN URUGUAY: STRATEGY, EXPERIENCES AND ACTION PLAN

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INTRODUCTION

The Oriental Republic of Uruguay has developed its forestry sector extraordinarily quickly due to a forestry development strategy based on special incentive measures, an active participation of the private sector (national and foreign investments), excellent natural conditions of suitable soils, climate and topography and an open market economic system to the region and the world.

In a natural pasture temperate ecosystem, Uruguay is a traditional livestock producer. Rural communities have very strong livestock culture in which trees play an important role. Livestock production has normally been associated with native forest, located mainly along streams and riversides and in low areas. We can consider these silvopastoral practices as dating from 1611 - 1617 when cattle were first introduced into the country. From that time, all actors recognize the "multiple uses of forests" and two roles - the "protection role" and "productive role".

Native forest is valued for its functions for soil protection, erosion control, water level control, climate regulation, habitat for native animals and shelter and shadow for livestock. On Uruguayan lands, man-made stands of trees were principally planted as shelter groves and windbreaks in meadows -in small areas- scattered throughout the country, to protect animals from severe climate conditions, especially when they are in their critical growth stage. These types of forests supply rural families with firewood, poles, piles and wood material for rural construction but they have no further industrial use. But indeed, native and man-made forests are fundamental pillars in rural areas for daily life.

FORESTRY AND AGROFORESTRY DEVELOPMENT AND STRATEGY

In early 1960´s, the government of Uruguay recognized a lack of forestry resources in rural areas and an important flow of imported forestry products, mainly from Argentina, Brazil, Paraguay, Europe and the USA. Several indicators were showing a good opportunity for developing a wood production sector, for the national market – replacing imports- and also for the world market. Because of this, a Forestry Agency was created in 1964, as a new branch of the Livestock and Agriculture Ministry, which began operation two years later; in December, 1966.

It was between 1968 – 1972 when a Forestry Policy and the first Forestry Law Nº 13723/1968 were created, addressing an active participation from the national and foreign private sector. Forestry Law Nº 13723 was implemented through years 1970-1977, imposing several conditions and requirements for forest investment and investors.

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By means of a national program, tree plantations were done in suitable soils, mainly with fast growing species which were locally adapted (*Eucalyptus saligna*, *E. grandis* and *E. globulus*; *Pinus taeda*, *P. elliottii* and *P. pinaster*; *Populus deltoides*, some poplar hybrids and willows, such as *Salix alba*) and consisting of a minimum plantation size of 10 ha, as a minimum limit. These species and 3.6 million hectares were declared of forestry priority with tax incentives from central and local governments. Forestry Policy became a State Policy with a well defined and structured legislation.

In 1987, a new Forestry Law – Nº 15939 – was approved. Very similar to the first one, this one had a strong impact caused by the establishment of a new strategy to promote tree plantations. The new strategy was assign a yearly amount of public money resources to a Forest Fund, as a partial cost plantation refund paid to qualified forest owners, covering 20% or 50% of the initial costs approved; depending on what kind of national tax each one of them were paying. This was done to accelerate man-made forest with rapid-growth tree species, to get landowners (ranchers and farmers) to invest in a very new, but risky sector, with long term incomes and taking into account that they were currently getting yearly incomes from their land production.

Figures on the evolution of Uruguayan forest areas are shown in Table 1 and Table 2. Average annual plantation rates through the years have been very different (Table 1).

Table 1: Forest development data in Uruguay: Average Annual Plantation Rate (AAPR).

Period of Time	AAPR
1970 – 1974	200 ha
1975 – 1985	1826 ha
1986 – 1990	4085 ha
1991 – 1995	37,388 ha
1996 – 2000	81,293 ha
2001 – 2005	23,614 ha

Source: Ma. C. Polla (2007).
Data from year 2005 is estimated.

In 1990, national and foreign forest owners began to get their partial plantation cost refund and then there was an explosive increase of forest plantations. This evolution of planted areas is shown in Table 2.

Table 2: Evolution of forested areas (ha) in Uruguay. Period 1992 - 2006.

1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
25,705	*41,992*	*44,330*	*58,568*	*58,964*	*73,243*	***84,803***	*72,958*
2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	
57,931	*51,242*	*26,932*	*13,217*	*2,876*	–	–	

Source: Statistics Bulletin – Dirección General Forestal (DGF) of Ministerio de Ganadería, Agricultura y Pesca (MGAP).

Total forestry areas in Uruguay are shown in Table 3, by type of forest.

Table 3: Forestry Areas in Uruguay – National Statistics.

TYPE of FOREST	***AREA (ha)***
PLANTED FORESTS	*714,081*
- Broadleaved Trees	*541,006*
- Coniferous	*173,075*
NATIVE FOREST	*810,816*
FORESTS (TOTAL)	*1,524,897*

Source: Stadistics Bulletin – Dirección General Forestal (DGF) of Ministerio de Ganadería, Agricultura y Pesca (MGAP).

Eucalypt species have been the most planted species, followed by pines.

Agroforestry development is taking place in Uruguay at the same time as forestry development; 90% of forested areas are been grazed. Landowners are using their forests for silvopastoral management, keeping cattle, sheeps, horses and trees in the same plot of land; so in most cases they are making better use of the natural resources, diversifying their production, lessening risks and getting short and long term incomes. In this way, farmers are still producing traditional national products as meat, milk, wool, leather, cereals and so on; getting yearly income while the forest adds value to their land, giving shelter and shadow to domestic animals and incrementing their capital until the trees are harvested in 7 or 8 years (roundwood for pulp production) from planting.

Rural producers with forestry soils in their land decided to take advantage of forestry legislation keeping mainly livestock in their plots and in this way they began to implement agroforestry practices and systems. With these innovations, people could still be ranchers, farmers and foresters at the same time without paying rural taxes if they fill Forestry Law requirements. Foresters integrate cattle and crops into forestry practices and farmers integrate forestry tree species into livestock and agriculture in different ways and with different production purposes.

There are very interesting silvopastoral practices and systems in addition to some agrosilvopastoral and silvoagriculture experiences improving sustainable forest management and sustainable development. Authorities and the new government are reformulating Forestry Policy changing some regulations and keeping others.

New regulations have changed the priority of some forestry soils and species. Soils with 40% or less of marginal land are not accepted for planting even if they have some forestry priority soils because they could be better used for grazing or crops. Ranchers and farmers can plant tree stands, occupyingup to 8% of their land, with any forestry species, in any type of soil and within a well-defined agroforestry project. In this case, planted areas don't pay taxes. For some forestry soils, in some particular zones, landowners are obliged to present a different type of project with integrated production, improved management and protected natural resources.

Other changes will encourage landowners and forestry investors to produce sawlogs rather than pulpwood.

EXPERIENCES AND AGROFORESTRY ACTION PLAN

Agroforestry and mainly silvopastoralism have been developed within Forestry Policy and Law. Rural producers have begun to integrate livestock and crops into forest and on the other hand, forestry into livestock and crop production, with good success. Agroforestry experiences have been done by landowners on forestry suitable soils with eucalyptus (also clones), pines, poplars and some other species and also in native forests.

Silvopastoral practices and experiences are being done mainly by foresters rather than ranchers or crop producers. Different experiences in tree planting densities and in plantation designs are good examples of silvopastoral systems and global management. Grazing on pastures in man-made forests, is done throughout the forest's lifespan when the objective is to produce good quality sawlogs. High quality wood production goes hand in hand with silvopastoral systems due to natural pasture production and the silviculture management needed for good quality logs. Pruning and thinning opens tree stands letting sunlight get to the ground and green pastures come up rather easily. We also improve natural pasture by fertilization and/or sowing better quality grass seeds and in other cases an artificial pasture is sown.

In pulpwood eucalyptus plantations, grazing is possible up to the first four to six years under trees before the stands close and after that, grazing continues in firebreaks, internal and peripheral roads and in low zones with rich soils and good grass; where forestry trees cannot develop well.

Forestry plantations and silvopastoral management are relevant in rural areas as new production alternatives with better incomes and as sustainable production systems. At the same time many questions about silvopastoral and other agroforestry systems management appear to lack good answers. In this situation, a National Agroforestry Action Plan (Polla 1991) was defined to collect data "in situ", to create a Temperate Agroforestry Data Bank, addressing to do "on farm research" and "on experimental station research"; to implement demonstration areas and research projects; to be able to define a specific Agroforestry Policy for rural communities and sustainable development.

The Action Plan considers one principal project or program, studying the first stages of the experience and other related projects that consist of several activities. The first step was to do the diagnosis of agroforestry systems at a national level, then to establish silvopastoral plot trials as "on farm research" and technical and economic studies of different examples of silvopastoralism and other cases of agroforestry productions. Very few of these stages could be done so there are many activities to take care of. At a political level, two regulations were approved by actual government, as mentioned above, to promote integrated productions as Agroforestry Systems; in order to improve economic, social and environmental aspects of rural life. High quality wood production goes hand in hand with silvopastoral systems due to natural pasture production and the silviculture management needed for good quality logs. Pruning and thinning opens tree stands letting sunlight get to the ground and green pastures come up rather easily.

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ANALYSIS OF SILVOPASTORAL SYSTEMS WITH *PINUS CONTORTA* (DOUGL. EX LOUD.), IN THE AYSEN REGION, CHILE

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Abstract: In the year 2003 a research was carried out in order to assess the potential of agroforestry systems with *Pinus contorta* (Dougl. ex Loud), in the Aysen Region of Chile (Chilean Patagonia). For the purpose of evaluation a traditional livestock farming model was compared with two agroforestry models and a pure forestry management model with *Pinus contorta*.

The study considered the intervention of a 12-year-old plantation with an original density of 1,514 trees ha^{-1}, and the management under 4 different treatments to be compared with each other: T1: a forestry management model, with a thinning intervention from 1,514 to 800 trees ha^{-1}, and pruning to 40% tree height; T2: a traditional agroforestry model, based on a density of 400 trees ha^{-1} evenly distributed in the area of intervention and pruned to 40% of tree height, T3: a strip agroforestry model with 400 trees ha^{-1} distributed in three rows of trees along altitude curves, distanced at 21 meters from one another; both silvopastoral systems were combined with a fertilized natural prairie, using local cattle of the area; T4: a traditional cattle grazing model with natural fertilized prairie without the protection of trees.

The results of this study suggest that silvopastoral systems is an interesting alternative for farmers in the Chilean part of Patagonia, as it allows them to create intermediate income through selling meat as well as timber from the thinning interventions, with a major final income from the final harvest of the forestry component. The meat production from livestock during the first two production seasons was higher in T3, with a similar production in T2 and T4, showing the beneficiary influence of the trees on climate factors as wind and low temperatures.

Key Words: Agroforestry systems, Chilean Patagonia, thinning, pruning, farmers.

INTRODUCTION

Currently the small and medium-size landowners in the XI Region of Aysen, Chile, dedicate the major part of their soils to extensive livestock farming, without concern about the soil use capacity and with vast extensions of soil categories VI and VII (forestry-livestock use) covered with natural grassland of regular or poor quality and low productivity for meat and/or wool production, and the occurrence of soil erosion as a consequence of overgrazing and poor protection by permanent vegetation. This situation arises from the fact that this activity is the only one offering a regular income on a yearly basis for maintaining the family income and the productive systems of the farms. .

For the reasons mentioned above, improving the productivity of the farms in the Region of Aysén or at least of a considerable number of them, must include innovation and the incorporation of adequate technology, to improve the production efficiency of the traditional farming activities and consider the sustainability of the system used. Within this innovation and incorporation processes an integration of forestry and livestock activities within the same physical space, generally called "Silvopastoral System", it is possible that both activities benefit from.

Incorporating trees into farming units destined to traditional livestock farming according to one or another agroforestry design, or as windbreaks or shelterbelt, may increase the productivity of the prairie and livestock (cattle or sheep) for the improvement of the environmental conditions due to the protection from the trees to the pasture and the animals (reduction of wind speed, increase of air and soil temperature, reduction of the irrigation deficit, protection of the livestock against rain and snow, etc.; Sotomayor 1990; Quam and Johnson 1999; Garret et al. 2004; Sotomayor et al. 2004; Red Agroforestal Nacional Instituto Forestal 2007).

At the same time the introduced forestry resources will benefit from the presence of livestock in the area through weed control, reducing the impact of weed vegetation on the establishment and growth of the trees, especially in the first years (thus reducing the danger of forest fires). Also will receive benefits from fertilizing to the forage crops or pasture associated with the plantations, and finally due to the increased physical space for tree growth as it is commonly used in an agroforestry system.

Another important environmental aspect of the presence of trees is the protection of soils against wind and rainfall, which should lead to a significant reduction of erosion.

OBJECTIVES

Increase the productivity of farms in the Region of Aysén, Chile, in a sustainable way, through soil use innovation by applying silvopastoral systems.

MATERIALS AND METHODS

In order to assess the feasibility of the silvopastoral combination in the Region of Aysén, in the year 2004 forestry and agroforestry modules were installed in existing plantations of 12-year-old *Pinus contorta* without management, comparing them with a traditional livestock farming system. Research units were installed in order to be able to study the behaviour of the species, trees and animals, under different densities and management, the influence on the productivity of natural prairie, livestock production and the development of the trees.

Features of the experimental unit

The experimental unit is located 20 km North of Coyhaique in the intermediate agro-climate zone (Table 1), on a slope with Western exposure.

The Region of Aysén is characterized by a cold climate with high variations in rainfall depending on the agro-climate zone, and strong winds (Table 1), with intensity depending however on the geographical location in accordance to the marked transversal gradient.

Table 1: Climate parameters of the agro-ecological zones of Aysén region, Chile.

Parameters		***Agro-climate zone***		
		Moist	**Intermediate**	**Steppe**
Medium T° (°C)		9.0	7.7	6.5
Minimum medium T° (°C)		5.7	3.9	2.2
Frost-free period (days)		187	117	39
Strong winds (days)	**20 knots <**	6	57	244
	30 knots <	0	10	117
Rainfall (mm year^{-1})		2,000 – 4,000	500 – 1,500	400 - 700
Irrigation		Surplus all year	Seasonal deficit +	Seasonal deficit ++
Soil		• Thin • Moderately acid to acid • Coarse texture	• Deep • Moderately acid • Light	• Thin • Moderately acid to neutral • Coarse texture

Source: IREN-CORFO (1979a) and IREN-CORFO (1979b).
[a]Reference location Pto. Aysén. [b]Reference location Coyhaique. [c]Reference location Balmaceda.

The occurrence of strong winds in the intermediate zone is generally limited to the months between December and February, and is the main problem for the productivity of prairies, as it coincides with the growth period. In the Steppe zone this situation is even more critical, with strong winds during 90% of the year, and a peak of intensity between December and February.

Another consequence or these strong winds is the loss of soil moisture. In the Intermediate and Steppe zones only 15% of the rainfalls occur between December and February, coinciding with the strong winds mentioned above. This explains the information of Table 1 in relation to the seasonal irrigation deficit in both zones.

Treatment description

The treatments, designs and surfaces are described in Table 2. At the commencement of the study in March 2004, the plantation of *Pinus contorta* presented the following features (Table 3) for all treatments.

Table 2: Name and size of treatments.

Nº. Treatment	Name of Treatment	Surface (ha)
T1:	Forestry management	0.5
T2:	Traditional silvopastoral	5
T3:	Strip silvopastoral	5
T4:	Traditional livestock farming	5

Table 3: Description of the plantations before the experiment. Situation of *P.contorta* plantation, March 2004.

Year of plantation	1991
Age (years)	12
Density (trees ha^{-1})	1514
H total (m)	5.84
DBH (cm)	14.0
Tree crown cover (%)	95

Description of forestry and agroforestry treatments:

T1: Forestry management model: this shows a management alternative for these kind of plantations through a forestry management scheme aiming at higher quality products, in the form of clear or almost clear logs (Table 4).

Table 4: Proposed management for the forestry management model (T1).

Height (h)(m)	H pruning (m)	Thinning until (*)	DOS
5.8 (year 2004)	2.3 m (50%)	800	< 20 cm
10	4.0 m	600	< 20 cm
14	5.5 m	400	< 20 cm
22	5.5 m	400 (harvest)	< 20 cm

H pruning: height to prune at the corresponding opportunity.
(*) number of trees per ha after thinning.
DOS: stem diameter of the pruned sector after pruning.

T2: Traditional agroforestry model: this treatment (Table 5 and Fig. 1) represents the most common agroforestry system used in Chile, where a plantation is established with low density and even distribution of the trees on the surface, and a planned tree crown cover of 30% as recommended by Garret et al. (2004). With this model a value equal to pure forestry and livestock use is achieved.

T3: Strip silvopastoral system (with trees distributed in three rows): trees and prairie are defined in separate areas with a planned use according to sectors, in order to facilitate later management. In this case the emphasis lies on prairie and animal production, dedicating a greater area for its development and reducing the trees to a smaller surface (Fig. 2), with a tree crown cover of 30%. The trees in rows of three act as windbreaks for grassland protection.

Table 5: Proposed management for silvopastoral systems (T2 and T3).

Height (H)(m)	H pruning (m)	Thinning until (*)	DOS
5.8 (year 2004)	2.3 m (20-30%)	400	< 20 cm
10	4.0 m	400	< 20 cm
14	5.5 m	250	< 20 cm
22	5.5 m	250 (harvest)	< 20 cm

H pruning: height to prune at the corresponding opportunity.
(*) number of trees per ha after thinning (different arrangement for trees en T2 and T3).
DOS (diameter over stub): stem diameter of the pruned sector after pruning.

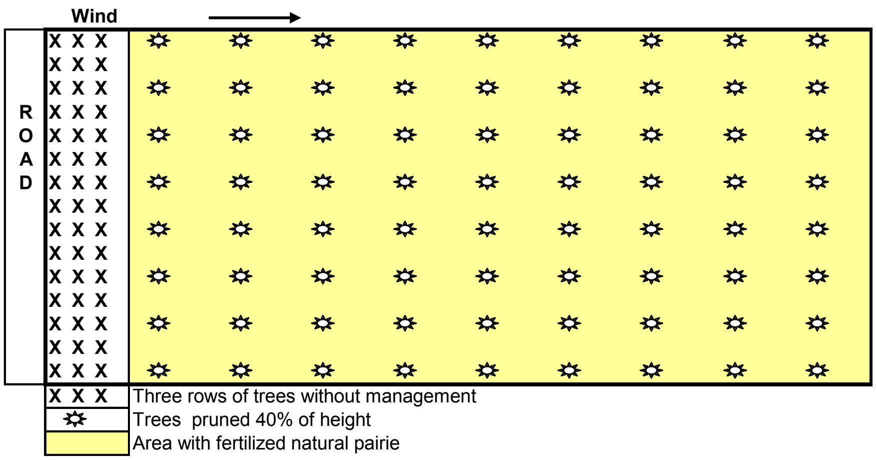

Fig. 1: Traditional agroforestry system design (T2), 400 trees ha^{-1} (2004).

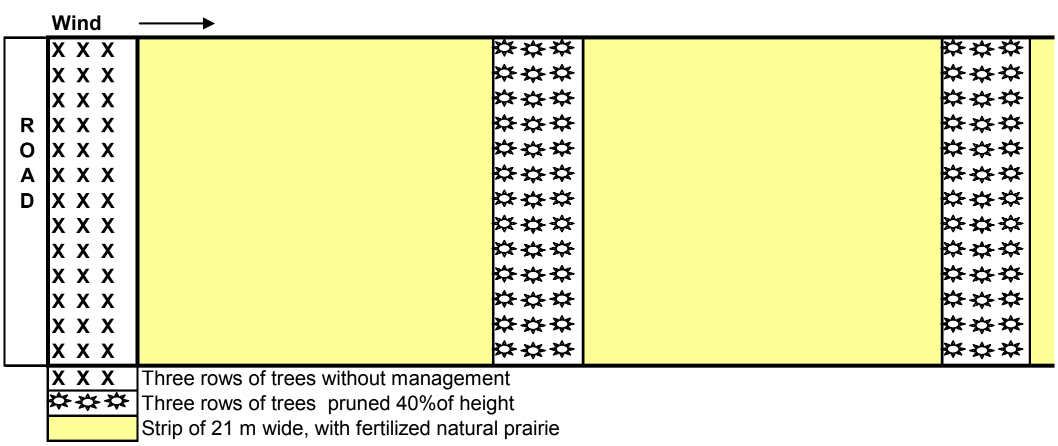

Fig. 2: Strip silvopastoral system design (T3), 400 trees ha^{-1} (2004).

T4: Traditional livestock management: this treatment considers the traditional management activities of livestock management in Aysén, Chile, including an improvement of the natural grasslands through fertilization with nitrogen and sulphur, and the use of bovine cattle. The surface is wholly covered with natural grassland without trees.

Design of the experiment: Permanent plots

Forestry evaluation

Three plots were installed per treatment, with a random design for each treatment including trees (T1, T2 and T3) in order to evaluate the forestry parameters. Parameters to be evaluated in the treatments including trees are: diameter at breast height (DBH in cm), tree basal area (BA m^2 ha^{-1}), total height (H), tree crown cover (%).

Design and size of the plots were the following:

T1: round plots of 200 m^2, distributed randomly within the treatment area for the evaluation of forestry variables.

T2: rectangular plots of 1,008 m^2 (24 x 42 m), distributed randomly within the 5 ha of the treatment area for the evaluation of forestry variables.

T3: rectangular plots of 1,008 m^2 (24 x 42 m), distributed randomly within the 5 ha of the treatment area. The plots are oriented according to the slope and perpendicular to the rows of trees, including two rows of trees (of three plantation lines each) and one complete prairie area in each plot for the evaluation of forestry variables.

Evaluation of livestock and prairie

Prairie Productivity: in order to measure the productivity of the pasture in the case of T4 in dry matter per hectare (dm ha^{-1}), variables are measured with metal exclusion cages (0.5 m width, 1m length and 0.5 m height). Seven exclusion cages were used for each treatment T2-T3-T4 in order to be able to compare productivities.

Evaluation of animal productivity: in order to evaluate animal productivity (live weight increase in kg) in treatments T2, T3 and T4, an animal mass consisting of 8 bovine cattle of approximately 300 kg live weight each at the beginning of each season was used.

RESULTS AND DISCUSSION

The results of the evaluation of all the productive factors are presented as follows:

Prairie productivity and development

The results for prairie productivity in dry matter per hectare are shown in Table 6 and Table 7. Considering all the dates evaluated in the two evaluation seasons, the prairie in the strip silvopastoral system (T3) reached the highest productivity, the traditional silvopastoral system (T2) showed a positive development in the second season, which was better than the traditional livestock system due to the longer time for prairie development under the open tree crown cover. Finally, the pure livestock model showed the poorest development, doubtlessly due to the negative influence of climate factors. These results show the positive tendency in the development of prairies in silvopastoral systems compared to pure livestock management.

Season 2004-2005

Table 6: Prairie production, season 2004-2005 (dm ha^{-1}).

Treatment	Feb-05	May-06	Total Period	Significance
T2	919	567	1486	**b**
T3	1884	801	2685	**a**
T4	2024	428	2452	**a**

Season 2005-2006

Table 7: Prairie production, season 2005-2006 (dm ha^{-1}).

Treatment	Dec-06	Jan-06	Feb-06	May-06	Total Season	Significance
T2	3877.5	1022.6	835.8	373.9	6109.8	**a**
T3	4262.8	1048.3	1130	540.5	6981.6	**a**
T4	2193.1	785.4	539.4	314.1	3832.0	**b**

Animal productivity

Season 2004-2005 (Table 8)

Table 8: Variation in bovine weight 2004-2005 (average weight kg).

Treatment	03-01-2005	03-17-2005	03-31-2005	04-15-2005	04-30-2005	05-15-2005	06-01-2005
T2	376.9	400.0	423.9	426.5	433.6	421.1	399.8
T3	380.0	401.5	424.3	429.5	439.6	435.4	414.6
T4	378.8	398.4	414.3	423.5	430.3	436.3	405.0

Season 2005-2006

The cattle in the T3 accumulated weight until May 2 during the last season (Table 9), increasing their weight from an average 305.4 to 443.8 kg $head^{-1}$, which corresponds to a total increase of 138.4 kg $head^{-1}$ during the entire grazing period. Animals under T2 increased their weight until May 2 from an original average of 305.6 to 424.6 kg $head^{-1}$, which corresponds to a total increase of 119 kg $head^{-1}$ for the entire grazing period. Animals under the T4 increased their weight until May 2 from an original average of 305.9 to 428.4 kg $head^{-1}$, corresponding to a total increase of 122.5 kg $head^{-1}$ during the entire grazing period. When weighed on May 2, the animals under the pure livestock system (T4) were beginning to lose weight, from an intermediate average of 437.5 to 428.4 kg $head^{-1}$, so it was decided to take these animals out of the system and end their evaluation with May 2.

Table 9: Variation in bovine weight 2005-2006 (average weight kg).

Treatment	12-15-2005	12-31-2005	01-16-2006	01-31-2006	02-15-2006	03-01-2006	03-15-2006	03-30-2006	04-17-2006	05-02-2006	05-24-2006
T2	305,6	318,9	341,0	359,4	370,9	382,5	386,6	402,6	419,1	424,6	413,4
T3	305,4	323,1	347,0	363,8	380,8	395,4	410,0	436,5	436,4	443,8	440,1
T4	305,9	317,3	341,4	360,6	385,0	402,4	401,8	426,0	437,5	428,4	-

This weight loss was due to the lack of forage at the end of May, as they had consumed practically all the available pasture in each of the areas, and to the natural growth of the grass, which at this time of year equals zero due to the low temperatures after mid May. This result coincides with the results presented by Feldhake (2001), who mentions that a possible protection by trees could help to extend the grazing period, both at its beginning and end, in regions where frost and low temperatures are common, which happened in T2 and T3.

Forestry Productivity and development

Diameter at breast height (DBH)

The development of the diameter with different treatments including trees is shown in Table 10.

Table 10: Diameter at breast height (DBH) of trees in different treatments at the beginning of the experiment, year 2004, and 2005 to 2006.

Treatment	DBH (cm)		
	2004	**2005**	**2006**
T1: Forestry management	12.72	13.55	14.77
T2: Traditional silvopastoral	12.90	14.21	15.96
T3: Strip silvopastoral	12.98	14.10	15.60

A clear difference in diameter at breast height can be observed between the different treatments applied in this experiment. At the beginning of the experiment all the treatments presented an average DBH of around 12.8 cm, but after two growth seasons a difference can be evidenced as a consequence of the different density applied in the models, leading to greater diameters in those models with fewer trees per hectare, i.e. silvopastoral, where the traditional silvopastoral system is slightly superior due to a lower individual competition situation.

Tree basal area (TBA)

In Table 11 the evolution of the tree basal area can be observed, indicating the site use by the different models. In this parameter the effects of density can be observed, as plantations were thinned from the original density of 1,514 (trees ha^{-1}) to the silvopastoral densities of 400 (trees ha^{-1}) and to 800 (trees ha^{-1}) in the case of the forestry management model.

Table 11: Evolution of basal area in the different experiments within San Gabriel farm, between years 2004 to 2006.

Treatment	BA (m^2 ha^{-1})		
	2004	**2005**	**2006**
T1: Forestry management	10.55	11.96	14.20
T2: Traditional silvopastoral	4.79	5.81	7.32
T3: Strip silvopastoral	5.44	6.40	8.31

In spite of each model having a different number of trees per hectare, it becomes apparent that this parameter has increased in all different systems. This is to say that in all treatments or densities there still a potential for growth, and competition between the individual trees is not too high. After a period of several years it is to be expected that the forestry management model, having more trees per hectare, will be the first showing a declining growth rate due to competition between trees after occupying the entire site.

On the other hand, the two silvopastoral models, having a lower tree density per hectare (400), should present a rather sustained increase of basal area.

Total tree height (H)

Tree height is a site quality index, and as the experiments all have been installed on a similar site, no significant variations in tree height can be observed (Table 12) when comparing the different treatment situations.

Table 12: Tree height of the different treatments in San Gabriel farm.

Treatment	Height (h) (m)		
	2004	**2005**	**2006**
T1: Forestry management	5.32	5.74	6.13
T2: Traditional silvopastoral	5.95	6.43	6.75
T3: Strip silvopastoral	5.64	6.12	6.54

Tree crown cover

The development of the tree crown cover, influenced by the tree competition, is showed in Table 13. Treatment T1 has greater crown cover than the silvopastoral treatments, but T2 has had the greater increment (49.5%) because trees have greater space for develop their crown and T3 the smaller increment (12%), due to the big competition in the tree growth space. Finally this cover of grassland by tree crown will have a decisive influence in the production of the prairie, due to light interception, and management of this factor will be the great challenge for prairie and animal production.

Table 13: Tree crown cover (%).

Treatment	Tree crown cover (%)		
	2004	2005	2006
T1: Forestry management	26.91	-	35.96
T2: Traditional silvopastoral	14.54	-	21.74
T3: Strip silvopastoral	24.19	-	27.10

CONCLUSIONS

Animal and prairie production

- In accordance with the results obtained in the two first evaluation seasons, an interesting development of the prairie component within the silvopastoral models with lower density could be observed. Prairie production in the case of the strip silvopastoral (T3) equalled 2,953 kg of dry matter, which is 45% above the pure livestock management model and 707 kg (11%) above the traditional agroforestry model.

- This result is directly related with the results obtained in the animal production component. As in the case of grass production, T3 showed the best results, with an average weight increase per animal in the season 2005-2006 of 138.4 kg/head, versus 122.5 in the pure livestock management model and 119.0 kg in T2.

- These results can be linked to the environmental benefits provided by the forestry component, such as the reduction of wind impact, the increase of air and soil temperature and the increase of relative moisture, all factors favouring vegetal growth. The trees themselves also have a positive impact on the animals, for the same reasons mentioned above, so they need less energy to regulate their body temperature, which coincides with the results obtained by Anderson et al. (1988), Sotomayor (1990) and Polla (1998).

Evaluation of the forestry component:

The combination of forestry management with silvopastoral purposes has a significant effect on the forestry variables.

- By reducing the density from 1,500 to 800 trees ha^{-1} in the forestry management area and 400 trees ha^{-1} in the different silvopastoral designs, the basal area as site use indicator per hectare is reduced drastically, but at the same time growth in diameter per tree is increased, and prairie production rises, which coincides with the results obtained by Polla (1998) and Sotomayor (1990). This means that there are fewer trees but with a higher diameter, which will in the future lead to trees with greater dimensions, meaning a higher productivity per tree for the production of saw-logs or veneer logs, but a lower production considering total volume per hectare.

- On the other hand, those models with a higher density generate a higher volume of solid timber, so they are rather designed for the production of wood biomass, especially the unmanaged plantations with its higher solid volume and lower wood quality. The forestry management model (T1) should obtain an interesting volume of clear wood and a major proportion of low-quality wood for industrial use such as pulp wood, firewood or fence-posts.

Analysis of the treatment results

After three years of evaluation and two seasons of measurements, a series of interesting results have been observed, indicating the actual possibility to apply silvopastoral models as a productive and economic alternative for farmers in the Chilean part of Patagonia. This coincides with the results of the studies carried out by Universidad Austral de Chile (1988) and Herve at al. (1990). As the results indicate, agroforestry models can provide the farmers with:

- Livestock production, by making use of the pasture growing between the tree rows or under the protection of a low-density plantation. This allows the farmers to have an annual income and to manage the land through innovative production systems.

- Forestry production, by including trees into the traditional livestock farming system, which allows the farmer to have another production alternative, achieving a certain diversification. Through managing the trees by thinning and pruning, logs of low dimensions can be obtained and be used as firewood, fence-posts, and medium size logs for sawn wood of small dimensions.

- Environmental benefits: integrating trees into the farming activities improve environmental aspects, like reduction of soil erosion, and protection of water streams and wildlife in the area.

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CHARACTERIZATIONS OF DISSOLVED ORGANIC MATTER IN SILVOPASTURE, PASTURE, AND FOREST LEACHATES

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Abstract: A major limitation to efficient forage-based livestock production in Appalachia is asynchrony of forage availability and quality with nutritional requirements of the grazer. Producers require dependable plant resources and management practices that improve the seasonal distribution and persistence of high quality herbage, sustainability, and environmental integrity of the agricultural landscape. Forests are one way to sequester carbon, but silvopasture also shows an ability to sequester carbon while also offering agricultural production benefits. Piezometers installed to the soil/bedrock interface in forest, pasture, and silvopasture were used to study the characteristics of dissolved organic carbon in leachate from each of the systems. There were no significant differences in mean concentrations of total dissolved carbon, dissolved organic carbon, or dissolved inorganic carbon between the land treatments. Excitation-emission matrix fluorescence spectroscopy identified five groups of organic matter compounds in the water samples: tyrosine-like, tryptophan-like, protein-like, fulvic-like, and humic-like. There was no significant difference in the relative fluorescence intensities of tyrosine-like, tryptophan-like, or humic-like substances in the three treatments. There were differences between treatments of the relative intensities of protein-like and fulvic-like substances. Both were greatest in the silvopasture leachates and least in the pasture leachates. Knowledge about the organic carbon cycling characteristics of each land treatment will benefit development of decision support tools.

Key Words: Dissolved organic matter, EEM, fluorescence, subsurface water.

INTRODUCTION

Efficient forage-based livestock production in Appalachia is limited by asynchrony of forage availability and quality with nutritional requirements of the grazer. Producers require dependable plant resources and management practices that improve the seasonal distribution and persistence of high quality herbage, sustainability, and environmental integrity of agricultural landscapes. Silvopastoral agroforestry systems are being investigated for potential production and environmental benefits on complicated landscapes common to the Appalachian region. Cycling of organic carbon in forested and agricultural landscapes is gaining in importance as we try to understand land use impacts on global carbon cycling. Knowledge about dissolved organic carbon (DOC) in soils and its transport through soils is important for understanding global carbon cycling, soil formation processes, and activities of soil microorganisms (Neff and Asner 2001; Jardine et al. 2006; Mertens et al. 2007). Leaching of dissolved carbon can represent a carbon fraction that is lost to the opportunity for sequestration by soil. DOC is associated with transport of nutrients, contaminants, and metals in soils (Qualls and Haines 1991; Mertens et al. 2007). Information about the mechanisms of DOC fluxes in soil is lacking. Neff and Asner

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(2001) suggested that forest ecosystems support larger DOC fluxes than grasslands and perhaps agricultural ecosystems. The opportunity for carbon sequestration in agroforestry systems is considered high among land use systems (Sanchez 1995; Robert 2001). Understanding the effects of land use management systems on carbon cycling is essential for understanding the potentials of such systems for storing carbon.

Field and model studies indicate that hydrologic and DOC fluxes are closely coupled (Neff and Asner 2001; Cooper et al. 2007; Mertens et al. 2007). The purpose of this study was to characterize dissolved organic matter leaching to the soil/bedrock interface in pasture, forest and silvopasture systems.

STUDY SITE AND METHODS

The study site is located in southern West Virginia at 37° 47' 39" N, 80° 58' 22" W (Fig. 1). The conventional pasture is composed primarily of orchard grass (*Dactylis glomerata* L.), Kentucky bluegrass (*Poa pratensis*), and white clover (*Trifolium alba*) and has been maintained as pasture for many years. The conventional pasture is surrounded by mixed hardwood forest, part of which was converted to silvopasture by thinning the primarily red oaks (*Quercus* sp.) and planting orchard grass, rye grass (*Lolium perenne* L.), and white clover. Four piezometers were installed to the soil/bedrock interface in each land use category (pasture, silvopasture, and forest). The pasture and silvopasture areas were rotationally grazed by sheep during the growing season. The lowest 30 cm of each piezometer was screened.

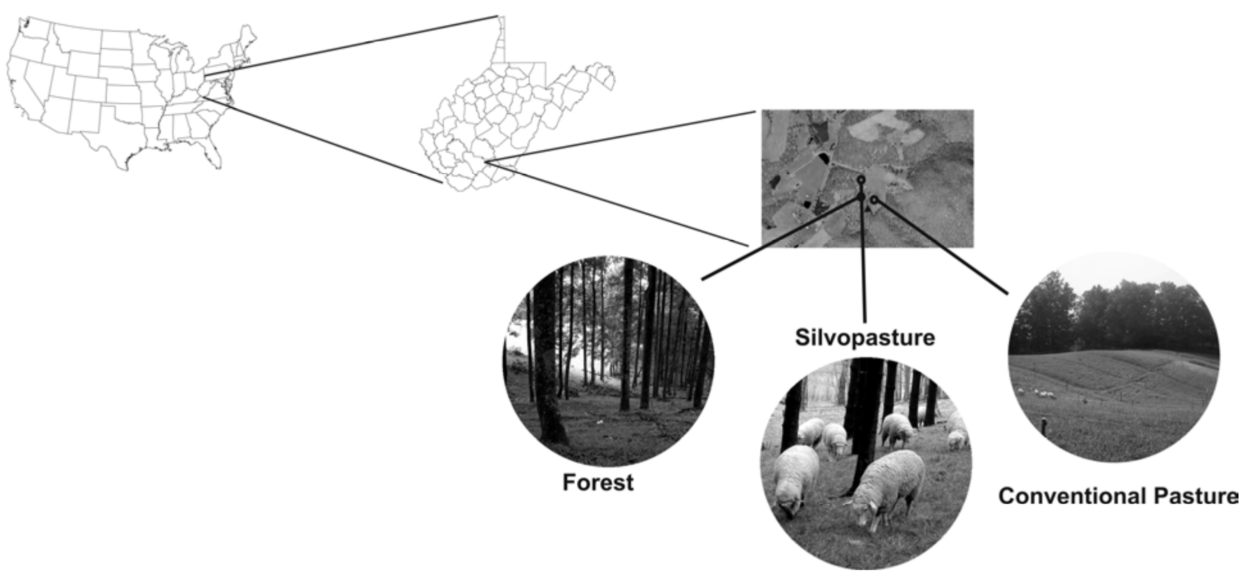

Fig. 1: Study location.

The piezometers were sampled immediately after each storm. The samples were filtered at 0.45 µm and analyzed for dissolved inorganic N (DIN) by suppressed ion chromatography and for total dissolved carbon (TC), dissolved organic carbon (DOC), and total dissolved N (TN) on a total organic carbon analyzer. Total dissolved inorganic carbon (DIC) was calculated as the difference between TC and DOC. Total dissolved organic N (DON) was determined as the difference between TN and DIN. The filtered water samples were also analyzed on a scanning spectrofluorophotometer to construct excitation/emission matrices (EEM) of sample fluorescence intensities. The scans were constructed at 2 nm wavelength intervals in the excitation range 220 to 585 nm and emission range 235 to 600 nm. An EEM of distilled, deionized water was subtracted from each sample EEM. Peak fluorescence intensities were recorded for each of five organic groupings (tyrosine-like, tryptophan-like, protein-like, fulvic-like, and humic-like) as shown by Baker (2002).

RESULTS

Table 1 lists the mean concentrations of TC, DOC, DIC, TN, DIN and DON for the three land use types. Analysis of variance failed to show any significant ($P < 0.1$) differences in mean TC, DOC, DIC, DIN, or TN between land uses. There were significant ($P < 0.1$) differences in mean DON between forest and pasture land uses. Leachate in the pasture had the highest DIN concentration (3.9 mg L^{-1}) and the lowest DON concentration (0.5 mg L^{-1}).

Table 1: Mean concentrations (mg L^{-1}) total dissolved C (TC), dissolved organic C (DIC), dissolved inorganic C (DIC), total dissolved N (TN), dissolved inorganic N (DIN), and dissolved organic N (DON) for the three land uses. Standard deviations are shown in parentheses.

C or N parameter	Pasture	Silvopasture	Forest
TC	33.3 (30.81)	36.1 (21.89)	33.8 (27.10)
DOC	12.4 (13.25)	14.6 (14.07)	19.1 (23.37)
DIC	20.9 (26.20)	22.0 (14.51)	14.7 (13.31)
TN	4.4 (2.90)	3.4 (4.05)	3.0 (4.09)
DIN	3.9 (3.04)	2.2 (3.36)	1.6 (2.35)
DON	0.5 (0.77)	1.2 (0.93)	1.4 (1.76)

The mean EEMs (Fig. 2, Fig. 3 and Fig. 4) for each of the three land uses showed differences in fluorescence properties. Mean peak fluorescence intensities were greatest in silvopasture for protein-like, fulvic-like and humic-like compounds (Fig. 5). Mean peak fluorescence intensity for tyrosine-like compounds was greatest in pasture leachates. No differences in mean peak fluorescence intensities were observed for tryptophan-like compounds.

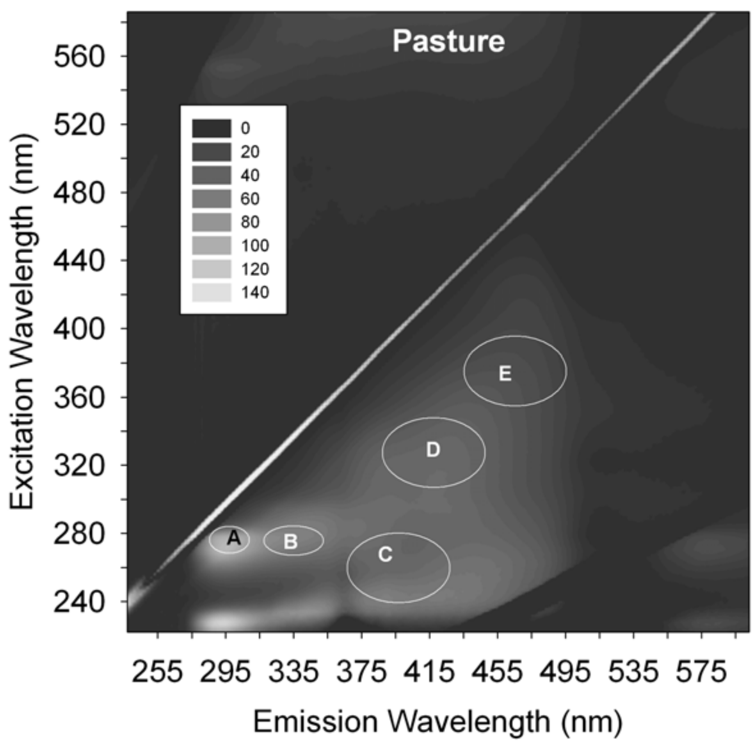

Fig: 2: Mean excitation/emission fluorescence spectra for the pasture leachates.

DISCUSSION AND SUMMARY

Although no statistical differences were observed in leachate concentrations of TC, DIC, or DOC between the three land uses the fluorescence character of the leachates from silvopasture were different from those of pasture and forest. Boyer and Neel (2006) reported that rainfall was percolating to the soil/bedrock interface more frequently and in greater volume in the silvopasture than the pasture or forest sites. The difference was presumably a result of macropore flow, coupled with an organic layer disturbed by animal grazing. Surface particles, such as fecal bacteria, were appearing in leachate at the soil/bedrock interface in greater densities in the silvopasture than in the forest or pasture (Boyer and Neel 2006).

The pasture area was presumed to not have as dense a network of large macropores as the forest or silvopasture areas since trees and tree roots have not been present in that area for many years.

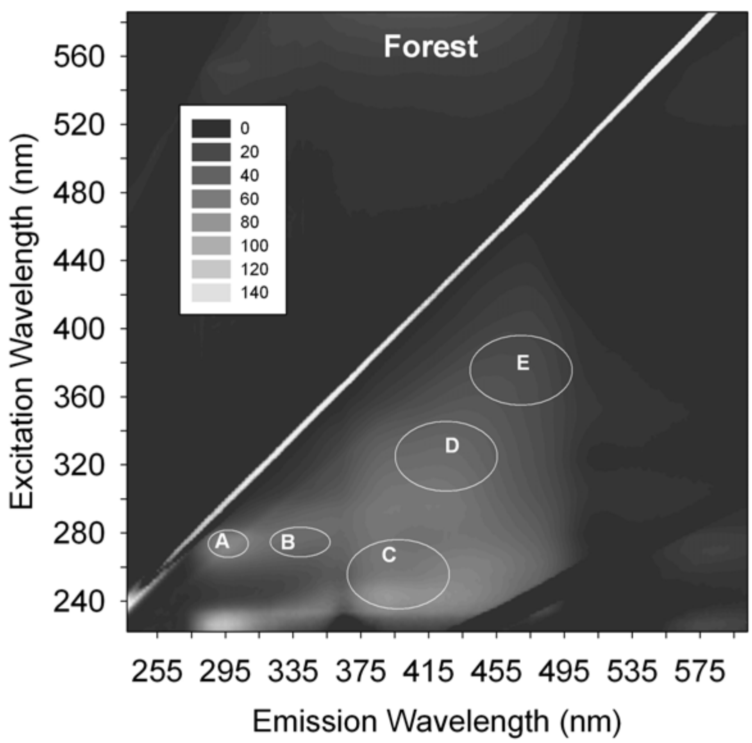

Fig. 3: Mean excitation/emission fluorescence spectra for the forest leachates.

The forest area responded infrequently and with low leachate volumes at the soil/bedrock interface, presumably because of the thick organic layer and shingling effect of recently fallen leaves. The differences in fluorescent properties of TC reaching the soil/bedrock interface are probably a result of the hydrologic response, amount of water interaction with surface organic and soil layers, and character of organic matter in the surface organic and soil layers. Further analysis with the parallel factor analysis (PARAFAC) described by Ohno and Bro (2006) might provide more information about the interactions of water and organic materials in the different land uses. Understanding the interactions between the hydrologic and carbon cycles in the different land uses will enhance our opportunities to maximize soil carbon sequestration. Carbon sequestration in agroforestry systems has already been identified as a promising ecosystem function (Sanchez 1995) and research such as that reported here will enhance the opportunity to develop management practices that maximize ecosystem functioning goals.

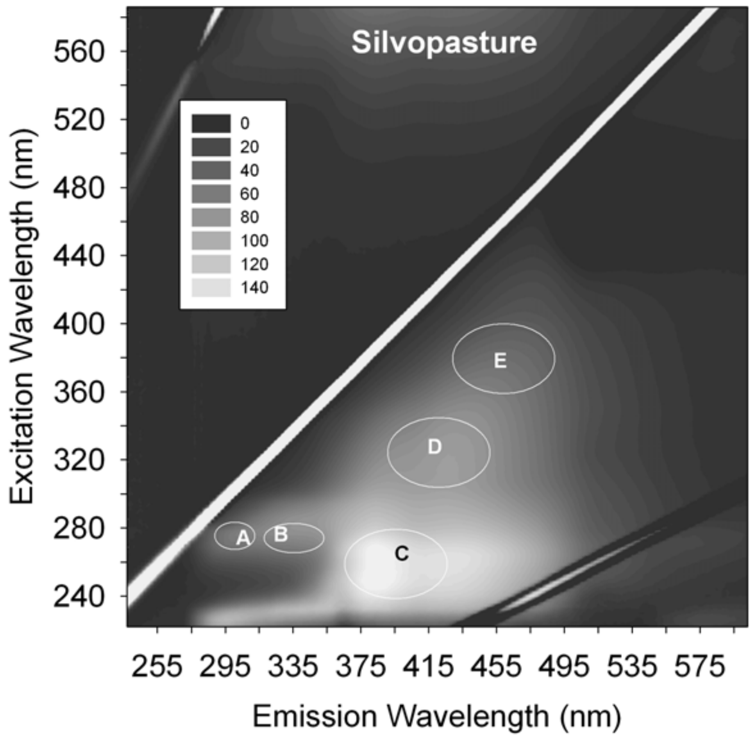

Fig. 4: Mean excitation/emission fluorescence spectra for the silvopasture leachates.

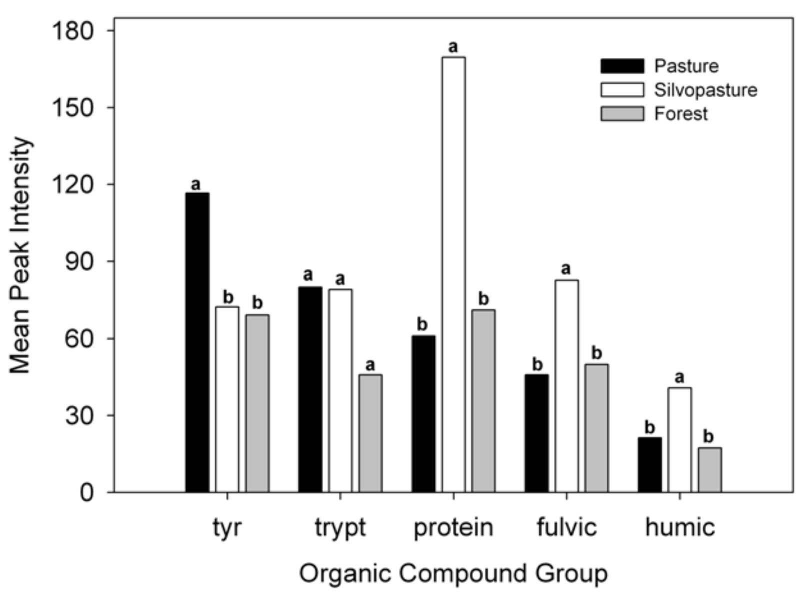

Fig. 5: Mean peak fluorescence intensities for tyrosine-like (tyr), tryptophan-like (trypt), protein-like, fulvic-like, and humic-like compounds in the three land use leachates. Bars with the same letter, in a group, are not significantly different ($P < 0.1$).

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SILVOPASTURE TREE ESTABLISHMENT AS AFFECTED BY THREE PASTURE GRASSES

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Abstract: Tall fescue (*Festuca arundinacea* Shreb.) is the predominant forage in the Midwest USA and it is known to inhibit silvopasture tree establishment. Little information is available on whether it affects tree growth more than other forage grasses and if endophyte status plays a role. We assessed the establishment of black walnut (*Juglans nigra* L.), red oak (*Quercus rubra* L.), and pitch X loblolly pine (*Pinus rigida* P. Mill. X taeda L.) when grown with seven ground covers (four tall fescue varieties differing in endophyte status, orchardgrass (*Dactylis glomerata* L.), Kentucky bluegrass (*Poa pratensis* L.), or bare soil). Four cultural management treatments (fertilization, irrigation, fertilization and irrigation, or nothing) were applied to the trees to determine if these inputs would alleviate growth inhibition. Black walnut and red oak tended to respond similarly to ground covers when averaged across cultural treatments. They grew best in bare soil, followed by Kentucky bluegrass. They grew poorest with orchardgrass and tall fescue, which affected growth similarly. Pitch X loblolly pine growth was not affected by ground cover. Tall fescue endophyte status had no affect on tree growth or response to cultural treatments. Irrigation or irrigation and fertilization tended to improve the growth of the trees in grass however, differences were not always significant. When applied to trees in bare soil, irrigation and fertilization tended to improve, although not significantly, growth of black walnut and red oak, while pine growth in bare soil was greatest when nothing was applied.

Key Words: Tall fescue, orchardgrass, Kentucky bluegrass, endophyte.

DRY MATTER PRODUCTION, NUTRITIVE VALUE, AND GRAZING ANIMAL RESPONSE TO HERBAGE GROWN IN OPEN AND HARDWOOD SILVOPASTURE

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Abstract: Most small farms in the Appalachian Region are made up of both open pasture and woodlots. A common problem in forage-based livestock production enterprises is the loss of forage quality and quantity during summer because of high temperature and low rainfall. Microsite conditions associated with woodlots can be used to improve distribution of forage availability, provide higher forage quality and possibly increase farm income. Dry matter production, nutritive value, and grazing animal response to herbage grown in open and hardwood silvopasture were evaluated. Silvopasture produced about 30% less dry matter per unit area than traditional open pasture. Silvopasture herbage in the vegetative state had more crude protein (CP), less nonstructural carbohydrate (TNC) and equivalent amounts of total digestible nutrients (TDN) when compared to open pasture. When herbage was more mature, silvopasture herbage had greater TDN. Herbage TDN:CP was below 5.0 during the entire grazing season for silvopasture, while below 5.0 only half of the time in open pasture. Lambs grazing open pasture or silvopasture had similar average daily gains, but blood urea nitrogen levels were greater in lambs grazing silvopasture. Silvopasture offers a means of increasing overall farm productivity, but additional information is needed to maximize nutrient utilization within the whole farm system.

Key Words: Silvopasture, herbage, nutritive value, dry matter, average daily gain.

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SECTION 5

Cultures sous couvert forestier et produits forestiers non ligneux

Forest Farming and Non-Timber Forest Products

KEYNOTE SPEAKER

GROWING AND MARKETING NATIVE FOREST BOTANICALS – CULTURE ET MISE EN MARCHÉ D'HERBES MÉDICINALES INDIGÈNES

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Abstract: Many of the plants used in the natural products industry are native to North American forests. With the exception of ginseng, however, most are collected from wild populations. As the demand for herbal products rises, the potential for damaging wild populations by over harvesting increases. The industry also has concerns over raw ingredient quality, consistency of supply, and species identification of wild harvested materials. The result is a rising demand for cultivated forest botanicals. This presents a new income opportunity for farmers and forest landowners, but entering the market can be challenging, and reliable and practical cultivation information is difficult to find and often not appropriate for a wide range of situations and locations. In response to an increasing awareness of the need to conserve these plants, the rising market demand, and a desire to develop new high value crops, about eighteen years ago I initiated studies on the propagation, production, economics, and marketing of a large number of forest botanicals. The results of some of these studies, the challenges and opportunities in producing and marketing these herbs, and a step by step approach to growing medicinal herbs are discussed here.

Key Words: Medicinal, herb, cultivation, woods.

INTRODUCTION

People have collected herbs from the forests of North America for generations. Traditionally, most of these herbs were primarily used by the family and within the local community. Ginseng was the major herb sold to provide supplemental income. During the past few decades, however, the demand for wild forest botanicals has increased as the public's interest in herbal medicine has risen. Although many of the herbs collected from our forests are abundant, a tabloid claim that one may cure cancer, reverse aging, or prevent AIDS could quickly cause a spike in demand that could severely reduce the populations of that particular species from our forests.

SOME NATIVE FOREST BOTANICALS THAT CAN BE CULTIVATED

Ginseng (*Panax quinquefolius*) is the most well-known and valuable of all the native forest botanicals. It is an herbaceous perennial with a fleshy root that sets a cluster of large red berries in late summer. Ginseng is indigenous to the forests of much of eastern Canada and the

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northeastern and mid-Atlantic United States and was once prevalent in some areas. It is a close relative of the native Asian ginseng (*Panax ginseng*) which has been used as a medicinal plant for thousands of years. The market demand is primarily for the dried root, although there is a small market for the fresh root and an even smaller market for the dried leaves. The active chemical constituents in ginseng are the ginsenosides, the amount and type of which varies between species of ginseng and depending on where and how the plants are grown. Ginseng is used to treat many medical conditions, as a general health tonic, and as a food. It is probably most often used to relieve stress and fatigue, enhance longevity, and increase fertility.

Ginseng is unusual because price is determined by how it is grown. Wild ginseng is the most valuable, but is also quite rare. High yields of ginseng root can be produced in three to four years under artificial shade, but the price per pound will be low. Ginseng grown in the woods, either in beds or in a wild simulated system, will be more valuable, but it will take seven years or more to mature and the yields will be less. Ginseng is not an easy crop to grow. It is vulnerable to a number of diseases, wildlife, and poaching. Ginseng is protected by international, national, and state laws. Of all the forest botanicals, ginseng has been under cultivation the longest.

Another native medicinal herb in high demand is goldenseal (*Hydrastis canadensis*). Like ginseng, goldenseal is an herbaceous perennial which grows in rich woods in the eastern United States and Canada. Goldenseal has an underground rhizome covered with fibrous roots, by which it readily spreads and is easily propagated. Both rhizome and roots have bright yellow interiors. The medicinal properties of goldenseal are attributed to alkaloids found throughout the plant, the major ones being hydrastine and berberine. The market is mostly for the rhizome and roots although there is a small market for leaves. Goldenseal has traditionally been used as a mouth and eye wash and is well known for its antiseptic properties. Many herbalists believe it has a synergistic effect when combined with other herbs. Goldenseal is protected by international, national, and in some cases, state laws. Although the majority of goldenseal is wild harvested, cultivation of the herb has increased steadily over the past fifteen years. Goldenseal was also cultivated in the early 1900's.

Bloodroot (*Sanguinaria canadensis)* is one of the first plants to emerge in the spring and has a thick underground rhizome with bright red sap. The rhizome has traditionally been used as a dye, to treat skin lesions, and to prevent tooth decay. The demand for bloodroot was low but steady for decades, and as a result, it has been almost exclusively wild harvested. Demand for bloodroot spiked suddenly in 2000 when a German company began using it as an appetite stimulant in cattle feed. Bloodroot is also being studied for the treatment of cancer. This demand resulted in some commercial cultivation, although it is still quite limited. The major alkaloid believed to be responsible for bloodroot's medicinal and anti-microbial properties is sanquinarine. Bloodroot is commonly propagated by rhizome cuttings and seed.

Black cohosh (*Actaea racemosa*) is an attractive plant with feathery foliage, tall spikes of white flowers, and a thick, knotty rhizome. The rhizome is commonly used as an alternative to hormone replacement therapy to treat unpleasant menopausal symptoms. It is in high demand, which is putting pressure on wide populations. There is some cultivation underway, particularly in Canada and Germany, but prices remain too low to interest many growers in North America. Black cohosh is most commonly propagated by rhizome cuttings, but may also be propagated by seed.

There are a large number of other woodland botanicals that are currently collected from the wild that can be cultivated. Examples include blue cohosh (*Caulophyllum thalictroides*), false unicorn (*Chamaelirium luteum*), mayapple (*Podophyllum peltatum)*, and wild ginger (*Asarum candense*). There is very limited information available on cultivation of these other botanicals.

PRODUCING FOREST BOTANICALS: A STEP BY STEP APPROACH

Step 1: Learn about the medicinal herb industry

Spend time reading about the industry, attending conferences and trade shows, and visiting growers and buyers. The medicinal herb industry is probably unlike any other industry you've been involved in before. You can't be a successful in this market if you don't take the time to learn about it. Several relevant books and websites are provided under References.

Step 2: Evaluate your resources and personal attributes

Take a serious, objective look at what resources you have already. For example, how much land do you have and what is it like? Do you have woods or open fields? Is the soil healthy and well drained or rocky and thin? What have you successfully produced on your land or what grows there naturally? Can you protect your crops from theft? What kind of equipment do you own? Also consider personal attributes, such as how much time, energy, and money do you have to put into this endeavor? And now is the time to start thinking about how you want to market your crop. Producing for the wholesale market versus producing for a direct market require very different approaches, personal strengths and personality, time, and volumes of product.

Step 3: Create a business plan

This is the least popular step in the process, but it is probably the most important. This is where you put it all down on paper and make sure that that your idea makes sense! Study enterprise budgets and plug in your own numbers. This is also the time to make the decision about whether you want to sell wholesale, retail, or make a value added product.

Step 4: Decide if you are going to produce organically or not

Before you even disturb the soil or plant a seed, you should decide if you are going to produce a certified organic crop or not. Certified organic herbs often command premium prices, but demand for volume is much less. Certified organic production requires extensive recordkeeping, annual inspections, and a higher level of management than a conventional production system does.

Step 5: Learn how to grow and market your herbs

Learn everything you can about how to grow and market native botanicals by reading books and websites, attending conferences, visiting growers and buyers, and communicating with agricultural specialists. I recommend that potential growers spend six months to a year on this step. During this time you will finalize what you are going to grow and how you intend to sell it. Most people think only about selling their herbs wholesale to a "big buyer". This may be appropriate for you, especially if you plan to grow large acreages of herbs. But you should also consider "adding value" to your herbs. This can be as simple as offering a variety of package sizes to your customers or you might want to go so far as to create your own tinctures, body care products, or tea blends. Whatever you choose to do, focus on producing a quality product.

Step 6: Grow your success

A major key to success is staying on top of the industry. Do this by continually networking with others, subscribing to major industry publications, and attending at least one annual tradeshow. Making your product stand out and getting it in front of buyers should be of utmost importance. Consider working with other growers to increase your market presence and ability to meet demand.

A SHORT PRIMER ON GROWING FOREST BOTANICALS

There are many fine publications providing detailed information on how to commercially produce ginseng and goldenseal. For the other herbs, however, most of the information available is more appropriate to a gardener than a commercial grower. Here are some basic principles of production that are appropriate for most forest botanicals. But, you should always read everything you can find on the herb you want to produce and expect to make minor adjustments, such as in level of shade or soil moisture, to accommodate the different plants.

Site selection

Proper site selection is critical for successful cultivation of forest botanicals. All of the plants mentioned in this article grow well under 75% to 80% shade provided by a deciduous forest, mixed deciduous and pine forest, or artificial shade structure. Most of these herbs require a moist, well-drained soil. If using a forest site, look for other woodland botanicals; if you see bloodroot, mayapple, and trillium growing on a site, your cultivated botanicals will also probably grow there.

Soils

Many woodland botanicals will tolerate a variety of soil types, although in general, heavy clays and very sandy soils should be avoided. An ideal soil is usually a silty loam with high organic matter. Collect soil samples from prospective sites and have them analyzed for nutritional status. Follow recommendations for ginseng or native ornamentals, using the lower end of the fertilizer range. Most of these plants prefer a soil pH of 5.5 to 6.0.

Shade

The most economical way to provide shade is to use the natural forest canopy. Deeply rooted deciduous trees such as walnut, oak, poplar, and basswood are good. Solid stands of conifers or other shallow rooted trees compete too much for water and nutrients. Remove undergrowth, such as rhododendrons, and weeds, which will also compete with the herbs and reduce air circulation. Although the natural forest is the most economical, most herbs grow faster in a good field soil under an artificial shade structure. There are several ways to provide artificial shade. Wood lath and polypropylene shade cloth are the most commonly used materials. Shade structures should be seven to nine feet tall to permit good air circulation. Heavy cable usually supports the cloth. Make sure that the shade covering extends beyond the planted areas, especially on the south and west sides, so the margins of the plantings will not receive excessive light.

Different production systems

When planting under a shade structure, start preparing the field months before planting by growing a cover crop, controlling the weeds, and then tilling under the cover crop. Make raised beds to promote good drainage and prepare the soil as for any seed bed. For natural sites, you have to decide what intensity of cultivation you want to use, wild-simulated or woods cultivated. In a wild simulated production system, your goal is to mimic what happens naturally as much as possible. This is a low-input system that produces plants that are very similar to wild harvested plants. A wild simulated system usually produces the lowest yields, but in the case of ginseng, produces plants of the highest value. For wild-simulated production, rake the leaf litter and top layer of soil aside, scatter the seed or plant the rootstock, and redistribute the soil and leaves over the planted area. Ginseng growers will often sprinkle a little gypsum on the soil, too. Expect a fairly large percentage of seed to be lost to rodents, disease, and desiccation. To make management easier, plant in defined areas so you aren't always walking through your planted areas. A woods cultivated system requires more inputs than a wild simulated system, but as a result, usually produces higher yields. In the case of ginseng, however, the roots will be worth less on a weight basis. For woods cultivation remove all obstructions such as stumps, rocks, and big roots. Till the soil, incorporate soil amendments, and if possible, build raised beds. Sow seed or plant rootstock, and cover with a good layer of mulch. Regular fertilizer and pest control programs are usually implemented in woods cultivated and artificial shade systems.

Seed and rootstock

Obtain the highest quality seed or planting stock that you can find. Make sure that the plants you purchase are obtained legally. Learn about the stratification requirements for seeds and chilling requirements for roots for each kind of plant you want to produce.

Diseases and pests

Many of these botanicals are rarely bothered by disease when grown in a garden setting. As plant populations and intensity of production increase, disease pressure often rises, too. Ginseng, however, tends to get all kinds of diseases whenever more than just a few plants are cultivated together. With the exception of ginseng, there is little information on diseases, disease control, or registered products to apply to prevent or control disease. Prevention is usually the best method for controlling disease. Select a site with good air and soil drainage. Establish small plantings in several locations and avoid overcrowding of plants. Insects are rarely a problem, but you should know what might be a threat and regularly scout your plantings looking for damage. Rodents, deer, and turkeys might also enjoy your botanicals and fencing and other deterrents might be required to prevent damage. Traps, baits, and cats are frequently used to keep down populations of rates, mice, and voles.

Seed collection

All of the forest botanicals must grow for several years before they reach harvestable size. During these growing years, seeds can often be collected and sown in another area or sold. Many of these seeds have exacting germination requirements and may require a stratification period.

Harvest and post-harvest handling

When it is time to harvest, carefully dig the roots to minimize root injury. Spades or forks can be used for small plantings and large tractor mounted diggers, similar to potato diggers, can be used for large plantings. Roots must be carefully washed and dried and properly packaged and stored. Consider having your herbs tested for bioactive constituents, heavy metals, pesticides, and microbial contaminants. For some buyers, this will add value to your product.

RESEARCH ON FOREST BOTANICALS

Most people can grow a few ginseng and goldenseal plants in the woods; that is not difficult. The problems arise when you try to make it a profitable enterprise. What works successfully in a hobby garden is often too costly to do on a commercial scale. My research has had two objectives. One is to help conserve native plant populations by making a high quality, reliable source of cultivated material available to the market. The other is to create new income opportunities for forest land owners. To that end, I have conducted studies on a number of woodland botanicals over the course of almost twenty years.

The earliest studies were on goldenseal and its response to various soil factors (Davis 1996). In one of these studies, goldenseal growth and alkaloid content reacted dramatically to changes in soil pH. Root growth increased as soil pH decreased. Unfortunately, root alkaloids levels responded oppositely. We concluded that a soil pH of between 5.5 and 6.0 would result in the highest yields of roots with high alkaloids. We also found that goldenseal plant survival and root yields decreased as soil nitrogen rate increased. Phosphorus reduced plant survival, but had no effect on root yields. Increasing soil calcium had a negative effect on goldenseal, reducing root growth and alkaloid content and increasing the incidence of foliar diseases (Davis 2003). In another study, we found that goldenseal grew best with bark and sawdust mulches whereas using straw mulch reduced yields and resulted in high levels of disease and extensive slug damage. In a shade study, the best combination of root and alkaloid yield was obtained with 63% shade. In propagation studies we found that it is important to have a large number of fibrous roots on the rhizome propagules. Goldenseal seed can be difficult to germinate and often doesn't emerge until the second spring after sowing. We found that the highest germination rates the first spring after sowing seed were obtained when the seed was sown outdoors as soon after collection from the plant as possible. Studies have continued on propagation, slug control, and the influence of various factors on alkaloid content. In new collaborative research with microbiologists, we are studying goldenseal medicinal properties and how they are influenced by how the plant is grown, handled, and its genetic makeup.

Bloodroot is another plant that, in cooperation with other researchers, we have studied extensively. A recent paper describes variability in yield of alkaloids in wild harvested and cultivated bloodroot (Graf et al. 2007). At this writing, a graduate student was preparing her thesis on bloodroot root bud response to chilling and bloodroot propagation. We also have studies on seed propagation, tillage systems, and companion planting with other woodland botanicals (Persons and Davis 2005).

Black cohosh was the subject of a Ph.D. dissertation at Clemson University in partnership with North Carolina State University (McCoy 2004). Studies focused on propagation in the forest and under artificial shade (McCoy et al. 2007). I have continued studies on black cohosh looking at commercial production methods, companion planting with other woodland botanicals, disease, and growth greenhouse systems (unpublished).

The biggest challenge to conducting research on these plants is finding funding that is long term enough to bring the study to conclusion. Most grants have a two to three year limit on the length of the project, but most forest botanicals require three to seven years to bring a study to completion. We know so little about these plants, too, that a very large number of studies need to be conducted on soil fertility, plant populations, propagation, pest control, and post-harvest handling, to name just a few.

I'm convinced that the future for forest botanicals is bright. Like all new enterprises, however, there will be some successes and many failures. This is true for the research and for the industry. Many growers will become discouraged, but there are already some who are quite successful.

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KEYNOTE SPEAKER

INCORPORATING SPECIALTY (NON-TIMBER) FOREST PRODUCTS INTO AGROFORESTRY SYSTEMS IN EASTERN CANADA
–
INTÉGRATION DE PRODUITS FORESTIERS NON LIGNEUX AU SEIN DE SYSTÈMES AGROFORESTIERS DANS L'EST DU CANADA

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Abstract: The forests of eastern Canada are a rich source of biodiversity. However, our uses of the forest are not as varied as the biodiversity within them. While most landowners would probably agree that our forests should be managed for multiple values and in many cases multiple 'products', developing the potential social, economic, and other benefits associated with extensive utilization of local biodiversity represents both an opportunity and a significant challenge. In reality, harvesting and processing 'traditional' wood products (i.e., pulp and sawlogs) have, and continue to be, the backbone of the economy for many rural communities.

Comprising commercial products from hundreds of species and plant parts, the direct and indirect economic value of Specialty Forest Products (SFPs) aka 'Non-timber Forest Products' (NTFPs) in eastern Canada and the northeastern United States is in the many tens of millions of dollars annually. Nevertheless, the level of harvesting and processing of any 'single' SFP cannot match wood fiber harvesting in total dollar value if the comparison is made only at the commodity level. Consequently, trying to justify managing for SFPs by comparing them to timber values using a conventional single product (or commodity) at a time economic model is destined to fail. However, specialty forest products do not have to be regarded as being 'economic second class citizens' – i.e., less important than timber. On the contrary, it is the analysis by which NTFPs are assessed and managed that needs to be changed to more accurately gauge their true economic potential. For example, such analysis might show that, compared to one-commodity systems, agro-forestry systems offer the flexibility to accommodate the production of both trees and SFPs profitably.

The goals of this presentation will be: A) to provide a brief introduction to the variety of SFPs being harvested in northeastern temperate forests, B) to describe, for selected SFPs, the method(s) of harvesting and scale of production, and C) to suggest how different agro-forestry systems can be used for the production of SFPs, as well as their potential for enhancing and diversifying the economy of rural communities. The focus throughout this presentation will be on using agro-forestry systems to manage for multiple values and multiple products.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

There is significant potential to capitalize on the experience and success of cooperatives for managing SFPs. Options for using a cooperative approach to creating an environment favorable for generating new and innovative products and services from our forests will be discussed.

Résumé : Les forêts de l'est du Canada accueillent une grande biodiversité. Toutefois, les utilisations que l'on en fait ne sont pas aussi variées. Plusieurs propriétaires fonciers s'entendent sur le fait que nos forêts devraient accueillir divers types d'exploitation et que nous devrions développer plusieurs types de produit. Cependant, le développement du potentiel social et économique et l'exploitation d'autres avantages reliés à l'utilisation à grande échelle de la biodiversité représentent une occasion à saisir et un important défi à surmonter. En effet, la récolte et la transformation de produits du bois (c.-à-d., la pulpe et les billots de sciage) ont formé la base de l'économie de plusieurs communautés rurales et continuent de l'être.

Englobant divers produits commerciaux issus de centaines d'espèces de plante et de parties de plante, la valeur économique directe et indirecte de produits forestiers non ligneux dans l'est du Canada et dans le nord-est des États-Unis représente un chiffre d'affaires de plusieurs dizaines de millions annuellement. Néanmoins, le niveau de récolte et de transformation d'un seul produit forestier non ligneux n'atteint par celui de la fibre ligneuse sur le plan des produits de base. En conséquence, toute tentative de justifier l'exploitation de produits forestiers non ligneux en la comparant à la valeur du bois sur pied à partir d'un seul produit de base et d'un modèle économique limité dans le temps est vouée à l'échec. Toutefois, les produits forestiers non ligneux n'ont pas à être considérés comme des citoyens de seconde zone, c'.-à-d. de moindre importance par rapport à la fibre ligneuse. Nous devons plutôt modifier le processus d'évaluation et de gestion des produits forestiers non ligneux afin de mieux saisir leur potentiel économique. Ainsi, une telle analyse pourrait démontrer que, comparée aux systèmes fondés sur un produit de base, l'agroforesterie est suffisamment flexible pour intégrer une production rentable de produits ligneux et non ligneux.

Cette présentation vise a) à tracer le portrait de divers produits forestiers non ligneux qui font l'objet actuellement d'exploitation dans les forêts tempérées du nord-est, b) à décrire les méthodes d'exploitation et l'échelle de production de ces produits et c) à proposer divers systèmes agroforestiers pouvant servir à l'exploitation de produits forestiers non ligneux, et à présenter leur potentiel d'amélioration et de diversification de l'économie des communautés rurales. Nous nous concentrerons sur l'utilisation de systèmes agroforestiers pour exploiter plusieurs ressources et plusieurs produits.

Il y a moyen de tirer profit de l'expérience des coopératives de gestion des produits forestiers non ligneux et de leurs succès. Nous discuterons des options d'une stratégie coopérative pour mettre en place un environnement favorable à la création de nouveaux produits et services avant-gardistes à partir de l'exploitation de nos forêts.

L'AMÉNAGEMENT DE BLEUETIÈRES EN MILIEU FORESTIER : UNE APPROCHE AGROFORESTIÈRE NOVATRICE

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Résumé : Les producteurs de bleuets (*Vaccinium* sp.) du Québec ont demandé au ministère des Ressources naturelles et de la Faune (MRNF) d'attribuer des terres pour l'aménagement de nouvelles bleuetières. Des terres propices à cette culture se situent sur des territoires publics grevés de droits forestiers qui restreignent, par le fait même, l'aménagement de bleuetières. Il fallait trouver une manière d'aménager des bleuetières et respecter les droits forestiers consentis.

La Corporation d'aménagement Forêt Normandin (CAFN) développe et expérimente depuis quelques années, en partenariat avec la Compagnie Abitibi-Consolidated du Canada, une approche novatrice d'aménagement de bleuetières par bandes en milieu forestier. Partant de cette initiative, le MRNF a convenu que l'aménagement des bleuetières par bandes, d'une largeur de 60 mètres, en alternance avec des bandes forestières de 42 mètres aménagées intensivement, constituait une avenue intéressante en matière de cohabitation. L'aménagement forestier intensif dans les bandes forestières compenserait la perte de production forestière des bandes aménagées en bleuetière et concourrait au respect des droits forestiers consentis.

Ce modèle de bleuetières de type forêt/bleuet serait avantageux tant sur le plan environnemental et social qu'économique :

- Cette approche rend accessibles des territoires actuellement sous aménagement forestier et qui sont propices à la culture du bleuet;
- Les bandes forestières protègeraient les sols contre l'érosion éolienne et les bleuetiers contre le gel, favoriseraient la pollinisation des fleurs, atténueraient les impacts sur la faune, etc.

Les travaux de recherche permettront de documenter ces divers aspects.

Mots-clés : Agroforesterie, bleuet, bleuetière, *Vaccinium*, cohabitation, aménagement forestier intégré, recherche, forêt/bleuet

Abstract : Québec's blueberry (*Vaccinium* sp.) producers asked the Ministère des Ressources naturelles et de la Faune (MRNF) to allocate land for the development of new blueberry fields. Many areas suitable for blueberry production are located in publicly-owned areas over which forestry rights (necessarily limiting blueberry field development) have already been granted. It was therefore necessary to find a way of developing blueberry fields while upholding the rights already granted to the forestry companies.

In recent years, the Normandin Forest Development Corporation (NFDC), in partnership with the forest company Abitibi-Consolidated of Canada, has devised and tested an innovative blueberry

field strip development concept suitable for use in forests. Based on their initiative, the MRNF has agreed on the potential interest of a multiple use approach involving the development of 60-metre blueberry field strips alternating with intensively managed 42-metre forest strips. Intensive management of the forest strips would compensate for the lost timber production in the blueberry strips, thereby ensuring that the previously-granted forestry rights are respected.

The forest/blueberry approach might offer a number of environmental, social and economic advantages.

- It releases land suitable for blueberry production but currently under forest management;
- Among other things, the forest strips protect the soil from wind erosion, shelter the blueberry flowers and fruit from frost, and foster pollination of the flowers.

The research will provide documentation on these various aspects.

Key Words: Agroforestry, blueberry, blueberry field, *Vaccinium*, cohabitation, integrated forest management, research, forest/blueberry.

INTRODUCTION

En 2000, à l'occasion de la commission parlementaire sur la révision du régime forestier québécois, les représentants du Syndicat des producteurs de bleuets du Québec (SPBQ) précisaient que le développement de l'industrie du bleuet passait nécessairement par l'aménagement de nouvelles bleuetières sur les terres du domaine de l'État. Formé à la demande du ministre, le *Comité interministériel (MRNF-MAPAQ) sur la contribution des terres du domaine de l'État au développement de l'industrie du bleuet* s'est penché sur les demandes du SPBQ visant à accroître la contribution des terres du domaine de l'État à la production de bleuets nains sauvages (*Vaccinium angustifolium* Ait. et *Vaccinium myrtilloides* Michx.).

La valeur des livraisons annuelles de l'industrie québécoise du bleuet varie selon les prix du marché et a été de l'ordre de 60 M$ en 2005. Plus de 98 % de la production québécoise de bleuets est vendue sous forme congelée. En saison, 2 % de la récolte est écoulée en produits frais, en grande majorité au Québec. Le bleuet congelé est vendu à des entreprises agroalimentaires pour la fabrication de gâteaux, pâtisserie, yogourt, confitures, etc. Les bleuets sauvages congelés sont écoulés sur le marché canadien et international, soit environ 1/4 au Canada, 1/4 aux États-Unis et 1/2 dans le reste du monde (Europe et Asie). À l'échelle du continent nord-américain, le Québec a produit et mis en marché en moyenne, entre 2004 et 2006, près de 30 % (24,2 millions de kilogrammes en 2005) de la production nord-américaine de bleuets nains sauvages (80,3 millions de kilogrammes en 2005). La région du Saguenay–Lac-Saint-Jean produit à elle seule 95 % de la production du Québec.

Tableau 1 : Répartition des superficies (en hectares) aménagées en bleuetière par région administrative du Québec – état de la situation en 2005

Régions administratives	Superficie totale aménagée	Superficie sur les terres privées	Superficie sur les terres du domaine de l'État
Gaspésie–Îles-de-la-Madeleine	120	0	120
Saguenay–Lac-Saint-Jean	19 600	6 157	13 443
Capitale-Nationale	218	218	0
Abitibi-Témiscamingue et Nord-du-Québec	630	64	566
Côte-Nord	1 568	186	1 382
Bas-Saint-Laurent	72	58	14
Chaudière-Appalaches	160	160	0
TOTAL	**22 368**	**6 843**	**15 525**

Source : Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ, avril 2007)

À LA RECHERCHE DE SOLUTIONS

Les forêts du domaine de l'État couvrent 90 % des forêts du Québec. Les terres privées propices à la culture du bleuet sont en grande partie déjà aménagées en bleuetière. La demande pour obtenir des baux de location à des fins de production du bleuet sur les terres publiques est en croissance. L'État a déjà consenti de nombreux droits sur les terres publiques propices à la culture du bleuet, en l'occurrence des droits forestiers, aux industriels forestiers pour l'approvisionnement de leurs usines de transformation du bois. Ces droits forestiers connus sous le nom de contrats d'approvisionnement et d'aménagement forestier (CAAF) couvrent des territoires propices à l'aménagement de bleuetières. Dans un contexte où ces territoires forestiers font l'objet d'importants investissements en sylviculture pour la production de matière ligneuse, il fallait trouver une façon d'aménager de nouvelles bleuetières sur ces territoires tout en respectant les droits forestiers (CAAF) consentis par l'État.

C'est dans ce contexte que la Corporation d'aménagement Forêt Normandin (CAFN) a développé une approche agroforestière novatrice pour aménager des bleuetières en milieu forestier public, dans le respect des droits consentis aux industriels forestiers. La CAFN, en partenariat avec la Compagnie Abitibi-Consolidated du Canada (détenteur de droits forestiers), planifie et réalise les activités d'aménagement sur le territoire de la Forêt Normandin (4 500 ha) située sur des terres publiques de la région du Saguenay–Lac-Saint-Jean.

UNE APPROCHE NOVATRICE : LES BLEUETIÈRES DE TYPE FORÊT/BLEUET

La CAFN expérimente depuis 1998 différentes approches de cohabitation pour la production combinée de matière ligneuse et de bleuets. Divers essais ont été tentés, y compris la culture du bleuet sous couvert forestier.

L'approche qui permet d'optimiser la production des deux ressources s'est avérée être l'aménagement de bleuetières en bandes alternées de type forêt/bleuet. Ces bleuetières sont composées de bandes en bleuetières de 60 mètres de largeur qui alternent avec des bandes forestières d'environ 42 mètres de largeur aménagés intensivement pour la production de matière ligneuse (Fig. 1). Lorsqu'il est comparé à une forêt naturelle, l'aménagement forestier intensif dans ces bandes compense la perte de production forestière des bandes aménagées en bleuetière, et ce faisant, concourt au respect des droits forestiers consentis.

Fig. 1 : Vue aérienne oblique d'une bleuetière de type forêt/bleuet. Photo : Compagnie Abitibi-Consolidated du Canada

Le comité interministériel a recommandé l'application de cette nouvelle approche sur les terres du domaine de l'État sous contrat d'aménagement forestier. Depuis 2005, près de 1 700 ha de bleuetières de type forêt/bleuet sont aménagés ou en voie de l'être. Le MRNF prévoit que d'ici 2009 il y aura environ 5 000 ha de ces bleuetières en territoire sous aménagement forestier.

Les avantages de l'approche : la complémentarité des cultures

Cette démarche de cohabitation s'inscrit dans une approche de gestion et d'aménagement intégré des ressources où l'on maximise le rendement des deux ressources « bois et bleuet » sur une même unité de surface. L'impact sur la possibilité forestière de l'aménagement de superficie en bleuetières serait compensé par l'aménagement forestier intensif réalisé dans les bandes forestières. Cette formule présente l'avantage de donner accès à des territoires sous aménagement forestier pour le développement de nouvelles bleuetières dans le respect des droits forestiers consentis. Les gains économiques de cette approche proviennent essentiellement de la production des bleuets et de leur transformation qui s'ajoute à celle de la matière ligneuse. En fait, la production de bleuet s'ajoute à la production de matière ligneuse qui est maintenue.

Cette approche présenterait d'autres avantages qui seront documentés avec les travaux de recherche. Les bandes forestières agissent comme régulateur de température. L'effet radiant de ces bandes contribuerait à la protection des bleuetières contre les gels tardifs des fleurs au printemps et les gels hâtifs des fruits à l'automne. Les bandes forestières agissent également comme brise-vent. Elles favorisent l'accumulation de neige au sol et protègent le bleuetier contre les gels hivernaux intenses. Les risques d'érosion éolienne des sols sablonneux sont considérablement réduits comparativement à ce qui est observé dans les vastes bleuetières de type traditionnel d'un seul tenant. La présence d'insectes pollinisateurs pour la fécondation des fleurs serait accrue. Comparativement aux bleuetières de type traditionnel de vaste superficie, celles de type forêt/bleuet auraient moins d'incidence sur la faune et les habitats fauniques. Il y a aussi une meilleure acceptation sociale de ces aménagements qui s'intègrent mieux au paysage rural.

Les inconforts de l'approche : la cohabitation

La cohabitation de ces deux productions nécessite l'établissement de mesures d'harmonisation entre les bénéficiaires de droits forestiers et les producteurs de bleuets. À l'étape de la planification des travaux d'aménagement, ils doivent convenir de la localisation des bandes à aménager en bleuetière. Au moment de la réalisation des travaux de récolte des arbres, généralement exécutés par les bénéficiaires des droits forestiers, il est nécessaire de convenir des techniques de récolte des bois ainsi que du type de machinerie utilisé pour protéger le plant de bleuetier à cultiver.

LA CULTURE DU BLEUET

L'aménagement des bleuetières se fait sur des emplacements où le bleuetier (*Vaccinium* sp.) est déjà présent naturellement et où le relief est assez plat avec un sol de pierrosité faible. Les techniques culturales visent donc à déboiser le terrain de manière à stimuler le développement du rhizome du bleuetier en place et à favoriser sa propagation, car il a besoin de lumière pour se développer et pour produire des fruits en abondance. Au moment du déboisement, il s'agit d'effectuer l'abattage et le débardage des arbres commerciaux de manière à protéger les rhizomes du bleuetier sauvage.

Après le déboisement, le passage d'une faucheuse (broyeur forestier) permet d'éliminer les souches, les résidus forestiers et les arbustes. Un herbicide est ensuite appliqué pour éliminer les plantes compétitrices du bleuetier. À ce stade, les bleuetières sont dites en phase d'aménagement.

Une première récolte, modeste, est généralement effectuée trois ans après le déboisement. Il faut compter de sept à huit ans avant d'atteindre les rendements optimums d'une bleuetière. D'autres travaux culturaux sont effectués pour obtenir de bons rendements, comme la fertilisation, le désherbage et la pollinisation. Le contrôle des plantes compétitrices est également nécessaire et essentiel pour atteindre des rendements intéressants et rentabiliser la production de bleuets. Une fois l'aménagement de la bleuetière terminé, celle-ci est exploitée selon un cycle de deux à trois ans, c'est-à-dire une année en végétation (année où le plant se régénère) et une ou deux années de récolte. Ce stade est maintenu par une taille des plants effectuée par un fauchage ras aux deux ou trois ans. Bon an mal an, la production moyenne des bleuetières du Québec est d'environ 1 600 kg/ha/an.

LA RECHERCHE

La Corporation d'aménagement Forêt Normandin (CAFN) s'est vue attribuer un bail de location pour poursuivre les travaux de recherche en vue de documenter cette approche de cohabitation. Le projet de recherche, mené conjointement par la CAFN, Agrinova et l'Agence de gestion intégrée des ressources (AGIR), est dirigé par l'équipe d'Agrinova. Commencé en 2005-2006, le projet se développe sur une portion (450 ha) du territoire de la Forêt Normandin. Le territoire du projet englobe également des bleuetières de type forêt/bleuet aménagées depuis 1999. Les premiers résultats sur les rendements forestiers et agricoles de cette approche devraient être diffusés au cours des prochaines années. Le projet a pour but de valider et d'optimiser le modèle de bleuetière de type forêt/bleuet en bandes alternées. Ainsi, les dispositifs de recherche sur le terrain vont permettre de comparer les résultats obtenus selon une diversité de largeurs de bandes forêt/bleuet. Le projet couvre les quatre principaux axes de recherche suivants :

1. **L'optimisation forestière** : Cet aspect vise à comparer les rendements forestiers, la qualité des bois et la valeur ajoutée des produits du bois. L'importance du phénomène du chablis dans les bandes forestières est également évaluée.

2. **L'optimisation agricole** : Le couvert aurait un effet sur le microclimat à proximité des bleuetières. Diverses analyses seront faites sur cet aspect, notamment l'effet radiant du couvert forestier agissant comme régulateur de la température. Ce phénomène thermique pourrait contribuer à protéger les fleurs et les fruits contre des gels tardifs au printemps ou précoces à l'automne. Les rendements en bleuets seront analysés selon les divers dispositifs de largeur (Fig. 2) et d'orientation des bandes qui influencent les conditions agroclimatiques (température, humidité, couverture nivale).

Fig. 2 : Bleuetière de type forêt/bleuet (bande expérimentale de la bleuetière de 15 mètres de largeur). Photo : Corporation d'aménagement Forêt Normandin (CAFN)

3. **Les impacts environnementaux** : Les impacts de tels modes de cultures mixtes d'aménagement sur la faune et son habitat seront documentés. De plus, des suivis seront faits sur les pesticides utilisés pour la culture du bleuet et, le cas échéant, des solutions seront proposées pour en réduire l'utilisation.

4. **Optimisation des facteurs de production** : Ce volet porte sur quelques phases critiques et spécifiques de la production de bleuets, notamment l'impact du modèle forêt/bleuet sur la population d'insectes butineurs responsables de la mise en fruit du bleuetier et l'utilisation des résidus forestiers pour réduire la compétition d'autres plantes indigènes.

CONCLUSION

L'approche d'aménagement des bleuetières de type forêt/bleuet a émergé d'une situation problématique où l'on voulait cultiver du bleuet sauvage sur un territoire grevé de droits forestiers. Cette approche s'annonce très avantageuse sur plusieurs plans :

- Elle ajoute à la production de matière ligneuse une production supplémentaire de bleuets.
- Elle favorise le développement de l'industrie du bleuet sans nuire à celui de l'industrie forestière.
- Les bandes forestières pourraient jouer un rôle important pour la production et la protection des cultures de bleuets.
- L'impact sur la faune de l'aménagement de bleuetières de type forêt/bleuet devrait être fortement atténué en comparaison de celui de bleuetières de type traditionnel.

Les travaux de recherche en cours devraient apporter des réponses à plusieurs de nos interrogations et, au besoin, améliorer le modèle des bleuetières de type forêt/bleuet.

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FROM TINDER TO TRUFFLES: FUNGI IN THE NTFP – AGROFORESTRY CONTINUUM

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Abstract: Hundreds of species of fungi are collected, consumed, and traded worldwide. The historic use of wild fungi has been documented by archaeological record back 13,000 years in Chile and by written record in China for over 2000 years. Wild fungi are used for food, medicine, ceremonial and utilitarian purposes such as fire starter, smudge, styptic, and dye. Currently, the uses of fungi range from cultural, subsistence, and recreational consumption to trade as commercial foodstuffs and commodities; their management follows a similar continuum, from wild-harvest to compatible management and ultimately agroforestry. In this presentation, we will consider the challenges and potential of fungi in NTFP (non-timber forest product) and agroforestry development. The mushroom cultivation industry in BC and Canada could expand with native or exotic species and strains of fungi, including edibles such as oyster mushrooms, nutraceuticals such as reishi, and the highly prized culinary truffles. There is potential for further development of the wild-harvesting of edible and medicinal mushrooms, but research into the sustainability of this activity is essential. Security and exclusivity of access to specific NTFP resources in specific forested land bases could provide incentive for sustainable NTFP harvesting or managing for improved productivity. Economic monitoring of international NTFP trade will only be possible when more specific commodity categories are used by the World Customs Organization and Statistics Canada. Nevertheless, there is a clear potential to boost the productivity of wild-harvested mushrooms, such as pine mushroom or matsutake, using a 'light development' approach to forest resources.

Key Words: Non-timber forest products, mushrooms, truffles, compatible management.

COMPETITIVE MARKET ANALYSIS – SHIITAKE MUSHROOM PRODUCERS

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Abstract: Shiitake mushrooms (*Lentinus edodes*) have many nutritional and medicinal benefits. The cultivation of log-grown shiitake encourages forest farming and can be an opportunity for farmers interested in developing an additional enterprise.

In 2006, the University of Missouri Center for Agroforestry (UMCA) conducted a nationwide survey of shiitake producers to analyze the U.S. shiitake industry by taking into consideration the forces that influence competition based on Porter's Five Forces Model.

People in the shiitake mushroom business consider shiitake a valuable crop because of its uniqueness, popularity and sustainability. The production of shiitake is a source of profit by itself or as addition to a farming operation because of low start-up costs and potential markets. Barriers to success in the shiitake business include hard work and serious commitment to produce and market shiitake, the one-year time lag to obtain a return on investment, and insufficient production and marketing information. Shiitake are grown more as a side business, especially those produced exclusively outdoors. Indoor production on sawdust generates higher income than outdoor production on logs but the log production is more suitable for a small-scale operation in an agroforestry setting. The majority of respondents sell their shiitake mushrooms locally. Gourmet restaurants, farmers' markets, and on-farm outlets are the main markets for shiitake. Trends in demand are increasing and prices are high. To help the market grow, UMCA and its partners are working to promote quality shiitake by disseminating production and market information to growers, grower associations and mushroom publications.

Key Words: *Lentinus edodes*, Porter's Five Forces Model, agroforestry, forest farming, log-grown mushrooms.

INTRODUCTION

Shiitake mushroom (*Lentinus edodes*), one of the most popular cultivated varieties of specialty mushrooms, is a tasty fungus native to Asia and grown in forests. Shiitake can be cultivated in any part of the U.S.A. in both small and large operations, providing a sustainable and potentially profitable way to recycle low-value forestry by-products. Shiitake are prized for taste, nutritional value and health benefits. They are low in calories, glucose, and sodium; and are high in potassium, phosphorus, copper and zinc. They are also a good source of fiber and high quality protein. Shiitake mushrooms contain lentinan, a polysaccharide that is being studied for its ability to increase immune system activity, reduce the potential for tumors, and lower blood-pressure. Shiitake helps the body to produce interferon, an anti-viral substance, as well as fight against asthma, colds and flu. Shiitake also contains eritadenine, which lowers blood cholesterol (Mattila et al. 2000; Mycosource Inc. n.d.).

As an alternative enterprise, log-grown shiitake mushrooms represent a way to utilize a forest resource in its original setting. The outdoor production of shiitake utilizes low quality hardwoods, providing an additional income while creating opportunities for timber stand improvement.

The University of Missouri Center for Agroforestry (UMCA) strives to establish new and profitable crops for Missouri land and forest owners to enhance and diversify their farm income opportunities. In the forest farming area, UMCA is conducting research and demonstration projects to identify the types of mushrooms best suited for Missouri soils, as well as the best production techniques and management practices for cultivation of specialty mushrooms in agroforestry settings. The goal is to develop specialty and gourmet mushrooms into profitable agroforestry crops in a forest farming practice that will enable Missouri landowners to diversify their farm income. In addition to production research, UMCA performs research to understand specific agroforestry markets in order to support widespread adoption of agroforestry. Market knowledge is a key ingredient in the success of agroforestry enterprises that produce specialty products.

This paper presents the results of research conducted to describe the shiitake market. The research builds upon previously reported research that sheds light on specific agroforestry markets such as red cedar and chestnuts (Gold et al. 2005; Gold et al. 2006). The objective of this study is to analyze the U.S. shiitake industry from the producer's perspective by taking into consideration the forces that influence competition based on Porter's Five Forces Model.

RESEARCH METHODOLOGY

Shiitake producers throughout the U.S. were identified using information from the Internet (e.g., keyword searches for businesses involved in all aspects of shiitake production, university websites that offered links to sources of specialty mushroom products) and shiitake growers' associations. A questionnaire-based survey was developed**.** A combination of yes/no, closed and open ended questions were designed to collect general information about the market participants and information specific to each of the Porter's forces that influence the market.

The Porter Five Forces Model (PFFM) looks at five areas of competition that market participants face: barriers to entry, bargaining power of suppliers, bargaining power of buyers, threat of substitute products and rivalry among existing firms (Porter 1980). The influence of governmental policies on the market was added to the PFFM. By understanding the competitive forces within the shiitake mushroom industry, market opportunities and threats can be identified and successful strategies can be developed.

The questionnaire was tested with two growers and a researcher. Questionnaires were mailed to all individuals identified. Using SPSS, descriptive analysis was performed on the data collected.

RESULTS AND DISCUSSION

Out of 104 questionnaires mailed nationwide, 36 were returned and analyzed (36% response rate). Responses came from 23 states, especially from the central and eastern regions of the United States.

General information about the respondents and the industry

Farming of exotic mushrooms is commonly recommended as a source of supplemental income (Beetz and Kustudia 2004) because of high investment in time and money required by commercial production and limited markets. Survey results confirm this approach. For 28% of respondents, shiitake is the predominant product in their business, while for half of the respondents, shiitake represent less than 50% of their farming operation. Out of the producers with more than 75% shiitake in their farming operation, half are full time farmers and grow shiitake indoor on sawdust and half of them are part time farmers that grow shiitake outdoor and indoor on logs.

Forty-two percent of respondents grow shiitake outdoor, exclusively on logs; 14% extended the outdoor log production with indoor production on logs; 14% supplemented their outdoor log operation with indoor production on sawdust and 30% grow shiitake only indoor on sawdust substrate. Although more respondents grow shiitake on logs, the highest production volume has been obtained from sawdust-grown shiitake. Production on logs in 2005 ranged from 50 to 7,000 pounds with most of the respondents producing 100-500 pounds. Production on sawdust ranged between 100 pounds to 370,000 pounds with most of the respondents producing 1,000-5,000 pounds. Respondents with exclusively outdoor production reported gross annual sales under $25,000. Returns up to $100,000 were obtained by respondents that extended the log-grown outdoor operation with indoor production on logs or by supplementing the log-grown production with indoor production on artificial substrates. Respondents that reported gross sales higher than $100,000 annually produce shiitake exclusively indoors, on sawdust substrate (Fig. 1).

A significant group of shiitake growers (40%) are new in the business (less than five years) while a quarter of the respondents began shiitake production 11-20 years ago with the smallest group (17%) producing for 20 years or longer.

In addition to shiitake, respondents grow oyster (58%), maitake (25%), reishi (19%), pom-pom (19%), and stropharia (11%). Other species mentioned were chicken mushroom, clamshell, nameko, enoki, and king oyster.

Shiitake growers are involved in various market-related activities. Thirty-one percent of respondents sell supplies for growing mushrooms while 33% broker for other growers. Most respondents sell their shiitake mushrooms fresh (78% sell bulk and 44% packaged). The value added dimension is well developed with 69% of respondents selling value added products. Among them, dried shiitake is the most common value added product. Besides dried shiitake, respondents sell soup mixes, gift packs, medicinals, and meals. To increase awareness about specialty mushrooms, some respondents provide related products such as books, videos, mugs, aprons, T-shirts, bumper stickers, playing cards, wood carvings, etc. (Fig. 2).

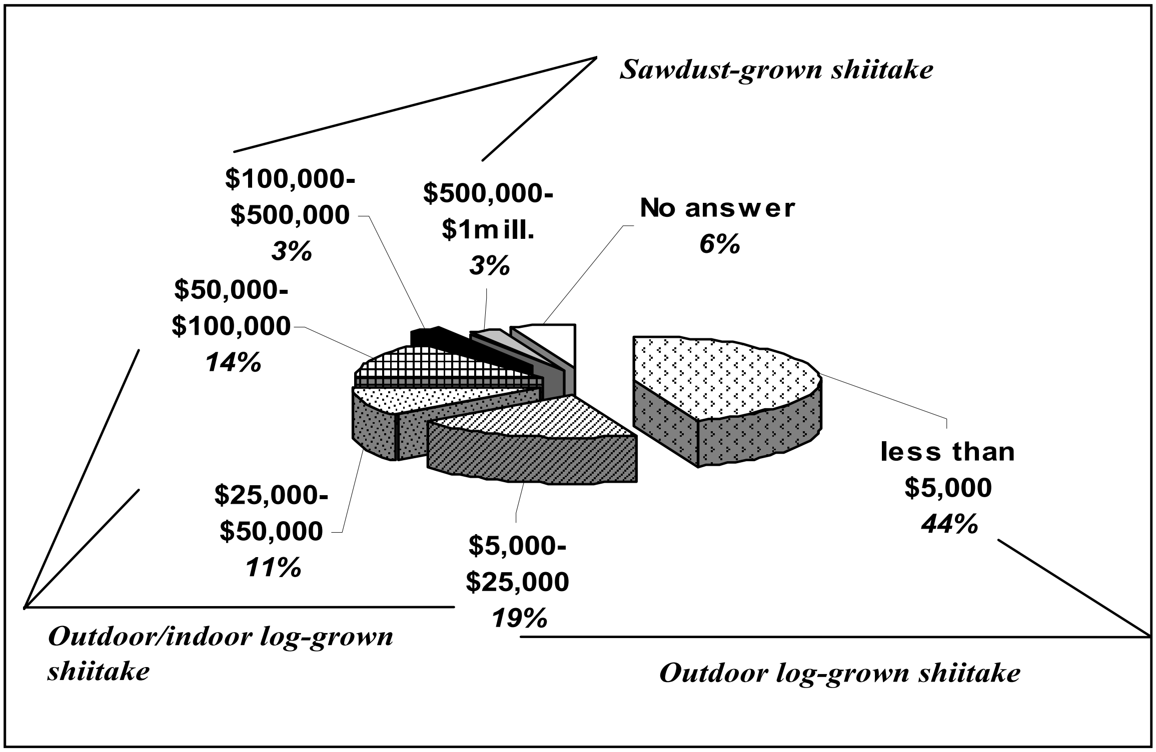

Fig. 1: Annual gross sales generated by shiitake mushrooms (N=36).

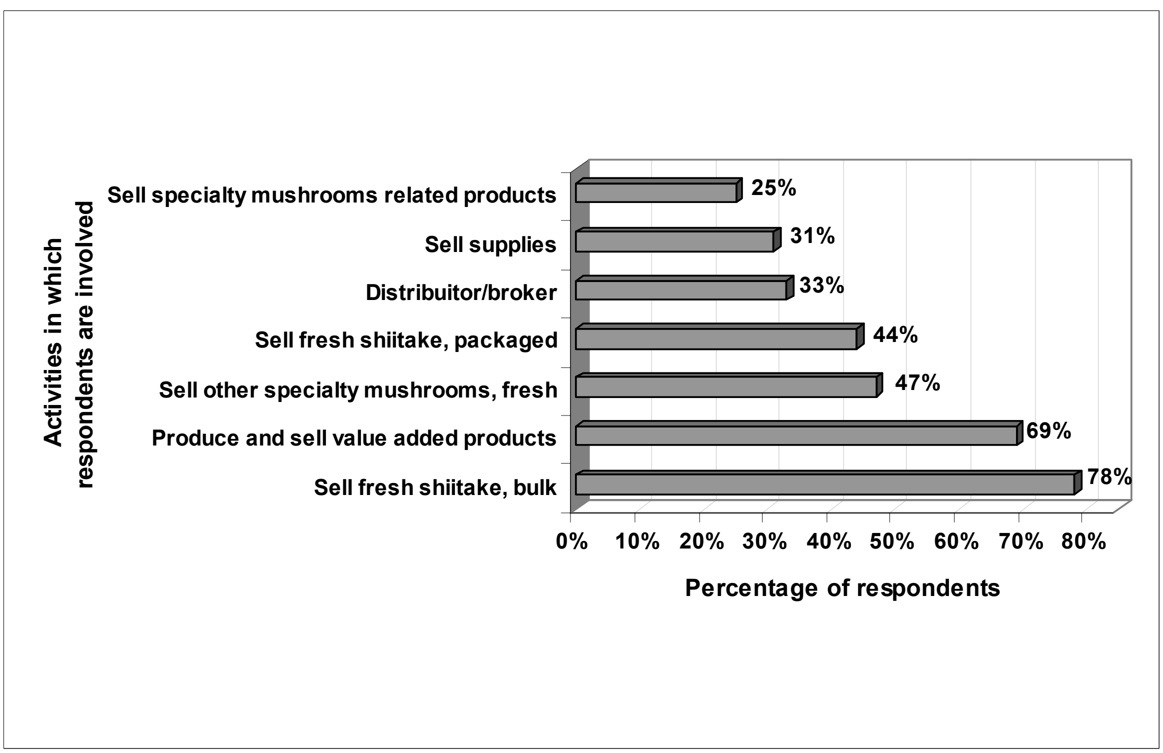

Fig. 2: Market-related activities in which respondents are involved (N=36).

Information about the forces that influence the shiitake market – Barriers to entry

Shiitake mushroom production has many positive aspects. Shiitake is cultivated by respondents because of its uniqueness, popularity for taste, nutritional value and medicinal properties. Respondents consider it worthwhile to produce shiitake when resources, such as logs, spawn, water and microclimate are available and when information and training are easily accessible. The production of shiitake mushrooms is considered a potential source of profit by itself or as an addition to a larger farming operation because of its low start-up costs and potential markets (especially restaurants and farmers' markets).

Identified barriers to success in the shiitake business include hard work and serious commitment to produce and market shiitake, the one-year time lag to obtain a return on investment, the lack of start-up funds, insufficient production and marketing information, and issues regarding organic certification.

Production skills and production information are considered the most critical resources for a successful shiitake business. Production skills and knowledge are necessary and are acquired in time through practical experience. Market knowledge, tools and equipment, and business skills are the next important critical resources. Other resources that contribute to the success of a shiitake business are labor availability and financial resources (Fig. 3).

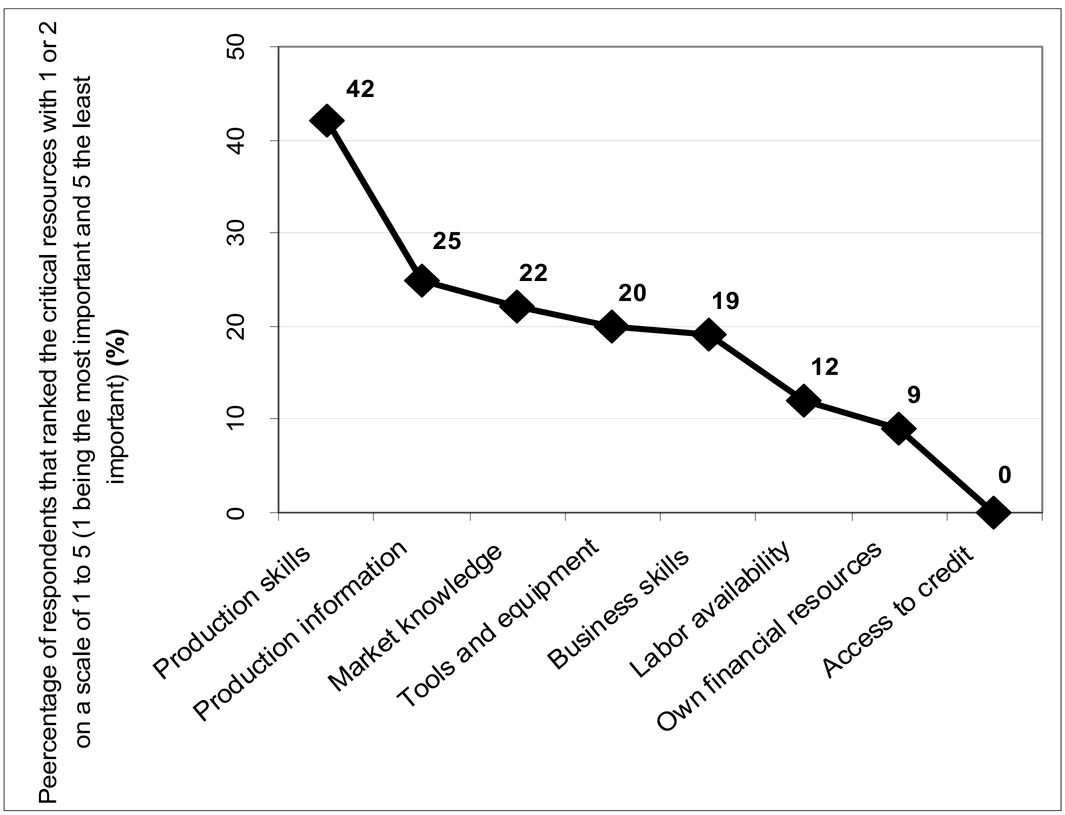

Fig. 3: Critical resources needed for a successful shiitake business (N=36).

Bargaining power of suppliers

There are some major suppliers of spawn for the shiitake industry. Field and Forest was mentioned by most respondents followed by Northwest Mycological, Fungi Perfecti, North Carolina A&T and Mushroom People. About half of the respondents have alternative suppliers for spawn, growing medium, packaging materials and tools. The majority of the respondents consider the spawn available through supply channels of good quality, readily available and stable.

Bargaining power of buyers

The market for log-grown shiitake mushrooms is still developing. The majority of respondents sell their shiitake mushrooms locally, within a 75-mile radius.

Gourmet restaurants, farmers' markets, and on-farm outlets are the main markets for shiitake. Health and natural food stores are next (Fig. 4). Shiitake growers prefer to sell direct to farmers' markets, restaurants and on-farm for a premium price rather than to sell through wholesalers and distributors or to grocery stores. Selling to supermarkets can be problematic because of the need of assuring product freshness and continuity in delivery.

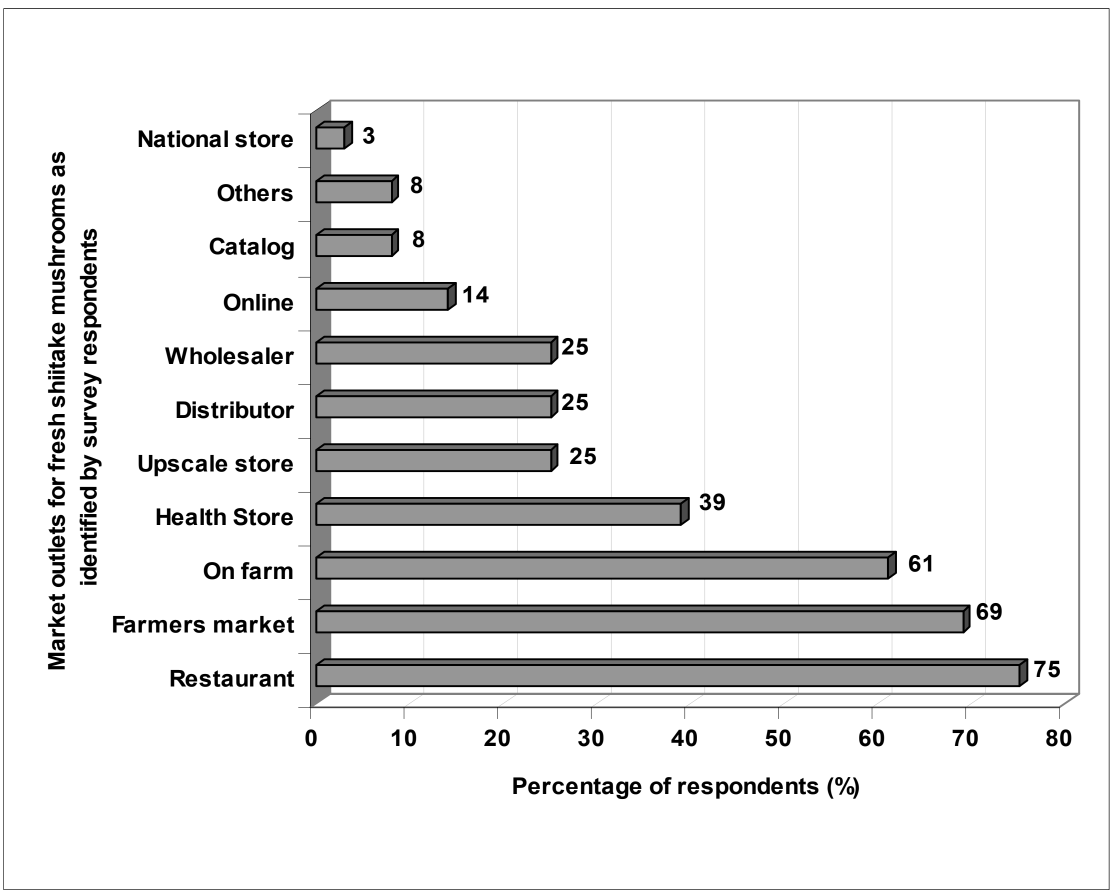

Fig. 4: Market outlets for fresh shiitake mushrooms (N=36).

Market prices for fresh shiitake vary seasonally and with the market outlet. Prices tend to be higher in the winter and summer when shiitake mushrooms need special environments in order to fruit. Growers that build climate controlled facilities have the opportunity to sell mushrooms at a higher price in the "out of season" periods and assure continuity in delivery.

For our survey sample, prices varied considerably: fresh shiitake bring $5 to $7 a pound wholesale for log-grown shiitake. Customers at farmers' markets are paying $6 to $16 for a pound of fresh, log-grown shiitake and chefs are paying $5.50 to $16 per pound to include log-grown shiitake on their menus. Retail stores pay $5.50 to $11 for a pound of fresh shiitake. Some respondents sell shiitake on-farm for $5 to $16 per pound (Fig. 5).

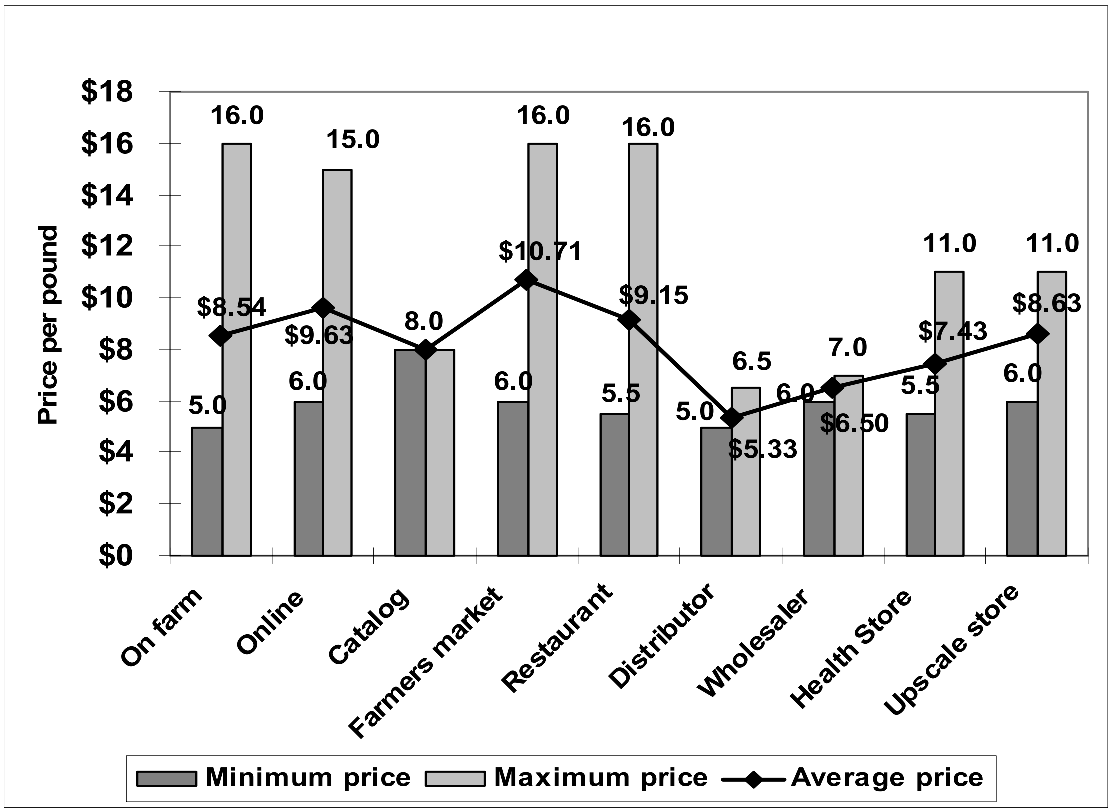

Fig. 5: Prices paid by different buyers for log-grown shiitake (N=36).

Mushrooms are perishable. In order to successfully market their products, producers need to ensure that quality remains high through the supply channel. Respondents indicated that care should be taken to assure quality before delivery (refrigerate, deliver fresh, grade carefully and use customized boxes). In addition, personal delivery and assurance that the delivery chain will be able to maintain freshness and high quality of mushrooms are necessary. Continuous communication and education are required throughout the process to ensure quality delivery. A high majority of respondents (81%) deliver direct to market; 22% use shipping companies; 14% use refrigerated freight; and, for 14%, the buyer is responsible for picking up the mushrooms.

Trends in supply and demand

Research on the consumer side revealed that specialty mushrooms, led by shiitake and oyster have grown in popularity over the past decade (Rose Research 2005). Production and consumption of specialty mushrooms in the United States is expected to increase at an accelerated rate in the next few years, according to the Agricultural Market Research Center (Burden 2006).

Most respondents indicated that demand for fresh log-grown shiitake and value added products is steady or strong and will increase over the next five years by approximately 10-25%.

Threat of substitute products

According to survey respondents, shiitake can be substituted by the common white button mushrooms and also other gourmet-type mushrooms such as portabellas and crimini for a lower price but higher availability. Oyster was mentioned as a same price, quality and availability substitute and chanterelle, maitake, matsutake, morels, porcini or truffles are potential higher price substitutes, less available than shiitake mushrooms.

Respondents consider that there are opportunities for new specialty mushrooms especially for cultured wild mushrooms and for those with medicinal properties.

Rivalry among existing firms

The shiitake industry is considered by our respondents as being moderately competitive (28%) to non-competitive (22%). The opinion about competitiveness of the market is not conclusive. Some respondents are the only shiitake farm in the area while others share their area with five or more shiitake farms.

Over the past five years the number of shiitake farms in one area remained stable for 30% of respondents, increased for 17% and decreased for 17%. Over the next five years, the number of shiitake farms is expected to remain stable according to 28% of respondents, increase (28%) or decrease (6%).

In wholesale markets, competition for log-grown shiitake is present primarily from shiitake produced on sawdust substrate which have higher production efficiency (Royse 2001; Mycosource Inc. n.d.). Chinese mushroom production and export to the U.S. has increased yearly over the last two decades, according to Agricultural Marketing Research Center. Chinese imports, particularly of very inexpensive dried shiitakes, have depressed prices and provided serious competition to small scale U.S. growers (Burden 2006).

Trends in price

According to our respondents, over the past five years, the price for fresh shiitake mushrooms remained stable or increased up to 25%. The same trend is expected over the next five years. A good practice will be to maintain competitive pricing along with a high quality product.

Policies that influence the industry

Grants and general support offered for small farms and direct marketing were mentioned among the policies that help establish a shiitake business. Information and support offered by university specialists, extension agents and state sponsored programs to promote local products (e.g., AgriMissouri) are also helpful.

CONCLUSION

Shiitake are grown more as a secondary business, especially for those producers who are involved exclusively with outdoor log-grown production. Indoor production on sawdust generates higher income than outdoor production on logs but production on logs is more suitable for a small-scale operation in an agroforestry setting.

Shiitake production on logs has many positive aspects. Shiitake can provide additional income by using available resources (thus reducing capital investment requirements), while increasing the value of the woodlot. Log-grown shiitake are popular for their taste, nutritional and medicinal properties and have a higher quality than sawdust grown shiitake. Trends in demand are increasing and prices remain high. Local sales to restaurants, farmers markets and on-farm are promising.

Barriers to success in the shiitake business include hard work and serious commitment to produce and market shiitake, seasonal production dependent on weather and the need for strong and direct relationships in the market. Compared to vegetable growing, there is a time lag to obtain a return on investment. New businesses entering the market for log-grown shiitake may face competition from firms that have already created relationships with the main buyers in the area, shiitake produced on sawdust, and from imports.

Respondents increased their return from log-grown shiitake by creating indoor facilities to extend production times, by producing value added products (especially dried shiitake), and by selling mushrooms for other growers to ensure continuity in supply. Additional success can be obtained by capitalizing on the log-grown properties of shiitake in the marketing effort (e.g., meatier, richer flavor, better shelf life, and higher nutritional and medicinal value), creating strong relationships with buyers, and acquiring and continuously improving production and marketing skills.

UMCA and its partners are working to promote quality shiitake by disseminating production and market information to growers, grower associations and mushroom publications, continuing to organize trainings, working with produce buyers to ensure that only quality products are offered for sale and by educating consumers about the nutritional and health benefits of shiitake mushrooms. Research on the consumer side would be very helpful to better understand what are consumers' requirements and expectations.

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FARMING THE FOREST: USING NON-TIMBER PRODUCTS AS ALTERNATIVE INCOME SOURCES

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Abstract: Forests are the source of a great diversity of flora, many of which are gathered for non-timber forest products (NTFPs). These products are made from resources that grow under the forest canopy as trees, shrubs, herbs, vines, moss and even lichen. They occur naturally or may be farmed in the forest. Over the last decade, interest in using NTFPs as alternative income sources has grown tremendously. Farming the forest can help to diversity productivity and profitability. It can generate short and medium tem revenue streams and help assuage economic uncertainties while longer-rotation crops mature. Creative and entrepreneurial forest landowners might cultivate NTFPs for a variety of markets -- floral and decorative, herbal medicines, culinary or crafts. Many native plants are valued for landscaping and industrious landowners might supplement their incomes by marketing live transplants. Unfortunately, efforts to promote these alternatives may be thwarted due to a lack of knowledge on how to produce, harvest, and market them. Forest landowners interested in pursuing forest farming enterprises need to understand all factors that could influence their success. They need to examine the markets and fully understand the potential and pitfalls of each alternative. Though there are may challenges of developing farm forestry enterprises, a diversified forest use strategy can be economically rewarding for those willing to invest time and energy. This presentation examines farm forestry market opportunities in southern United States, and explores the challenges of undertaking farm forestry alternatives.

Key Words: Assessments, culinary, decoratives, income opportunities, medicinal, non-timber forest products.

NON-TIMBER FOREST PRODUCTS

A variety of terms (e.g., non-traditional, secondary, minor, non-wood, and special or specialty) have been used to describe products that come from the forests that are not timber-based. National legislation uses the term "Forest Botanical Products" to describe these products (H.R. 2466 1999). The USDA Forest Service defines them as special forest products (USDA Forest Service 2001). A more common and widespread term is "non-timber forest products". Whatever the chosen term used to describe these products, they are all based on plants or fungi or other flora materials. They do not include wildlife or other fauna.

Non-timber forest products are defined as plants, parts of plants, fungi, and other biological material harvested from within and on the edges of natural, manipulated or disturbed forests. This includes fungi, moss, lichen, herbs, vines, shrubs, or trees. Plant parts harvested include the roots, tubers, leaves, bark, twigs and branches, fruit, sap and resin, as well as the wood (Chamberlain et al. 1998). These products are commonly classified into four major product categories: culinary,

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wood-based, floral and decorative, and medicinal and dietary supplements. A newly emerging category of NTFPs used in the landscape industry includes products such as pine straw and live native plants collected from the wild. More than 50 species of plants are commonly gathered as non-timber forest products in the southern United States. The majority of non-timber forest products are used for medicinal purposes, though plants used for floral and decorative uses are also well represented. With so many plant species from which products can be harvested, an entrepreneurial landowner has many opportunities to farm the forest.

Though no formal estimates have been made of the total value of the NTFP markets in this region, available data illustrates the economic importance of some individual products. For example, in 1995, the U.S. exported moss and lichen, much of which was from southern forests, valued at more than $14 million (Goldberg 1996). In 1996, collectors of the fruit of black walnut, which is found in eastern hardwood forests, were paid more than $2.5 million (J. Jones, Hammons Products Company, personal communication). One company in southwest Virginia specializing in pine roping had sales in excess of $1.5 million in 1997 (Hauslohner 1997). A volunteer fire department in western North Carolina generates approximately 35percent of its budget from its annual ramp (wild onions) supper. In 1999, the retail sales of saw palmetto exceeded $45 million, representing a 34 percent increase over the previous year (Blumenthal 2000). Based on 2001 prices, I estimate the average wholesale value of forest-harvested ginseng to collectors in a four state region exceeds $18.5 million. The aggregate value of non-timber forest products to the southern economy far exceeds these examples. Though it may require persistent and tenacity, there are economic opportunities to be realized by farming the forest for non-timber products.

ALTERNATIVE INCOME OPPORTUNITIES

Landowners interested in pursuing farm forestry alternatives have many opportunities to do so. Raising bees can generate income through the sale of honey and related products. There has been a resurgence of interest in growing short-rotation woody crops as fuel prices continue to skyrocket. Creative and entrepreneurial landowners might consider farming their forest to supply the floral and decorative markets. Shiitake and other edible mushrooms may be feasible for some forest farming situations. Many native plants are valued in the landscaping industry, and industrious landowners might supplement their income by selling live transplants or greenery. Landowners with long leaf or slash pine forests might consider contracting for the harvest of the "straw" or combining timber and cattle production.

Edible Products

Edible and culinary products that can be farmed in the forests of North America include mushrooms, ferns, and the fruits, leaves and roots of many species. In many parts of the hardwood region of eastern United States, the most commonly collected culinary forest product are ramps (*Allium tricoccum*), a wild onion that is one of the earliest spring emergents. Another important culinary species, eastern black walnut (*Juglans nigra*), which is native to Eastern United States, also is used in the medicinal and dietary supplement industry. Huckleberries, blueberries, and other brambles also can be farmed in a forest setting.

Mushrooms and fungi, such as shiitake (*Lentinula edodes*), maitake (*Grifola frondosa*), lion's mane (*Hericium erinaceus*), and oyster (*Pleurotus* spp.) can be grown commercially in a forest farming setting. The shiitake mushroom is the most popular for small-scale cultivation. Production of shiitake in this country started about 2 decades ago, when demand exceeded the ability of importers to fulfill orders, and the technology for landowner production became readily available and simple. Rural development agencies have been promoting shiitake mushroom production as an alternative income source. Many landowners started producing this valuable mushroom, and today it is well accepted in gourmet markets.

The land under forest trees can be used to raise honey bees (*Apis mellifera* L.) to provide products such as flavored honeys, packaged honey gifts, creamed honey, honey wine and mead which may command higher prices. A single hive can produce 80 to 120 pounds of harvestable honey each year. Pollen, which contains high levels of protein and other nutrients, is used as a food additive, medicine, and in cosmetics. Beeswax is used in candles, cosmetics, foundation sheets for frames, and other assorted products. Wax is harvested from the cappings removed during honey extraction and from other broken combs in the hive. Propolis is a mixture of beeswax and resins from plants and is used in the hive to reduce the entrance, repair cracks, cap brood, and seal off intruders. Antibacterial properties of propolis make it useful in medicines, particularly for wound healing. Further, hives may be rented out to crop growers for pollination services.

Decorative products

Entrepreneurial landowners can farm their forests for plants used for the production of decorative products or landscaping. Entire plants and parts of plants are used in arrangements, to complement and furnish the backdrop for flowers, as well as for the main component of dried ornaments. Final products for many floral greens include fresh/dried flowers, aromatic oils, greenery, basket filler, wreaths, and roping. Some forest plants that grow in southern Appalachia and are used in the floral industry include various species of grapevine (*Vitis* spp.), kudzu (*Pueraria lobata*), smokevine (*Aristolochia macrophylla*), and galax (*Galax urceolata*). These and others can be farmed from the forests by private landowners.

Christmas trees farms produce important and lucrative seasonal crops. Species grown as Christmas trees include Fraser fir (*Abies fraseri*), pines (*Pinus* spp.), Eastern red cedar (*Juniperus virginiana*), spruces (*Picea* spp.), Leyland cypress (X *Cupressocyparis leylandii*), and Arizona cypress (*Cupressus arizonica*). The appearance and health of a tree is very important. Trees should have ample amounts of rich, dark foliage; have a straight trunk; retain needles for a long time after being cut; have branches thick and durable enough to support ornaments; have a symmetrical, dense, conical form; and a pleasant odor. Trees are harvested when they are five to seven feet tall. Landowners may harvest trees to sell at seasonal retail lots, or allow customers to cut their own tree on the property (known as a "choose and cut" operation). In a "choose and cut" operation, trees that are ready to be harvested should be well-marked. Landowners may cut trees that customers choose or provide saws and sleds for customers to cut and transport trees.

Integrating production of pine straw, the harvesting of the needles, into forest management offers an interim income stream while the trees are maturing. Pine straw makes attractive landscape mulch as it protects the roots of plants from extreme temperatures, supplies some nutrients upon decomposition and reduces weed growth, erosion, and evaporation of water from the soil. The low pH of the resin on the needles creates a preferred environment for acid loving landscape plants such as azalea, rhododendron, camellia, gardenia and blueberries. Compared to other mulches, pine straw may last longer and cover more area per cost of materials.

A good site to establish a pine straw operation should be relatively flat with minimal soil erosion potential. The species that produce the most desirable straw are longleaf (*Pinus palustris*) and slash (*Pinus elliottii*) pine. Loblolly pine (*Pinus taeda*) also may be used, though the needles are shorter and more difficult to bale. Stands with basal areas of 75 to 125 square feet per acre can produce approximately 125 to 175 bales per raking, respectively, each weighing about 30 pounds. If pine straw is the secondary crop to timber, then spacing should be determined by the primary objective of growing wood. The first harvest can begin as early as 8-12 years old in old plantations, later in natural stands.

CONCLUSIONS

There are many opportunities to farm the forests for alternative income and this paper presents only a few as examples. Medicinal and aromatic plants can be farmed in a forest setting. Landowners who have cattle may consider integrating pasture and tree management to increase overall economic productivity. Those with large holdings of pine forests might think about tapping trees for the resin or selling the needles for 'straw." A forest landowner with lots of native plants might do well to investigate supplying the landscape industry. Those with a partiality to gardening or animal husbandry could grow mushrooms or raise bees.

Whichever alternative appeals to the landowner, always investigate the costs, benefits and potential pitfalls of each option. One of the first things a landowner should do is to inventory and identify resources, habitats, opportunities and constraints. Many new enterprises may require additional skills and expertise. There may be additional capital or labor investments for which landowners will need to budget. The competition in some markets, such as edible mushrooms, firewood, and bees, may be such that the profit margins make these alternatives less attractive. Interested landowners need to examine the markets and fully understand the potential and pitfalls of each possible venture. Though there are many challenges, developing forest farming enterprises can be rewarding to landowners willing to invest time and energy.

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CASE STUDY:
MANAGEMENT OF SALAL AS FLORAL GREENERY

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Abstract: Floral greenery is an important economic crop in British Columbia. Salal, an evergreen shrub native to the Pacific Northwest, is a prime example, with an export value of CAN$40M/year from BC and providing income for an estimated 15,000 people. Salal is wild-harvested in the PNW, where compatible management strategies (thinning, pruning, fertilization of conifers) can increase both salal and timber values. Salal is rarely harvested under forest canopies manipulated to optimize salal production rather than timber (e.g., a family in BC; a UK floral company in SE England); Columbia also imports salal plantlets from BC, and sells high-quality, horticulturally-produced greenery. Wild harvesters in BC tend to be long-term Asian harvesters; in Washington State, there has been a change from long-term harvesting by Hispanic immigrants to short-term young Hispanics using salal as a first step towards higher paying employment outside the NTFP sector. Increased volumes of shipments and commoditization (consolidation) plus changes in harvester attitudes have led to increased scarcity of resource, regional over-harvesting, reduction in quality, and reduced satisfaction with wild-harvested products in markets. Loss of markets could cause socio-economic hardship to disadvantaged wild-harvest workers unable to move to other sectors in the PNW, and may favour more capital-intensive private land agroforestry production of salal, perhaps overseas. An understanding of world trends, the wild-harvest to agroforestry continuum, commoditization, the socio-economic context, NTFP tenure and management options for Crown and private land, and compatible management strategies is required for the stability and long-term sustainability of the salal sector in BC.

Key Words: Non-timber forest products, salal, compatible management, resource management, gaultheria shallon.

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RESEARCH ON BRINGING GOLDENSEAL, A NATIVE WOODLAND BOTANICAL, INTO COMMERCIAL CULTIVATION

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Abstract: Goldenseal (*Hydrastis canadensis* L.) is a native woodland botanical that has been wild harvested from North American forests for centuries. In the late 1800's and early 1900's, its popularity as a medicinal herb resulted in a serious reduction in wild populations. For a short time, it was cultivated, most notably in the Pacific Northwest. By the mid-1900's, however, there was no commercial production to speak of and once again, all goldenseal on the market was obtained from wild populations. Resurgence in popularity in the late 1900's brought new concerns for the conservation of goldenseal, regulations on international trade, and demand for cultivated material. Much of the public research on cultivation of goldenseal has taken place in western North Carolina over the past eighteen years. The studies have been focused on propagation, cultivation methods, soil factors, and economics of production. The influence of cultivation practices on goldenseal growth, yield, and alkaloid content has been of particular interest. The results, benefits, and limitations of these studies will be discussed.

Key Words: Forest, *Hydrastis canadensis*.

INTRODUCTION

High demand for goldenseal root (*Hydrastis canadensis*) has resulted in serious reductions in natural populations throughout its native range. In North Carolina, goldenseal is an endangered species, making harvest from public lands illegal. In 1997, goldenseal was also listed on Appendix II of the Convention for International Trade on Endangered Species of Wild Fauna and Flora (CITES), an international treaty monitoring trade in threatened and endangered species. This puts controls on international trade of goldenseal and encourages sustainable use. This has not stopped people from collecting it, however, and populations continue to decrease. Fortunately, cultivation of goldenseal is fairly easy.

The medicinal properties of goldenseal are attributed to the alkaloids hydrastine and berberine which are usually present in the rhizome and root in concentrations of 2-10%. Goldenseal is a top selling herb in North America and is sold in pharmacies, health food stores, and discount stores in many formulations. Traditionally, goldenseal has been used to treat eye infections, sore throats, mouth sores, ear aches, and digestive disorders. It is now commonly used as a topical antiseptic and to treat fungal conditions on the skin. Some herbalists claim that goldenseal helps boost the immune system and increases the efficacy of other medicinal herbs. Many users believe that goldenseal will mask the presence of illegal drugs in urine tests. Goldenseal also has veterinary uses. Thus, goldenseal can be found in a wide array of products, from hair conditioner to tea blends.

PLANT DESCRIPTION AND GROWTH

Goldenseal is an herbaceous perennial which emerges in mid-March to early May from buds on a perennial rootstock. Almost immediately after emergence, the plant puts on a rather inconspicuous white flower which develops into a single green fruit. The mature plant is 6 to 14 inches tall with two or more stems that usually end in a fork with two leaves. The 3 to 12 inch wide leaves are 5 to 7 lobed. In late June to early July, the fruit turns red and ripens into a raspberry like fruit with many seeds. The plant may die down slowly after the fruit matures or remain green until first frost.

Goldenseal spreads naturally by underground rhizomes and an extensive fibrous root system. The interior of the rhizome and root (from hereon these will be referred to as "root") are bright yellow. Next year=s plant develops from one of usually two buds which form near the base of the stem on the thickened rhizome. Goldenseal also propagates itself by seed.

HOW TO GROW

Site selection is the most important factor for producing healthy goldenseal. It grows best in rich, moist, loamy soil with good air and water drainage. Do not plant goldenseal in a bottom or in a heavy, poorly drained soil. If growing in the forest, look for a site where there are other woodland plants growing such as mayapple, trillium, bloodroot, and black cohosh. Avoid sites where there is no undergrowth or where undergrowth is very thick. Goldenseal requires shade and usually thrives in a site with mixed, deeply rooted hardwood trees. Goldenseal plantings in stands of oak, poplar, walnut, and basswood have been successful.

If growing under artificial shade in an open field situation, choose a site with few weeds or control the weeds before planting the goldenseal. Grasses can be a big problem if planting into a pasture without adequately turning the soil to kill existing weeds and seeds. Artificial shade can be provided by a wood lath structure or polypropylene shade cloth in a solid or lath weave pattern. Shade structures are expensive, but if properly cared for, can last a very long time. Whatever system you use, air circulation is important. Make the structure seven feet tall or higher with ends open to prevailing winds, if possible.

Several years ago I conducted a study in western North Carolina in which goldenseal was grown under four levels of shade, 30%, 47%, 63%, and 80%, provided by polypropylene shade cloth. Plant stand counts and annual survivability were highest under 47% and 63% shade. On the other hand, the more light there was, the more problems we had with foliar diseases and weeds. These were especially bad under the 30% and 47% shade treatments. The highest root yield after four years of growth was obtained with 63% shade, but the highest root alkaloid content was obtained with 30% shade. When root yield was multiplied by root alkaloid content, it was demonstrated that the highest alkaloid yield per unit land area was obtained with 63% shade.

In a natural forest site, prepare the area by removing undergrowth and small trees. Collect soil samples for fertility testing and nematode assays. Till or turn the soil and amend if necessary. To promote good water drainage and to warm the soil early in the spring, raised beds can be constructed. We often construct beds that are about 6 inches tall and 3 to 4 feet across.

Studies conducted on western North Carolina forest soils showed that soil pH had a dramatic effect on goldenseal growth, root yield, and root alkaloid content. Goldenseal produced the highest root yield when grown in soil amended with 2.7 to 5.2 tons of lime/acre which resulted in a soil pH of 5.5 to 6.0. Goldenseal will grow in a wide range of soil pH, but in my studies, at a low pH, e.g., 4.5, goldenseal grew very slowly, but the root alkaloid levels were high. At a high pH, e.g., 6.8, goldenseal grew quickly, but root alkaloid levels were low and the plants were more susceptible to disease. I also looked at how goldenseal responded to different rates of nitrogen and phosphorus. Plant survival and root yields decreased dramatically as the rate of nitrogen increased. Additional phosphorus reduced plant survival rates, but had no effect on root weight. Because ginseng responds favorably to additional soil calcium applied as gypsum, some goldenseal growers were also adding gypsum to their soils. Results from my studies, however, do not support this practice. Gypsum applied at 2,000 to 5,000 pounds of calcium per acre, resulted in reduced leaf number and leaf size, increased disease incidence, earlier dieback, and lower root weights and root alkaloid contents than goldenseal plants grown in soil without additional calcium.

Goldenseal can be propagated from rhizome pieces, root cuttings, one year old seedlings, or seed. It takes 5 to 7 years to grow harvestable roots from seed and 3 to 5 years to grow them from rhizome pieces. Fall planting is most common, although we have had great success with spring planting, too. Although I am not recommending it, several years ago we planted rhizome pieces in early July with no ill effects.

It is easiest to propagate goldenseal from rhizome cuttings. Divide the rhizomes into 1/2 inch or larger pieces, each with healthy roots, and ideally, a bud. Do not trim the fibrous roots. Set the pieces in narrow trenches about 2 to 3 inches deep and bury with soil.

It is common practice to plant goldenseal on a 6-inch x 6-inch spacing and this has been supported by our research as being the spacing that provides the greatest increase in root weight from planting to harvest under the conditions in western North Carolina.

Propagation of goldenseal from seed can be difficult with unpredictable results. Germination rates of purchased seed can range from 0% to 90%. I want to promote seed propagation so established populations don=t have to be destroyed to propagate the plants. Unfortunately, our study results have not been consistent. Right now our recommendation is to plant seed as soon as possible after the fruit are ripe red. If that is not feasible, in our studies seed held in moist sand at 40E F until spring have done best. However, many of the seeds may not germinate until the second spring after sowing and germination may be very low.

When you are ready to plant, sow 10 to 12 seeds per foot in rows three inches apart with seeds 1/2 inch deep. Use of a mechanical seeding devise is recommended. Cover lightly with soil. Seedlings should emerge the following spring; or maybe the spring after!

Goldenseal should be mulched to hold in soil moisture, reduce weed growth, moderate temperatures, and provide winter protection. The mulch should be several inches deep and replenished when necessary. Where the soil tends to freeze and thaw, several extra inches of mulch can be added for the winter, but should be raked back in early spring. In many regions, goldenseal is mulched with straw. We have had poor success with this in NC. The straw holds excessive moisture near the crown of the plant, which causes rot, and the slugs seem to love it. In our studies, the hardwood bark and sawdust mulches performed the best. Plants grown with fresh sawdust mulch were nitrogen deficient the first year, but grew well the following three years.

When grown under a forest canopy, goldenseal rarely, if ever, requires irrigation. Under drought conditions, however, if not irrigated, the plants will drop their foliage and go dormant earlier than usual. This usually does not harm the plant, but will reduce root growth for that year. If that loss is not acceptable, site selection should include consideration of how to irrigate if necessary.

Under natural conditions, and when grown in small, isolated plots in the woods, goldenseal rarely has any pest problems. In most of our small commercial plantings, slugs are the major problem. Slugs can devastate a young planting and do considerable damage to a mature planting, as well. Slug control can be difficult and successful methods are often site specific. Some growers have reported success with beer traps, diatomaceous earth, a mix of lime and woodashes, or commercial snail and slug bait. If populations become intolerable, sometimes the best thing to do is remove the mulch.

If the field is properly prepared and beds mulched adequately, weeds are rarely a problem in forest plantings. In open field situations, however, if weeds were not controlled adequately before planting or if the field is surrounded by sources of weed seeds, some weeding may be necessary. Usually the mulch and the dense goldenseal foliage prevent much weed growth within the beds so weed control in the aisles is all that is necessary.

For many years, botrytis leaf spot was the only foliar disease we observed on goldenseal. This usually appeared late in the season and was not a cause for concern. In recent years we have received reports many diseases on goldenseal , including Alternaria, Rhizoctonia, and Fusarium. Disease seems to be more of a problem under artificial shade structures than in forested sites. Currently, there are no agricultural chemicals cleared for use on goldenseal, so prevention is your best line of defense. Using proper sanitation practices, providing good air and water circulation, and not overfertilizing the plants seems to help. Plants will naturally die down sometime after the plants have fruited. This may vary from year to year depending on conditions.

When the goldenseal plants have fully occupied the beds, usually in 3 to 5 years, the plants can be dug or divided. CITES (Convention on International Trade in Endangered Species and Fauna) now requires four years of growth before digging if the roots will be exported. If left undisturbed the plants will start to crowd themselves out and the oldest roots will die.

Dig roots in the fall after the tops have died down. If a market exists for the leaves and stems, harvest them in late summer when the foliage is still green. Dig roots carefully, keeping the many fibrous roots intact. Small plots can be dug with a fork. Large fields will require some kind of mechanical digger. Select large healthy plants for replanting and have a container available to keep them moist and cool or have beds prepared to replant immediately.

Carefully wash the remaining roots by spraying with a hose over a large-mesh screen, or put them through a root washer. Roots must be clean or they won=t pass the ash tests conducted by many buyers. Spread the clean roots on screens and dry in a well-ventilated area or a forced air drier. Simple driers can be constructed from small sheds or tobacco barns. The key points are to keep temperatures low and to provide good air flow. If dried too hot and fast, the outside of the root dries first leaving the inside moist. The quality of the roots is then destroyed. Roots will lose about 70% of their weight during drying.

Good yield estimates are extremely variable, primarily due to differences in planting stock, spacing, bed size, age, etc. Most commonly reported yields for artificial shade structures are 1000 to 2000 lbs. of dried root per acre. Yields as low as 800 lbs and as high as 4300 lbs have been reported. Dried roots should be packed loosely into cardboard cartons, polysacks, or cardboard barrels. Store in a cool, dry, dark place secure from insects and rodents.

MARKETING

The market for goldenseal is currently good and prices are up over the last several years. Goldenseal is a long-term crop which requires a sizeable investment. Thus, I urge great caution if you are considering large-scale goldenseal production. Have several markets identified and contacts made before planting. Currently, the medicinal herb market is volatile and competitive. To sell your roots for a reasonable price, they must be of the highest quality. Expect that your roots will be tested for ash (dirt), bacterial contamination, and alkaloid concentration. Consider options to selling to the natural products industry. In many areas there are markets for goldenseal planting stock and goldenseal potted up for garden center sales. There may be an herbalist in your area looking for fresh, organic root for extraction. Creative, direct marketing has been successful for some growers.

CONCERNS

Unfortunately, to date there has not been much other field research on commercial growing of goldenseal. Most of the research has been done in western North Carolina. Growers in other parts of North America, particularly in Canada, report that they do not always get the same results when they try to follow the recommendations from the southeastern United States. Ideally, there should be a series of studies coordinated across North America to compare how goldenseal responds to a wide variety of environmental and cultural practices. Funding for such an extensive and long term project will not be easy to come by. In the meantime, growers should be aware of this problem and conduct their own experiments and keep detailed records.

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EDIBLE FOREST MUSHROOMS OF THE GASPÉ PENINSULA

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Abstract: Most of the edible forest mushroom species are symbionts of tree species. As forest cover varies among regions, synecological studies are fundamental for assessing the mushroom harvest potential of each region, in order to warrant sustainable development of this resource. The objectives of this study were to establish (1) the role of forest cover and abiotic factors in determining the abundance of selected edible forest mushrooms and (2) the developmental phenology of sporocarps, in the Gaspé peninsula (Québec, Canada). We established 895 permanent plots in 14 forest stand types representative of the study area (21,099 km^2). We collected fruit bodies every 7 days at every plot during two consecutive growing seasons (2005-2006), from mid-July to late-September. We measured vegetation, soils and landforms at each plot. The species more frequently recorded were *Leccinum* spp., *Catathelasma ventrisosum*, *Boletus* aff. *edulis*, *Lactarius deterrimus* and *Rozites caperata*. Each year, the greatest abundances were noticed in *Picea glauca* plantations (14.7 and 28.9% of total sporocarp occurrence for 2005 and 2006) and in pruned and thinned *Picea abies* plantations (13.7 and 18.5%). Although natural forest stand surveyed showed greater fungic richness, high interannual fluctuations in abundances were observed. Meteorological factors, especially humidity, appear to be responsible for the interannual variations of productivity, showing 31.8% more observations in 2006. Overall, our results suggest that harvest of edible forest mushrooms would be interesting, especially in plantation, (1) to diversify the forest resources and (2) to provide annually substantial incomes without compromising benefits from timber products.

Key Words: Edible mushrooms, fungi-forest relationships, NTFP, sustainable forestry.

FROM FORESTS TO FOREST FARM: NTFP'S AND AGROFORESTRY IN BC. CASE STUDY: BLACK HUCKLEBERRY (*VACCINIUM MEMBRANACEUM*)

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Abstract: Huckleberries (*Vaccinium* spp.) are a valuable non-timber forest product with significant cultural, economic, and ecological values in British Columbia. Black huckleberry (*Vaccinium membranaceum*) is one of the most important huckleberry species in BC and has a long history of human use by First Nations people as well recreational and commercial harvesters. Under current utilization levels, there are concerns whether land management practices will ensure a sustainable supply of berries for human use and for wildlife, as there is an increasing global demand for huckleberries due to their neutraceutical properties. This case study will explore wildharvesting and agroforestry practices used by First Nations as they historically had burned areas to enhance berry production, and will discuss current research in which various agroforestry and cultivation regimes are being developed in the Pacific Northwest. As there is currently no policy for managing, maintaining, or enhancing berry productivity on public forest lands in BC, and a recent survey of BC huckleberry harvesters indicated that there should be some form of regulation implemented for managing huckleberry resources, we will discuss potential compatible management opportunities for timber and berries, the potential for expanded agroforestry applications and the necessary policy changes to accomplish these multiple use objectives.

Key Words: *Vaccinium*, First Nations, compatible management, agroforestry innovation, public policy.

FROM CULTURE TO COMMERCE: A NTFP USAGE CONTINUUM

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Abstract: While NTFPs and agroforestry are developing as different fields of study and practice, there are many common considerations in their management and development. Research has identified that NTFPs in many cases have multiple uses which include commercial and non-commercial uses and NTFPs can be classified as consumptive as well as non-consumptive goods. There are only a few large commercial NTFPs which have sizable economic contributions, with most NTFPs contributing more modestly to the economy. However, the income generated is a significant factor for sustaining rural communities. In addition to their value as commercial products extracted from forest systems, non-timber forest products at all points along the production continuum have significant recreational, subsistence and cultural values, and may contribute as well to the rationale for maintaining diverse forest ecosystems.

This presentation will outline various NTFPs by their classification as a commercial, recreational, traditional and or subsistence type products and compare these with their current and potential applications in an agroforestry context, or for intensified cultivation. As many NTFPs may progress in their product life cycle from a wildharvested beginning into an agroforestry and even a cultivated state over time, the factors driving this progression will be explored and the methods of compatible management with timber to reach multiple use objectives will be discussed.

Key Words: NTFP valuation, commercial-recreational-traditional NTFP uses, NTFP production life cycle, compatible management.

FROM FOREST TO FOREST FARM: NON-TIMBER FOREST PRODUCTS AND AGROFORESTRY IN BRITISH COLUMBIA; PANEL DISCUSSION

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Abstract: Non-timber forest products (NTFPs) include all of the botanical and mycological species of the forest except for conventional timber products. Although societies have used NTFPs since time immemorial, formal study of the sector in Canada has only begun recently. There is still lack of clarity surrounding species' use and values, through to how management of the NTFP sector fits within other management models. Understanding of the sector requires recognition of the extreme diversity of both the values and the management of NTFPs that results from the wide range of people of diverse cultural backgrounds and different socio-economic contexts that are involved. Progress in developing concepts has been made by recognizing these ranges along continua, rather than discrete categories. For example, the value and use of NTFP species range from cultural, to subsistence, to recreational, through to commercial. Although there are overlapping uses, such as commercial production of traditional products, there are often very different people involved at different points along the continuum. Management of NTFP species falls along a similar continuum, from wildharvest, to compatible management, through to agroforestry. Again, there are very different individuals within different socio-economic contexts engaged at each point along the continuum. These diversities and continua must be understood so that management techniques can be developed that will ensure both ecological and socio-economic sustainability for all of the individuals involved. This panel will explore these concepts in light of the case studies presented before the panel, with perspectives and lessons learned applicable across North America.

Key Words: Non-timber forest products, agroforestry, compatible management, economic diversification, resource management, community development, First Nations.

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MEDICINAL AND ORNAMENTAL UNDERSTOREY HERBACEOUS SPECIES CULTIVATED UNDER DIFFERENT LIGHT AND SOIL CONDITIONS IN MAPLE FORESTS OF THE EASTERN TOWNSHIPS IN QUÉBEC, CANADA

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Abstract: Many understorey plants have either medicinal or ornamental properties. Because of the high cost of production under conventional cultivation practices, most of the plants that make it to the market are harvested in their natural habitat, putting the natural populations at risk. This study is aimed at assessing the impact of canopy opening and soil conditions on the growth of three ornamental species: *Adiantum pedatum*, *Matteuccia struthiopteris*, and *Trillium grandiflorum*, and on the growth and production of active components of four medicinal plants: *Actaea racemosa*, *Asarum canadense*, *Caulophyllum thalictroides*, and *Sanguinaria canadensis*. Rhizome cuttings were planted in the fall of 2003 in two sugar maple forests. Mortality and total leaf area were monitored during the following three years and subplots were harvested at the end of the second year for biomass and active component analyses. Multiple regressions indicated that all species, except *Matteuccia* and *Trillium*, were either responding to soil pH or aluminium concentration. None of the species responded positively to soil richness but all were affected by the presence of elements such as aluminium or sodium. Growth increased with irradiance in nearly all species, indicating that forest openings could be part of an appropriate forest management plan for their cultivation. Concentration of active components in the medicinal plants was not influenced by the environmental conditions, while their total content was mainly influenced by light. Thus, it seems that soil and light conditions that favour the growth of these medicinal plants also favour their total yield in active components.

Key Words: Forest farming, medicinal plants, ornamental plants, shade, soil pH.

ECOPHYSIOLOGY OF THE CHANTERELLE AND LOBSTER MUSHROOM IN THE EASTERN CANADIAN BOREAL FOREST

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Abstract: Boreal forest trees rely on symbiotic ectomycorrhizal fungi for their survival and the fruit bodies of many of these are edible. Moreover, it has been estimated that the boreal forest of Eastern Canada produces thousands of tons of edible forest mushrooms annually. There is the potential to simultaneously manage the commercial exploitation of this resource and of mature trees present at the same location. However, before doing so, more information about the ecology of the species of interest is needed. Two valuable fungal species: chanterelle (*Cantharellus cibarius*) and lobster mushroom (*Hypomyces lactifluorum* + *Russula* spp.) where chosen for this study. Our current research aims to: 1) define the spatial distribution of the chanterelle fruit bodies relative to different environmental factors, 2) establish the physiological relation between chanterelle production and the carbon allocation pattern of the host tree, and 3) determine how the canopy cover influences the distribution and fructification of lobster mushrooms.

During the first two years of the project, lobster mushroom and chanterelle colonies were studied in a Jack pine (*Pinus banksiana*) stand. For each colony, stand composition and structure were recorded, together with associated vegetation, age, soil characteristics and meteorological data. These data permitted the selection of a limited number of ecological characteristics that explain the distribution of the lobster mushroom. We also developed an experimental design in order to link seasonal tree growth and root respiration to sporocarp production. We hypothesised that chanterelles only produce sporocarps after host tree growth has stopped and when all needs are satisfied.

Key Words: Agroforestry, boreal forest, commercial harvest, ecophysiology of ectomycorrhiza, forest management, forest mushroom ecology, mycoforestry.

LA CULTURE DE LA MÉDÉOLE DE VIRGINIE EN SOUS-BOIS D'ÉRABLIÈRE

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Résumé : La médéole de Virginie (*Medeola virginiana*) est une plante indigène que l'on retrouve dans le sous-bois des érablières à bouleau jaune et hêtre. Son rhizome est comestible et pourrait augmenter le potentiel économique des érablières si cette plante était exploitée comme un produit forestier non ligneux. Le but de cette étude est de développer une culture durable de la médéole de Virginie. Un dispositif expérimental a été installé de mai à septembre 2006 dans une érablière située dans le Nord-Ouest du Nouveau-Brunswick afin d'identifier le microenvironnement favorisant la croissance et la propagation du rhizome en sous-bois. Pour ce faire, cinq traitements ont été appliqués afin de modifier la température du sol et la quantité de lumière reçue (paillis noir, scarifiage du sol, scarifiage du sol avec planche de 15 cm de hauteur, ombrière et témoin). Une seconde expérience a débuté à l'automne 2006 afin de déterminer si la taille du rhizome mère et la position des bourgeons sur le rhizome influencent la taille des rhizomes fils. Pour ce faire, les bourgeons provenant des rhizomes de différentes tailles seront utilisés pour la propagation in vitro de la médéole. Les résultats concernant le nombre de rhizomes fils, l'augmentation de la biomasse des rhizomes fils en sous-bois seront discutés de même que la pertinence d'utiliser la culture in-vitro pour favoriser la propagation végétative du rhizome.

Mots-clés : *Medeola virginiana*, culture in vitro, plantes comestibles, produit forestier non ligneux, propagation végétative.

EXPÉRIMENTATION DU CONCEPT DE PRODUCTION FORÊT/BLEUET DANS UN MODÈLE DE GESTION INTÉGRÉE DES RESSOURCES AU SAGUENAY–LAC-SAINT-JEAN

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Résumé : Le concept forêt/bleuet en bandes alternées a été élaboré dans le but de maximiser le rendement de deux ressources (forêt et bleuet) sur une même unité de surface. Toutefois, comme ce concept est novateur, un projet de recherche a été élaboré, afin de valider les hypothèses concernant les avantages et les inconvénients du modèle et de l'optimiser.

Deux orientations et quatre combinaisons de largeurs de bandes sont expérimentées sur le territoire de la Corporation d'aménagement forêt Normandin (CAFN), afin de cibler le modèle qui permettra d'atteindre un rendement optimal en forêt et en bleuet. Plusieurs projets d'étude sont menés à l'intérieur des volets agricole, forestier et environnemental. Au niveau agricole, les essais serviront à déterminer l'impact des différents modèles d'aménagement (largeur de bande et orientation) sur les conditions agroclimatiques à l'intérieur des bandes de bleuets, sur la productivité du bleuet et sur la population de butineurs indigènes. Au niveau forestier, des essais permettront de mesurer l'impact des différents modèles d'aménagement sur la ressource forêt et sur l'effet chablis, et ce, afin de déterminer le modèle permettant de minimiser les pertes de matière ligneuse. Au niveau environnemental, les essais serviront à évaluer l'impact de l'aménagement forêt/bleuet sur la faune et son habitat. L'évolution des pesticides dans l'environnement est également évaluée.

Mots-clés : Expérimentation, forêt, bleuet, gestion intégrée, optimisation, validation, modèle d'aménagement

Abstract: The forest-blueberry concept was developed in order to maximise the yield of both natural resources (forest and blueberries) using the same unit of production area. The objectives of the project are to validate certain hypotheses concerning the advantages and disadvantages of forest-blueberry production in alternate strips and to optimize the yield of such a production.

Two field orientations and four strip widths are being evaluated at the Corporation d'aménagement forêt Normandin (CAFN) in order to determine which model can achieve an optimal yield of both forest and blueberry. Various studies with respect to agriculture, forestry and the agro-environment are being undertaken. At the agricultural level, the trials are being used to determine the impact of various landscaping models (strip width and orientation) on the agro-climatic conditions in the blueberry strips, on blueberry productivity and on the population of indigenous pollinators. At the forestry level, the trials are being used to measure the impact of the different landscaping models on the forest resource and on the effect of natural factors (wind, storms, snow, etc.) on the tree stand in order to determine the model that minimizes the loss of ligneous material. At the environmental level, the trials are being used to evaluate the impact of the different forest-blueberry landscaping models on wildlife and their habitat. The fate of pesticides in the environment is also being evaluated.

Key Words: Experimentation, forest, blueberry, integrated management, optimisation, validation, installation model.

MISE EN SITUATION

Le concept de production forêt/bleuet a été élaboré dans le but de permettre la mise en valeur de deux ressources (forêt et bleuet) sur une même unité de surface. Pour y parvenir, la Corporation d'aménagement forêt Normandin (CAFN) a élaboré un modèle en bandes alternées qui permet le maintien de la possibilité forestière, tout en favorisant le développement de nouvelles bleuetières.

Agrinova, un centre collégial de transfert technologique, et l'Agence de gestion intégrée des ressources (AGIR) mènent actuellement un projet qui vise à expérimenter le concept de production de type forêt/bleuet. Ce projet de recherche se déroule sur le site de la CAFN et couvre une superficie de plus de 400 hectares.

Comme le concept est nouveau, il était nécessaire d'effectuer de l'expérimentation afin de connaître les impacts de ce type d'aménagement sur la production de bois et de bleuets. Également, le projet de recherche permettra de comparer différentes largeurs de bandes de bleuets et de forêt de même que différentes orientations. Ainsi, jusqu'en 2009, plusieurs paramètres seront évalués, et ce, dans le but de connaître le modèle qui permet d'atteindre un rendement optimal en matière ligneuse et en bleuet.

Ce type d'aménagement étant basé sur le principe de la gestion intégrée, toutes les ressources ont été considérées. Ainsi, des données seront recueillies non seulement sur la forêt et le bleuet, mais également sur la faune, la flore et l'environnement.

OBJECTIFS

L'objectif principal de ce projet de recherche est de valider et d'optimiser le concept de production forêt/bleuet en bandes alternées. Les objectifs spécifiques sont les suivants :

- connaître les impacts de ce nouveau mode d'aménagement sur la production de bois et de bleuets;
- comparer différentes largeurs de bandes de bleuet et de forêt de même que différentes orientations;
- connaître le modèle qui permet d'atteindre un rendement optimal en matière ligneuse et en bleuet.

DESCRIPTION DU PROJET DE RECHERCHE

Dispositif expérimental

Le dispositif expérimental implique différentes orientations des bandes de forêt et de bleuet de même que différentes largeurs de bandes. Deux types d'orientation sont retenus, soit nord/sud et nord-est/sud-ouest. Ces orientations ont été choisies en fonction des vents dominants et de la topographie du terrain.

Au niveau de la largeur des bandes, plusieurs combinaisons ont été sont considérées. Le modèle théorique (42 m de forêt et 60 m de bleuets) est le résultat de la réflexion d'un comité interministériel. La largeur de la bande bleuet est, pour une raison pratique, un multiple de 15 m, alors que la bande forêt doit être divisible par 3. Les combinaisons suivantes seront expérimentées (respectivement forêt et bleuet) :

- 42 m/60 m : Ce ratio représente le modèle de base qui a été élaboré compte tenu de la largeur minimale de forêt et de la largeur optimale de bleuets, selon les experts gouvernementaux. Avec ce modèle, la forêt occupe 41 % du territoire.
- 42 m/45 m : Ce modèle porte à 48 % l'occupation de la forêt sur le territoire. Il permet d'augmenter la possibilité forestière et, potentiellement, de maintenir la productivité de bleuets par une augmentation des impacts de proximité, comme l'effet radiant.
- 60 m/60 m : Ce ratio permettra de voir, par rapport au modèle de base, si l'augmentation de la largeur de la bande boisée permet d'augmenter les rendements globaux en forêt, sans pour autant réduire la productivité en bleuets. Ce modèle porte à 50 % l'occupation forêt sur un territoire donné.
- 60 m/45 m : Ce ratio permettra de voir l'effet combiné d'une augmentation de la largeur de la bande forestière et d'une diminution de la largeur de la bande de bleuets sur les rendements globaux par rapport au modèle de base. Ce modèle porte à 57 % l'occupation forêt sur le territoire.

Axe de recherche # 1 – Optimisation forestière

Inventaire préliminaire

Dans un contexte de gestion intégrée des ressources, l'inventaire vise à acquérir un ensemble de données forestières et écologiques précises du territoire étudié afin d'analyser les possibilités d'optimisation de la production forestière. Le premier élément de contenu est l'aspect du maintien de la possibilité forestière, de la mesure du rendement forestier et de la valeur marchande de la matière première. Suite à l'aménagement du dispositif expérimental, des inventaires seront réalisés afin de déterminer les éléments de structure, de composition et de rendement de la ressource, et ce, pour la totalité des parcelles aménagées.

Afin de mesurer les impacts possibles de même que les « performances » du modèle à l'étude, les caractéristiques forestière et écologique du territoire à l'étude doivent être connues. L'objectif de l'inventaire est donc de procéder à la détermination du « type écologique » qui correspond à la caractérisation de la capacité de support d'un milieu donné**.** Les données de base de l'inventaire forestier seront déterminées comme suit : stratification et caractéristiques du peuplement, structure du peuplement, origine et perturbations passées, régime hydrique, composition par strates et recouvrement des graminées, du carex, des sphaignes et de la mousse.

Étude du rendement forestier et des effets du mode de production

Une étude réalisée par le ministère des Ressources naturelles, de la Faune et des Parcs a démontré qu'il était théoriquement possible de maintenir la possibilité forestière d'un peuplement naturel avec le concept forêt/bleuet, et ce, par l'intensification de l'aménagement sur la portion forêt. Les données théoriques doivent donc être validées.

L'aspect de valeur ajoutée fait référence à la capacité d'augmenter la valeur marchande de la ressource forestière en regard des produits à en tirer. En effet, l'aménagement en bandes constitue un nouveau type d'aménagement physique où l'accès à la ressource forêt sera modifié. Cette approche pourrait constituer un avantage en permettant la production de produits à plus forte valeur ajoutée, par exemple du bois destiné à la production de poteaux. D'un autre côté, l'effet de bordure créé par le morcellement de la forêt pourrait favoriser le « branchage » des tiges en bordure, un facteur ayant une influence négative sur la qualité du bois.

L'hypothèse de travail est la suivante : le concept forêt/bleuet permet le maintien de la possibilité forestière ou de la valeur commerciale au même niveau que la moyenne des peuplements forestiers naturels en place, sans la présence de bleuetières.

L'objectif est donc d'étudier l'effet de la largeur et de l'orientation des bandes boisées et de leur aménagement sur la production forestière. Ainsi, un suivi des travaux sylvicoles sera réalisé afin de vérifier les hypothèses de rendement forestier dans les bandes boisées.

Mesure de l'effet chablis

Comme la création de bandes forestières entraîne des risques de chablis des tiges par exposition aux vents latéraux, il était nécessaire de mesurer l'impact de ce phénomène « naturel ». L'hypothèse de travail est que la vulnérabilité au chablis varie en fonction de l'orientation et de la largeur de bandes dans le concept forêt/bleuet.

Le dénombrement du nombre de tiges et des volumes affectés par le chablis permettra de déterminer les combinaisons d'orientation et de largeur de bandes qui permettent de minimiser les pertes de matière ligneuse causées par le chablis.

Axe de recherche # 2 – Optimisation agricole

Étude de variation des conditions agroclimatiques de production

Les facteurs climatiques sont des éléments qui influencent grandement les rendements en bleuetières. Qu'il s'agisse du gel printanier ou automnal, de l'ensoleillement, de la température de l'air au niveau des plants ou de l'indice d'assèchement, tous ces paramètres peuvent être influencés par la disposition en bandes dans le concept forêt/bleuet.

Le gel tardif printanier ou hâtif à l'automne demeure un des principaux facteurs pouvant nuire grandement à la productivité des bleuetières. Parmi les aspects agroclimatiques, l'effet radiant des bandes de forêt est un facteur identifié comme pouvant influencer positivement la productivité des bleuetières. L'hypothèse de travail est que l'arrangement spatial des bandes (orientation et largeur) à l'intérieur du concept forêt/bleuet influence les conditions agroclimatiques (température, humidité et couverture nivale). En retour, ces dernières peuvent influencer la productivité des bleuetières.

L'objectif est de déterminer les combinaisons d'orientation et de largeur de bandes permettant d'obtenir les conditions agroclimatiques les plus propices au développement d'une bleuetière productive.

Impact du mode de production forêt/bleuet sur la productivité du bleuet

L'hypothèse de travail est la suivante : une bleuetière aménagée selon le modèle forêt/bleuet permet d'assurer une rentabilité pour la production de bleuets. L'objectif est donc de déterminer les combinaisons d'orientation et de largeur des bandes permettant d'obtenir les meilleurs rendements de bleuets. Le dénombrement des tiges et des bourgeons de même que la mesure du rendement permettront également de comparer la productivité d'une bleuetière de type forêt/bleuet par rapport à une bleuetière conventionnelle.

Axe de recherche # 3 - impact sur la faune et son habitat

Étude de la faune et de la flore

L'aménagement du territoire contribuera à la différenciation de l'habitat. Ainsi, cet aménagement agroforestier risque de réduire la capacité de maintenir les populations fauniques des sites en question. Cependant, l'aménagement de forêt/bleuet devrait permettre de conserver un habitat de meilleure qualité que les bleuetières conventionnelles où le milieu est totalement perturbé.

L'objectif est d'évaluer les impacts de l'aménagement forêt/bleuet sur la faune et son habitat en comparaison avec des témoins non aménagés (pinèdes grises) ou aménagés (bleuetières conventionnelles).

À partir des résultats obtenus, il sera donc possible d'évaluer à quel point les groupes fauniques étudiés et leur habitat sont affectés par ce nouveau type de production de bleuets et ainsi proposer des façons pour minimiser les impacts de cet aménagement. De plus, ces inventaires permettront de vérifier la présence et la nidification d'espèces aviaires rares et, par la suite, des moyens pourront être proposés afin d'assurer leur présence sur le territoire étudié.

Suivi des pesticides dans l'environnement

L'aménagement et l'exploitation d'une bleuetière à des fins commerciales nécessitent l'utilisation de pesticides pour éliminer ou réduire les espèces végétales compétitrices aux plants de bleuets. Toutefois, le recours à des pesticides pour l'exploitation commerciale d'une bleuetière est une pratique susceptible de contaminer les nappes d'eau en aval hydraulique du lieu d'épandage.

Les techniques d'épandage de pesticides sur les sols, la très grande solubilité de ces produits et leur persistance (faible biodégradabilité) ont pour effet d'induire une contamination des nappes d'eau de type libre sous-jacentes à la bleuetière. L'écoulement des nappes d'eau a pour conséquence de transporter les contaminants jusqu'à un point de résurgence qui confirme le passage du contaminant à un écosystème nouveau (milieu humide, lac et rivière).

L'objectif est de suivre l'évolution des pesticides dans l'environnement à la suite de leur utilisation dans un contexte de production de bleuets sous le concept forêt/bleuet et d'évaluer des pratiques pouvant permettre une réduction de l'utilisation des pesticides.

Axe de recherche # 4 – Optimisation du milieu de production

Optimisation de la pollinisation

La productivité du bleuetier repose sur un ensemble de facteurs qui doivent être optimisés, dont la pollinisation. En effet, la pollinisation représente une étape clé dans la production du bleuet et celle-ci doit être efficace afin de favoriser la plus grande mise à fruit du plant.

L'objectif est d'analyser l'incidence du mode de production forêt/bleuet sur la population de butineurs indigènes et de mesurer l'impact de cette population sur la mise en fruit du bleuetier.

Effet du mode gestion des résidus de coupe forestière

La gestion des résidus forestiers lors de l'aménagement des bleuetières influence l'implantation naturelle du bleuetier et sa croissance. L'hypothèse de travail est que les résidus de la coupe forestière laissés sur place lors de l'implantation des bandes de bleuets ne nuisent pas au développement des plants de bleuets. Le fait de laisser les résidus de coupe forestière sur place permettrait également une réduction des travaux lors de l'aménagement et, par conséquent, une réduction des coûts d'aménagement.

Lors de l'aménagement, deux modes de gestion des résidus de la coupe forestière sont envisageables. Il est possible d'enlever les résidus de la parcelle de bleuets ou de les déchiqueter et les répartir sur le sol. L'objectif est donc de comparer ces deux modes de gestion des résidus de coupe forestière.

Résultats attendus

Au niveau forestier, le projet de recherche permettra de mesurer l'impact des différents modèles sur la ressource forêt, en plus de déterminer le modèle qui permet de minimiser les pertes en matière ligneuse.

Au niveau agricole, le projet permettra de mesurer les conditions agroclimatiques à l'intérieur des bandes de bleuets, de déterminer la productivité du bleuet en fonction des modèles, d'analyser l'incidence des différents modèles sur la population de butineurs indigènes et de comparer deux modes de gestion des résidus de coupe forestière lors de l'aménagement des bandes de bleuets.

Au niveau environnemental, le projet permettra de mesurer l'impact des différents modèles sur la faune et son habitat et d'effectuer un suivi des pesticides dans l'environnement.

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CULTURE DE L'ASARET DU CANADA EN VUE DE LA PRODUCTION D'HUILE ESSENTIELLE

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Résumé : L'*Asarum canadense*, asaret du Canada ou gingembre sauvage, est une plante commune des érablières du centre et du sud-est du Canada dont le rhizome a une forte saveur de gingembre et contient une huile essentielle très aromatique, recherchée en aromathérapie médicinale et en parfumerie.

L'objectif du projet est de mettre au point des méthodes de domestication et de culture de l'asaret en vue d'augmenter la productivité et la commercialisation de cette huile essentielle.

Le projet a démarré au printemps 2004 par la transplantation de 50 plants d'asaret sur chaque parcelle de 16 m^2 dans des érablières à La Pocatière, Cap-St-Ignace, Pohénégamook et Grondines. Le site de La Pocatière a été choisi en fonction d'obtenir trois intensités lumineuses différentes.

Le comportement des transplants a été suivi tout au cours des trois étés. La récolte de certains plants a été effectuée pour permettre d'estimer la croissance des plantules au cours de chaque saison. Les meilleurs rendements ont été obtenus au site de 25 % d'ombre de La Pocatière pour des poids par rhizome de 8,3 g, 13,7 g et 26,8 g respectivement pour les récoltes de la 1[ière], 2[ième] et 3[ième] année.

Mots-clés : Asaret, gingembre sauvage, *Asarum canadense*, agroforesterie, culture.

Abstract: *Asarum canadense,* asaret of Canada or wild ginger, are a common plant of the maple grove of the center and south-east of Canada whose rhizome has a strong flavour of ginger and contains a very aromatic essential oil, required in aromatherapy, medicinal and perfumery.

The objective of the project is to develop methods of domestication and culture of the asaret in order to increase the productivity and the marketing of this essential oil.

The project started in spring 2004 by the transplantation of 50 seedlings of asaret on each piece of 16 m2 in a maple grove in Pocatière, Cape-St-Ignace, Pohénégamook and Grondines. The site of La Pocatière was selected according to obtaining three different light intensities.

The behavior of the transplants was followed all during three summers. The harvest of certain seedlings was carried out to make it possible to estimate the growth of the seedlings during each season. The best outputs were obtained with the site of 25% of shade of Pocatière for weights by rhizome of 8,3 g, 13,7 g and 26,8 g respectively for harvests of 1st, 2nd and 3rd year.

Key Words: Asaret, wild ginger, *Asarum canadense*, agroforestry, culture.

INTRODUCTION

L'*Asarum canadense,* asaret du Canada ou gingembre sauvage, est une plante herbacée vivace densément pubescente à rhizome ramifié qui pousse à l'état indigène dans les forêts décidues riches du sud du Québec et de l'est des États-Unis (Marie-Victorin 1995; Lamoureux 2002). Les feuilles au nombre de deux, réniformes, de 10 à 18 cm de diamètre, issues directement du rhizome forment souvent un tapis dense et bas au sol.

Le secteur des plantes médicinales est en plein essor partout dans le monde. En Amérique du Nord, la tendance s'observe avec la hausse de leur présence dans la composition de médicaments thérapeutiques en vente libre ainsi que dans l'augmentation des récoltes dans leur milieu naturel. Parmi ces plantes, on retrouve des espèces sciaphytes poussant dans les forêts canadiennes (Lapointe 2007).

Le marché des produits forestiers non ligneux produits en érablière s'inscrit dans la croissance d'un secteur en hausse de 4 à 5% par année partout en Occident (Duchesne et Wetzel. 2003). Dans un concept de culture sous couverts forestiers, la productivité des érablières pourrait générer 55 millions de dollars d'ici la fin de la première décennie, ce qui pourrait représenter une répartition du supplément moyenne de 5 524 $ par acériculteur canadien (Duchesne et al. 2003). De plus, cette plante bien adaptée au milieu ombragé est très jolie et intéresse le milieu horticole : on commence à l'apercevoir dans les centres de jardin et certaines pépinières spécialisées ont commencé à la multiplier en quantité.

Les conditions propices à la croissance de l'asaret gingembre ne se rencontrent que dans les érablières riches et humides du sud du Québec. Bien que sa disparition ne soit pas appréhendée pour le moment, plusieurs facteurs contribuent à sa raréfaction: le broutage par le cerf de Virginie, la coupe forestière, certaines pratiques non appropriées d'aménagement forestier et la destruction de son habitat résultant du développement urbain et agricole. Le prélèvement de spécimens entiers aux fins du commerce de l'horticulture ou de l'alimentation exerce également une pression non négligeable sur les populations sauvages de l'espèce. Comme il faut plusieurs années à un plant pour atteindre une taille intéressante pour le commerce, il est tentant pour les fournisseurs de s'approvisionner directement en milieu naturel. En effet, la culture en serre ou tout autre moyen de propagation en milieu contrôlé sont plus coûteux.

Depuis 2005, l'asaret gingembre bénéficie, à titre d'espèce vulnérable, d'une protection juridique au Québec. Les interdictions relatives à cette espèce se limitent toutefois à la récolte de plus de cinq spécimens entiers ou parties souterraines en milieu naturel et à la vente d'un seul de ces spécimens. Selon les données du réseau NatureServe, l'asaret gingembre serait vulnérable au Manitoba. Aux États-Unis, on considère qu'il est très menacé en Louisiane et dans le Maine, menacé dans le Mississipi, le Nebraska et le Dakota du Sud et qu'il est vulnérable en Illinois et dans le Kansas.

MATÉRIEL ET MÉTHODES

Matériel végétal

Les plants d'asaret au stade de 2 à 3 feuilles provenant de chez Horticulture Indigo s.e.n.c. d'Ulverton Qc (www.horticulture-indigo.com) ont été transplantés à la fin de mai ou de juin de chaque année. Le projet a démarré au printemps 2004 par la transplantation de 50 plants d'asaret dans chaque parcelle de 16 m^2 dans des érablières de la région du Bas-Saint-Laurent et des Appalaches, soit à La Pocatière (47^o 20' 35.096''N, 70^o 01' 19.823''O, altitude 85 m), Cap Saint-Ignace (46^o 58' 29.098''N, 70^o 19' 59.405''O, altitude 360 m) et Pohénégamook (47^o 28' 51.299''N, 69^o 08' 54.363''O, altitude 360 m). Le site de La Pocatière (Lap) a été choisi en fonction d'obtenir trois intensités lumineuses différentes, soit environ 25 %, 55 % et 90 % d'ombre. Les parcelles à Cap Saint-Ignace (Cap) et à Pohénégamook (Pohé) ont été établies dans des érablières en opération et le taux d'ombre était semblable à celui de La Pocatière à 55 %. Le comportement des transplants a été suivi tout au cours de chaque été par des relevés d'observations visuelles, de la transplantation à la collecte des derniers échantillons à la mi-octobre. La récolte de 3 plants par parcelle a été effectuée pour permettre d'estimer la croissance des plantules au cours de chaque année et d'en analyser le contenu en huile essentielle. Les rendements en huile essentielle sont calculés sur les poids des rhizomes séchés.

RÉSULTATS

Les meilleurs rendements ont été obtenus dans les parcelles du site de La Pocatière ayant les taux d'ombre de 25 % et 55 % (Tableau 1). Pour la parcelle de 25 % d'ombre, le poids des rhizomes récoltés double chaque année passant de 24 g à 41 g et à 80 g respectivement pour les récoltes de la première, deuxième et troisième année (Fig. 1).

Les rendements dans la parcelle à 90 % d'ombre de La Pocatière furent très décevants à cause surtout du ravage fait par les limaces qui ont grignoté les feuilles de plus de la moitié de la parcelle dès la première année de l'implantation.

Tableau 1 : Poids des rhizomes et rendement en huile de 2004 à 2006.

	2004			**2005**			**2006**		
	Rhiz.	**huile**		**Rhiz.**	**huile**		**Rhiz.**	**huile**	
Lieu	g	g/m^2	%	g	g/m^2	%	g	g/m^2	%
Lap 25%	24.76	0.10	**1.84**	41.18	0.28	**2.95**	80.39	0.68	**3.22**
Lap 55%	25.21	0.11	**2.31**	36.79	0.17	**2.20**	81.11	0.63	**2.79**
Lap 90%	5.90	0.02	**2.25**	6.35	0.03	**2.85**	20.14	0.15	**2.95**
Cap 55%	10.62	0.05	**1.87**	13.91	0.10	**3.06**	11.48	0.10	**3.10**
Pohé 55%	18.36	0.05	**1.40**	25.10	0.19	**3.31**	28.13	0.25	**3.39**
Grond 50%	n/a	n/a	**n/a**	21.85	0.11	**2.20**	42.91	0.30	**2.87**

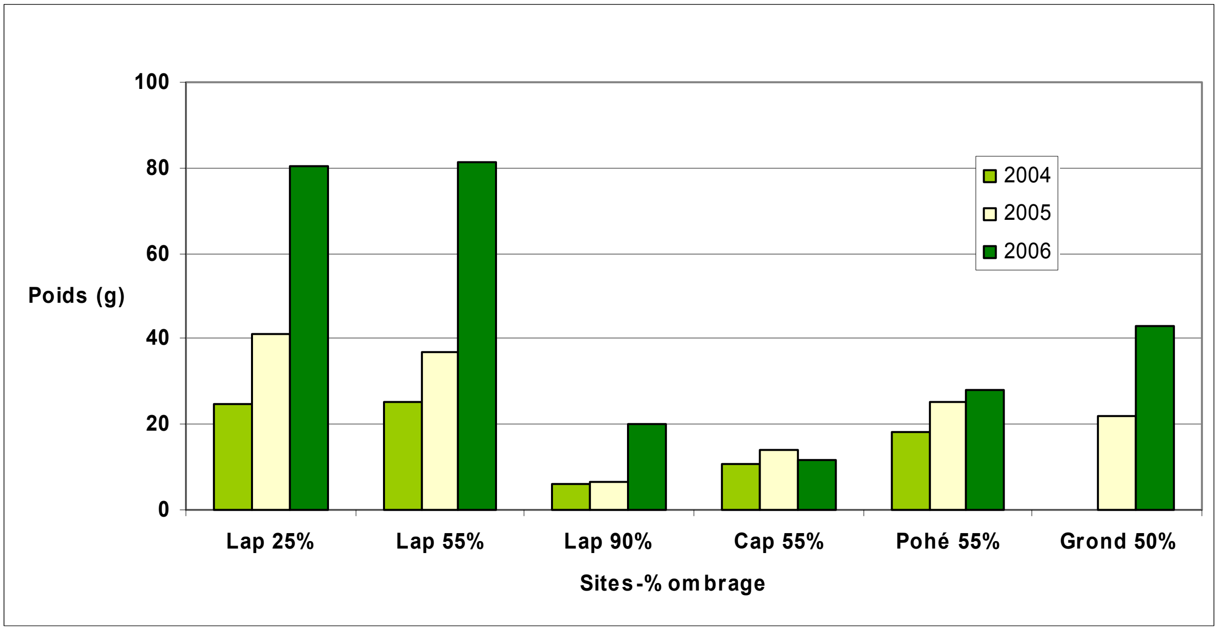

Fig. 1 : Poids des rhizomes récoltés à chaque site pendant les trois années[1]

Les plants d'asaret de Cap Saint-Ignace et Pohénégamook avec 55 % d'ombre ont donné des rendements nettement inférieurs à ce qui était attendu. Après la troisième année, le rendement en poids de trois rhizomes était de moins de 12 g à Cap Saint-Ignace et de 28 g à Pohénégamook. Le sol dans l'érablière de Cap Saint-Ignace était mince et enchevêtré de racines, ce qui laissait peu de place pour la croissance des asarets à cet endroit. La cause des rendements plus bas rencontrés dans les parcelles de l'érablière de Pohénégamook peut être due en partie à l'altitude de 380 mètres à cet endroit, ce qui fait que la saison végétative est plus courte et qu'il y a des gels printaniers tardifs en montagne. On a remarqué que le feuillage au cours de la troisième année était fragmenté et cela était peut-être à causé par des gels tardifs au printemps lors de la formation des feuilles.

Le rendement en huile essentielle augmente d'année en année atteignant en moyenne 3% lors de la troisième année (Fig. 2). Par contre, si le rendement est mesuré en fonction de la surface de production, ces rendements sont nettement différents et reflètent la production qu'on peut estimer d'une parcelle (Fig. 3). Les deux parcelles de La Pocatière pourraient produire jusqu'à 0,68 g/m^2 trois ans après l'implantation. Ce rendement est de six fois inférieur à Cap Saint-Ignace et de deux fois et demie inférieur à Pohénégamook.

On peut espérer que la quantité d'asaret sous forme de rhizomes va doubler à chaque année dans des conditions favorables comme dans les parcelles de La Pocatière à 25 % et 55 % d'ombre.

[1] Cette figure est en couleur dans la version électronique des Actes (CD)

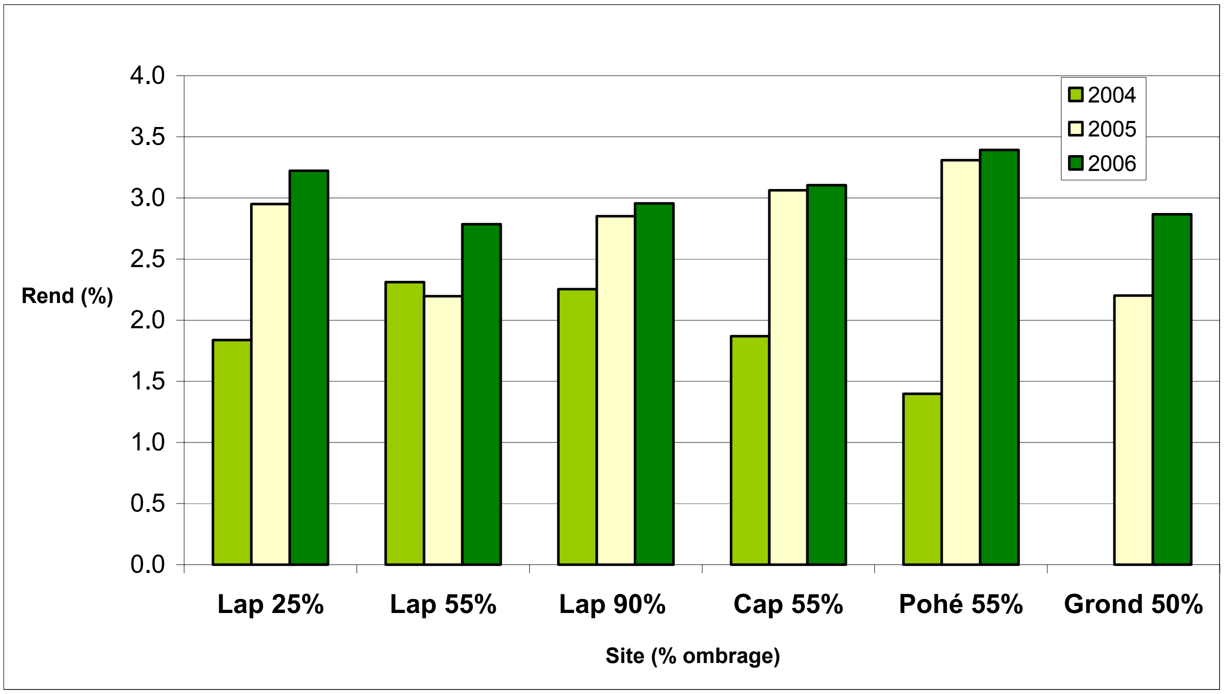

Fig. 2 : Rendement de l'huile essentielle d'asaret.[1]

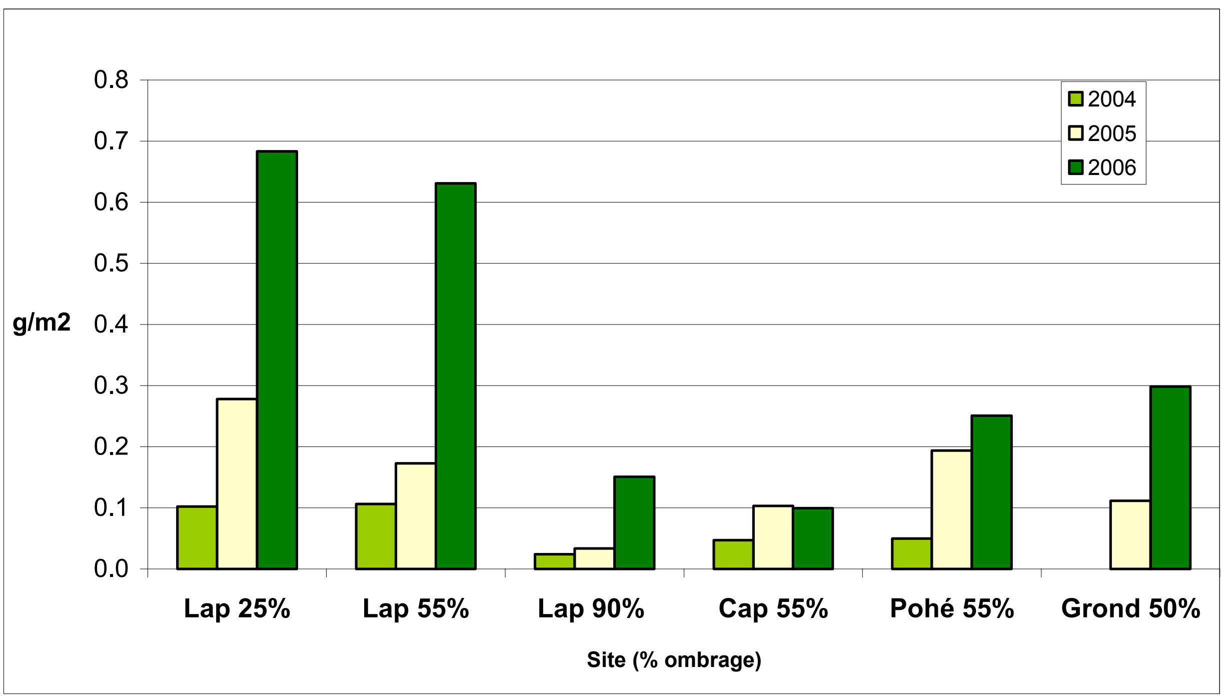

Fig. 3 : Rendement de l'huile essentielle par unité de surface.[1]

[1] Cette figure est en couleur dans la version électronique des Actes (CD)

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VARIATION DE LA COMPOSITION DE L'HUILE ESSENTIELLE D'*ASARUM CANADENSE* CULTIVÉ SOUS CANOPÉE FORESTIÈRE

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Résumé : L'*Asarum canadense*, asaret du Canada ou gingembre sauvage, est une plante commune des érablières du centre et du sud-est du Canada dont le rhizome a une forte saveur de gingembre et contient une huile essentielle très aromatique, recherchée en aromathérapie médicinale et en parfumerie.

Les analyses des huiles ont été effectuées par chromatographie gazeuse (GC) et confirmées par chromatographie gazeuse couplé à la spectrométrie de masse. La composition chimique de l'huile essentielle des plants d'asaret qui ont été transplantés dans des érablières de La Pocatière, Cap-St-Ignace, Pohénégamook et Grondines a été suivie au cours des trois années. La récolte de certains plants a été effectuée pour permettre d'estimer la croissance des plantules au cours de chaque saison ainsi que la composition de l'huile essentielle du rhizome.

Dans les rhizomes, on retrouve majoritairement des monoterpènes tel que le méthyl eugénol et le linalol qui caractérisent cette huile essentielle ainsi que des notes très aromatiques conférées par les acétates de géranyle, bornyle, néryle et linalyle. Le méthyl eugénol varie de 53,8 % à 73,1 % et le linalol varie de 3,9 % à 17,4 % selon l'âge de la plante, son emplacement et le taux de lumière reçue.

Mots-clés : Asaret, gingembre sauvage, *Asarum canadense*, huile essentielle, agroforesterie.

Abstract: *Asarum canadense*, Wild Ginger or Canada Snakeroot, are a common plant of the maple grove of the center and south-east of Canada. The rhizome has a strong flavour of ginger and contains a very aromatic essential oil, which is used in aromatherapy or natural medicine and perfumery.

The analyses of the oils were carried out by gas chromatography (GC) and were confirmed by gas chromatography coupled with mass spectrometry. The chemical composition of the essential oils of the seedlings of asaret transplanted in maple groves at La Pocatière, Cap-St-Ignace, Pohénégamook and Grondines were followed during three years. The harvest of some plants was carried out to evaluate the growth of the plant during each season as well as the composition of the essential oil of the rhizome.

The chemical compositions of the essential oil of the rhizomes are mainly monoterpenes such as methyl eugenol and linalool. The characteristic of this essential oil as well as the very aromatic notes are conferred by geranyl, bornyl, neryl and linalyl acetate. Methyl eugenol varies from

53.8% to 73.1% and the linalool varies from 3.9% to 17.4% according to the age of the plant, the site and the rate of light received.

Key Words : Asaret, wild ginger, *Asarum canadense*, essential oil, agroforestry.

INTRODUCTION

L'*Asarum canadense,* asaret du Canada ou gingembre sauvage, est une plante herbacée vivace densément pubescente à rhizome ramifié qui pousse à l'état indigène dans les forêts décidues riches du sud du Québec et de l'est des États-Unis (Marie-Victorin 1995; Lamoureux 2002). C'est une plante commune des érablières du centre et du sud-est du Canada dont le rhizome a une forte saveur de gingembre et contient une huile essentielle très aromatique, recherchée en parfumerie et en aromathérapie médicinale. On utilise l'asaret contre les malaises dus à la grippe et au rhume. Il soulage les gaz intestinaux et favorise la sudation.

Les deux molécules se trouvant en plus forte concentration dans l'*A. canadense* sont le méthyl eugénol (44 %) et l'acétate de linalyle (41 %; Locock 1995). Le méthyl eugénol aurait des propriétés sédatives et narcotiques (MacGregor et Layton 1974). D'autres ont rapporté que cette molécule a, entre autres, des propriétés anesthésiques, anticonvulsives, antiseptiques, bactéricides, préventifs du cancer, antifongiques, insecticides et myorelaxants (Duke 2004). L'acétate de linalyle, aussi présent en forte concentration dans l'huile de lavande et dans l'huile de bois de rose, entre dans la composition des parfums incorporés dans les savons, détergents, crèmes et lotions. Les autres molécules, en faible concentration, sont le géraniol, le linalool, l'alpha terpinol, l'acétate de bornyle, l'élémicine et l'acide aristolochique (Locock 1995). Ce dernier, présent dans la plante sous forme d'acide aristolochique I et II, serait néphrotoxique (U.S. Food and Drug Administration 2000; 2001; Arlt et al. 2002). Certaines sources affirment qu'il pourrait être à la fois cancérigène et anticancérigène. Les indigènes l'utilisaient comme abortif. La plus forte concentration en composés secondaires se trouve dans le rhizome (Duke 2004). Jusqu'à maintenant, aucune étude a été faite sur le temps de l'année le plus favorable à la récolte pouvant donner la plus forte teneur en ces composés.

MATÉRIEL ET MÉTHODES

Matériel végétal

Les plants d'asaret provenant de chez Horticulture Indigo s.e.n.c. d'Ulverton Qc (www.horticulture-indigo.com) ont été transplantés au stade de 2 à 3 feuilles à la fin de mai ou de juin de chaque année. Le projet a démarré au printemps 2004 par la transplantation de 50 plants d'asaret dans chaque parcelle de 16 m^2 dans des érablières de la région du Bas-Saint-Laurent et Appalaches, soit à La Pocatière, Cap Saint-Ignace, Pohénégamook. Le site de La Pocatière (Lap) a été choisi en fonction d'obtenir trois intensités lumineuses différentes, soit environ 25 %, 55 % et 90 % d'ombre. Les parcelles à Cap Saint-Ignace (Cap) et à Pohénégamook (Pohé) ont été établies dans des érablières en opération et le taux d'ombre était semblable à celui de La Pocatière à 55 %. Le comportement des transplants a été suivi tout au cours de chaque été par des relevés d'observations visuelles, de la transplantation à la collecte des derniers échantillons à la mi-octobre. La récolte de trois plants par parcelle a été effectuée pour permettre d'estimer la croissance des plantules au cours de chaque saison et d'en analyser le contenu en huile essentielle.

Traitement après récolte

Trois plantes entières avec les rhizomes et les racines ont été arrachées puis lavées à l'eau. Les racines et les rhizomes ont été séparés, pesés puis séchés dans une étuve à courant d'air forcé à 32 °C pendant 24 heures. Les racines et les rhizomes ont été extraits par la méthode d'entraînement à la vapeur d'eau ou hydrodistillation et analysés séparément.

Extraction par hydrodistillation

Les rhizomes séchés de 3 plants ont été déposés dans un ballon de 1000 ml, contenant 400 ml d'eau distillée. L'hydrodistillation s'est poursuivie pendant 3 heures et les vapeurs ont été condensées dans un récupérateur de type Clavenger avec 10 ml d'hexane. Les huiles extraites ont été séchées sur du sulfate de sodium anhydre et l'hexane a été évaporé sous un léger courant d'azote. Les échantillons de 2004 et 2005 ont été évaporés à sec tandis que ceux de 2006 avaient encore des traces d'hexane ce qui a été pris en considération lors des calculs de rendement.

Analyse par chromatographie gazeuse

Les huiles essentielles ont été analysées par chromatographie en phase gazeuse (GC) employant un système de Varian modèle 3800. Deux colonnes de Supelco, SPB1 et SWax (30 m X 0,25 mm de diamètre interne avec 0,25 µm d'épaisseur de phase) ont été employées avec de l'hélium comme gaz porteur (1 ml/min). La température du four a été maintenue à 40 °C et programmée pour atteindre 240 °C à un taux de 2 °C/min. Le rapport du gaz à l'entrée a été ajusté à 30:1. La température de l'injecteur a été placée à 230°C et celle du détecteur à 250 °C. Les compositions ont été obtenues à partir des mesures électroniques d'intégration (logiciel Workstation version 6.2 de Varian) en utilisant la détection d'ionisation de la flamme (FID). Les n -alcanes (C_8 à C_{30}) ont été employées comme référence dans le calcul des indices relatifs de rétention (Ki).

RÉSULTATS

Les différents composés de l'huile essentielle de rhizomes, récoltés en 2006 selon des sites, sont regroupés par ordre chronologique de leur indice de rétention Ki sur la colonnes de chromatographie SPB1 (Tableau 1). Le composé majoritaire de ces huiles est le méthyl eugénol à une exception près, soit dans le cas de la parcelle de La Pocatière avec 55 % d'ombre où c'est le linalol qui est majoritaire. Le linalol et le méthyl eugénol cumulent plus de 65 % de la quantité totale de l'huile pour chaque site. Le ratio du méthyl eugénol sur le linalool est près de 1 pour tous sauf pour ceux de Pohénégamook et Grondines qui sont respectivement de 1 sur 3 et 1 sur 5. C'est dans la parcelle ayant 25 % d'ombrage que le taux d'acétate de linalyle est le plus élevé avec 6 %. Le taux d'élémicine est plus concentré à Cap St-Ignace et à Pohénégamook avec des taux respectif de 1,6 et 3,2 % alors qu'ailleurs il ne dépasse pas 0,7 %.

Les rendements en huiles essentielles ont augmenté d'année en année pour atteindre presque 3 % la troisième année (Tableau 2). La quantité de rhizomes est très faible lors de la prise d'échantillon en octobre 2006 dans la parcelle de La Pocatière de 90 % d'ombre. On recueille à peine 20 g de rhizomes à cet endroit et 12 g à Cap St-Ignace et 28 g à Pohénégamook alors qu'on recueillait plus de 80 g de rhizomes aux deux autres sites de La Pocatière.

Tableau 1: Composition de l'huile essentielle des rhizomes d'*Asarum canadense* de 2006.

Lieu % ombrage		Lap 25%	Lap 55%	Lap 90%	Cap 55%	Pohé 55%	Grond 50%
Nom	**Ki**	%	%	%	%	%	%
α-pinène	927	0.56	1.13	0.46	0.39	0.36	0.54
camphène	938	-	0.45	-	-	-	0.45
sabinène	963	0.67	1.28	0.60	0.60	0.57	0.50
β-pinène	965	1.01	1.83	0.82	0.81	0.57	0.80
myrcène	983	0.96	1.70	0.86	0.90	0.49	0.81
1,8 cinéole	1013	0.78	1.16	0.53	0.70	0.33	0.56
limonène	1017	0.40	0.68	0.36	0.43	-	0.44
Z-β-ocimène	1029	0.37	0.62	0.36	0.40	-	0.31
E-β-ocimène	1040	0.80	1.31	0.78	0.85	0.43	0.67
linalol	1088	31.60	39.11	29.88	31.61	17.61	24.05
4-terpinéol	1155	0.64	0.88	0.93	1.86	0.71	0.94
α-terpinéol	1169	9.71	10.86	10.16	9.51	6.57	8.80
nérol	1208	1.41	1.45	1.64	1.40	1.17	1.44
géraniol	1238	4.10	3.99	4.88	3.93	3.73	4.58
acétate de linalyle	1243	6.29	4.54	4.86	2.98	3.54	3.58
acétate de bornyle	1262	0.78	0.80	1.00	1.23	1.00	1.84
acétate de néryle	1344	0.64	0.58	0.94	0.72	0.91	0.84
acétate de géranyle	1362	1.26	1.07	1.81	1.33	1.89	1.71
méthyl eugénol	1376	36.50	25.49	37.93	37.34	54.24	45.51
élémicine	1517	0.68	0.28	0.70	1.59	3.23	0.51
furopelargone A	1552	-	-	-	-	0.52	-
E-isoélémicine	1610	-	-	-	-	0.61	-

Tableau 2: Poids des rhizomes et rendement en huile de 2004 à 2006.

	2004		2005		2006	
	Rhiz.	**huile**	**Rhiz.**	**huile**	**Rhiz.**	**huile**
Lieu	g	%	g	%	g	%
Lap 25%	24.76	**1.84**	41.18	**2.95**	80.39	**3.22**
Lap 55%	25.21	**2.31**	36.79	**2.20**	81.11	**2.79**
Lap 90%	5.90	**2.25**	6.35	**2.85**	20.14	**2.95**
Cap 55%	10.62	**1.87**	13.91	**3.06**	11.48	**3.10**
Pohé 55%	18.36	**1.40**	25.10	**3.31**	28.13	**3.39**
Grond 50%	n/a	**n/a**	21.85	**2.20**	42.91	**2.87**

La cause des rendements très bas obtenus dans la parcelle à 90 % d'ombre de La Pocatière est surtout due au ravage fait par les limaces qui ont grignoté les feuilles de plus de la moitié de la parcelle dès la première année de l'implantation et celle-ci a eu de la difficulté à s'en remettre. Les causes de rendements faibles obtenus dans la parcelle de l'érablière de Cap Saint-Ignace peuvent s'expliquer par le fait que le sol était mince et enchevêtré de racines à cet endroit, ce qui laissait peu de place pour la croissance des asarets. L'altitude aussi peut jouer un rôle important car cette parcelle a été établie à une altitude de 380 mètres.

La composition des huiles essentielles des rhizomes d'asaret cultivé dans les parcelles de La Pocatière sous trois luminosités différentes ne varie pas beaucoup (Tableau 3).

Tableau 3: Composition de l'huile des parcelles de La Pocatière à luminosités différentes.

Lieu % ombrage		Lap 25%		Lap 55%		Lap 90%	
		2004	2005	2004	2005	2004	2005
Nom	**Ki**	%	%	%	%	%	%
linalol	1088	13.85	16.19	18.64	10.03	10.00	9.05
4-terpinéol	1155	0.63	0.60	0.60	0.36	0.49	0.38
α-terpinéol	1169	6.65	7.27	7.24	6.61	5.66	6.20
nérol	1208	1.31	1.31	1.37	1.40	1.24	1.35
géraniol	1238	4.53	4.16	5.33	4.83	4.19	4.75
acétate de linalyle	1243	2.56	1.21	3.66	2.17	2.93	2.35
acétate de bornyle	1262	0.77	0.84	0.93	0.78	0.87	0.79
acétate de néryle	1344	0.97	0.89	1.06	1.01	1.28	1.16
acétate de géranyle	1362	2.07	1.88	2.26	2.19	2.79	2.51
méthyl eugénol	1376	61.90	59.46	54.79	63.14	65.38	66.24
élémicine	1517	2.10	2.25	1.66	1.96	1.63	1.59
furopelargone A	1552	0.47	0.38	0.43	0.52	0.91	0.58
junenol +?	1585	1.82	1.20	1.45	1.63	2.21	0.88
E-isoélémicine	1610	0.38	0.69	0.29	0.86	0.43	0.42

La composition des huiles essentielles des rhizomes d'asaret cultivé dans les parcelles de même intensité lumineuse luminosités ne varie pas beaucoup (Tableau 4).

Il est difficile d'attribuer un effet dû à la localisation du site ou dû à un effet de la luminosité sur la composition chimique des huiles essentielles de rhizomes d'asaret cultivés en forêt. Il y a des variations mais celles-ci ne sont pas assez marquées pour être mentionnées car il n'y a aucune tendance.

L'emplacement des parcelles a été le facteur déterminant sur le rendement en plantes produites, conséquemment de rhizomes, ce qui s'est traduit directement sur la quantité d'huiles essentielles obtenue. Comparé aux deux parcelles de La Pocatière, le rendement en huile essentielle est six fois inférieur à Cap Saint-Ignace et deux fois et demi inférieur à Pohénégamook. La qualité de l'huile ne semble pas être affectée.

Tableau 4: Composition de l'huile essentielle de rhizomes d'asaret de milieu mi-ombragé.

Lieu % ombrage		**Lap 55%**		**Cap 55%**		**Pohé 55%**		**Grond 50%[1]**
		2004	**2005**	**2004**	**2005**	**2004**	**2005**	**2005**
Nom	**Ki**	%	%	%	%	%	%	%
linalol	1088	18.64	10.03	14.59	13.75	9.07	17.41	6.87
4-terpinéol	1155	0.60	0.36	0.56	0.61	0.37	0.58	-
α-terpinéol	1169	7.24	6.61	7.10	6.87	6.03	7.34	6.88
nérol	1208	1.37	1.40	1.48	1.30	1.35	1.33	1.66
géraniol	1238	5.33	4.83	4.97	4.32	4.68	4.32	5.87
acétate de linalyle	1243	3.66	2.17	1.95	3.13	2.09	2.99	2.07
acétate de bornyle	1262	0.93	0.78	0.93	0.91	0.82	0.95	0.92
acétate de néryle	1344	1.06	1.01	0.99	0.95	1.14	0.96	1.20
acétate de géranyle	1362	2.26	2.19	2.16	2.01	2.52	2.02	2.72
méthyl eugénol	1376	54.79	63.14	59.97	61.27	65.58	57.37	67.70
élémicine	1517	1.66	1.96	1.34	2.43	1.91	2.59	1.44
furopelargone A	1552	0.43	0.52	0.42	0.42	0.63	0.49	-
junenol +?	1585	1.45	1.63	2.21	0.51	1.82	0.39	-
E-isoélémicine	1610	0.29	0.86	0.57	0.38	0.76	0.50	-

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DEFINING THE NON-TIMBER FOREST PRODUCTS INDUSTRY IN SOUTHERN UNITED STATES

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Abstract: One of the major factors inhibiting development of economic opportunities with non-timber forest products (NTFPs) is the lack of knowledge of the type and locations of the enterprises that constitute this industry. Unlike the wood products industry, where primary and secondary processors have been identified and located, similar information regarding the NTFP segment has not been organized. Industry production of timber-based products has been assessed and articulated at the national, regional and state levels. For most states, timber-based product output assessments are provided all the way to the county level. Unfortunately, this type of information has not been done for NTFPs. An initial step in assessing the output of the NTFP industry is to define and locate the enterprises. This poster presents results of a study that was designed to provide an overview of the NTFP industry in the southern United States. The findings are based on the perceptions of Cooperative Extension agents, working primarily at the county level, although some states have had to extend the geographic responsibilities of the agents due to budget constraints. Each Cooperative Extension agent throughout the region was sent a one-page fax explaining the purpose of the project with a request to complete a short data matrix of pertinent information. The results are presented in perception maps that illustrate the distribution of NTFP enterprises by major product categories. The results provide an overall assessment of enterprise distribution which will help to target development efforts. Further investigation is needed to ground-truth the actual number and density of the enterprises.

Key Words: Enterprise distribution, industry assessment, non-timber forest products, southern United States.

LA RÉCOLTE D'ALIMENTS SAUVAGES : VERS UNE ORGANISATION RÉGIONALE

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Résumé : La cueillette de divers aliments sauvages (petits fruits, têtes de violon, etc.) a toujours fait parti des mœurs sur le territoire gaspésien. Jadis destinés à un usage domestique, serait-il possible que la cueillette de produits sauvages contribue aujourd'hui à la diversification économique durable de nos communautés?

En plus de cueillir pour sa consommation personnelle, le cueilleur trouve sa motivation dans la possibilité de se procurer un revenu. Pour que cela soit possible, il faut qu'un ensemble de facteurs essentiels et interdépendants soient réunis : la présence d'une ressource, de cueilleurs et d'un marché. Ces éléments représentent la base de la cueillette commerciale.

Toutefois, si l'on désire développer ce secteur de façon durable, cette base doit être stabilisée. L'expérience gaspésienne démontre la pertinence de la stratégie des postes d'achats. Il s'agit de personnes qui assurent le relais entre les cueilleurs et le marché. De par leur situation privilégiée, ils peuvent également jouer un rôle de premier plan pour contrôler la qualité de la matière première et la formation des cueilleurs.

Pour les intervenants régionaux, un travail en collaboration avec ces postes est donc essentiel. Les formations sont l'un des outils à utiliser à ce niveau, en tenant compte des besoins des cueilleurs et des acheteurs. Le réseautage entre eux peut être bénéfique puisqu'il favorisera la répartition géographique, l'augmentation du volume et une plus grande diversité de produits. Ces facteurs contribueront à allonger la période de récolte, créant des opportunités d'emplois bienvenues dans cette région dévitalisée.

Mots-clés : Cueillette, diversification, développement durable, économie, communautés, formation, création d'emplois.

Abstract: Gaspesians have always picked various kinds of wild food (berries, fiddleheads, etc.). In the past, this was done for home use, but maybe today wild food could be gathered in order to help bring sustainable economic diversification to our communities.

Besides picking for personal consumption, gatherers are interested in the possibility of deriving income from it. In order to do this, a set of essential and interdependent factors must come together: the food, the pickers, and a market. These elements form the basis of commercial gathering.

However, that basis must be stabilized if the sector is to be developed in a sustainable way. Gaspesian experience has shown how important buyers are. Buyers act as middlemen between

gatherers and the market. The special role of middlemen can also extend to the indispensable ones of raw material quality control and training pickers.

Working together with buyers is therefore essential for regional stakeholders. Training is one way to do this, taking into account the needs of gatherers and buyers. Networking between them can be beneficial, since it will foster geographic distribution, increasing quantity, and a greater diversity of products. These factors will help make the gathering season longer, creating welcome job opportunities in this devitalized region.

Key Words: Gathering, harvesting, sustainable, diversification, income, training, job opportunities.

MISE EN CONTEXTE

La diminution des emplois reliés à l'un des principaux moteurs économiques de la péninsule gaspésienne, soit l'exploitation de la matière ligneuse, a motivé les intervenants à se tourner vers d'autres richesses naturelles, souvent regroupées sous le terme de produits forestiers non ligneux (PFNL). C'est donc vers la fin des années 1990 que les PFNL deviennent un point de mire sur lequel des énergies sont investies afin de voir, si effectivement, ces ressources alternatives pourraient contribuer à la revitalisation des communautés.

La cueillette a toujours fait parti des mœurs en Gaspésie. Jadis, à titre d'usage domestique, la récolte de divers aliments sauvages (petits fruits, têtes de violon, noisettes, etc.) évolua en activités lucratives, reliées à l'économie parallèle. Mais jusqu'à récemment, peu d'entre elles possédaient une organisation de mise en marché permettant la création d'emplois reconnus.

La diversité des ressources présentes, la notoriété et les 20 743 km² du territoire[4], motivèrent d'importants alliés à enclencher des efforts de structuration reliés à la récolte d'aliments sauvages. Le Comité régional pour le développement des ressources naturelles alternatives de la Gaspésie et des Îles-de-la-Madeleine a permis, aux acteurs impliqués et intéressés par la diversification durable de l'économie, ainsi qu'à la région, de se doter d'une vision commune de développement de ce secteur d'activité. Cette volonté de collaboration régionale entama en 2005 cette structuration sous la coordination de la Conférence Régionale des Élus de la Gaspésie et des Îles-de-la-Madeleine (CRÉGÎM).

Les différents portraits et études régionales reliés aux PFNL ont contribué à découvrir l'ampleur des activités déjà présentes ainsi que le potentiel que ces alternatives pouvaient représenter. L'analyse de la situation régionale a mis en lumière des pistes de solution visant à améliorer les retombées de ces activités ancestrales et a mené à l'élaboration du plan de développement régional.

Ce document vous présente donc l'approche d'un territoire visant à favoriser la création d'emplois pour ses occupants en soutenant l'organisation d'activités de récolte en milieu naturel. Ce feuillet touche principalement à la cueillette d'aliments sauvages mais permet aussi, comme

[4] Superficie de la Gaspésie administrative.

vous le constaterez, de comprendre la possibilité d'intégrer une multitude d'autres ressources, telles que les plantes médicinales ou les produits d'ornementation.

VERS UNE SRUCTURATION

Pour arriver à la mise en place d'une structure fonctionnelle et acceptable socialement, il importait de comprendre le fonctionnement déjà en place dans le milieu; principalement ses problématiques et ses besoins. Après diagnostic de la situation régionale, nous avons constaté une lacune majeure dans le maillage entre les intervenants (cueilleurs, acheteurs). Plusieurs cueilleurs motivés à décrocher des revenus se retrouvaient isolés des acheteurs. L'inverse était également vrai, puisque restaurateurs, épiciers et transformateurs avaient de grandes difficultés d'approvisionnement. En effet, l'inconstance de l'offre des aliments dans leurs qualités et leurs quantités ne favorisait guère la mise en marché. Donc, malgré la disponibilité et la diversité des matières premières, l'abondance de cueilleurs enthousiastes et la présence de marchés, les quantités totales d'aliments sauvages mis en marché et transformés étaient maigres.

La stabilisation de l'approvisionnement et la structuration de la mise en marché ont donc été les deux principales pistes de solution permettant d'améliorer la situation. En stabilisant l'approvisionnement et en regroupant l'offre, il devient alors possible de penser à développer et fidéliser différents marchés. Cet agencement entre l'offre et la demande se traduit en opportunités d'emplois ajustées aux habitudes de travail et au positionnement de la population. Par conséquent, l'augmentation du volume et la diversification des ressources récoltées conduiront à l'objectif souhaité : des emplois stables dans un corps de métier reconnu et valorisé.

C'est en regroupant les connaissances sur la biologie des espèces et celles d'intervenants reliés aux marchés (transformateurs, hôteliers, etc.), que la cueillette phénologique devient intéressante et viable. La nature délivre plusieurs variétés d'aliments et de plantes recherchés tout au long de la saison. Celle-ci débute en mai avec les têtes de violon et fait ensuite place à une multitude de fruits sauvages et de champignons forestiers, menant les activités de cueillette jusqu'à tard en automne. L'expertise en place (savoir-faire ancestral, professionnels, chercheurs, etc.) ainsi que les projets d'acquisition de connaissances (études) permettent de développer le potentiel du territoire, tout en allongeant la période de récolte. La transformation de produits, devenue possible par la structuration de l'approvisionnement, crée également des opportunités d'emplois croissantes.

LA MISE EN MARCHÉ

Bien évidemment, il faut mettre en place, parallèlement aux efforts de stabilisation de l'approvisionnement, une structure pour atteindre les marchés. Il importe donc qu'un fonctionnement simple et efficace qui assure un contrôle de la qualité et la pérennité de la ressource, soit présent. Ce système rend possible la fidélisation des marchés et une cohérence de l'offre (qualité, prix, variétés, écologie, quantités, livraison).

Dans la mise en place de ce fonctionnement, l'expérience gaspésienne démontre que les stations d'achat ont une importance frappante. Il s'agit de lieux stratégiques et de personnes (revendeurs) qui assurent le relais entre les cueilleurs et le marché. Ces grossistes peuvent être des entreprises ou des individus qui ont comme rôles principaux le contrôle de la qualité des variétés ramenées et le paiement des cueilleurs en fonction des quantités reçues et des prix du marché. Ces postes d'achat doivent rassembler et classifier les aliments puis les acheminer dans les marchés préalablement ciblés. La position de ces stations d'achat leur confère des responsabilités importantes quant au contrôle de la qualité, au respect de l'environnement et aux relations avec les acheteurs et ce, afin que tout ce développement soit durable. C'est pour cette raison qu'une collaboration étroite entre les intervenants du projet et ces postes d'achat est non seulement souhaitable, mais essentielle.

Diverses rencontres ont permis d'informer les différents postes d'achat sur les objectifs visés par les efforts de structuration, de les informer sur les forces et les lacunes du fonctionnement en place et d'établir une collaboration entre eux. Le réseautage entre les postes d'achat peut être bénéfique puisqu'il favorisera la répartition géographique, l'augmentation du volume et une plus grande diversité de produits. Par son immensité et ses positionnements géographiques variés, la Gaspésie présente des avantages certains au niveau de l'étalement de la période de récolte d'une même ressource, ce qui tend à abaisser les pièges reliés à l'approvisionnement telle que la pression sur la ressource ou une saison peu productive.

LA FORMATION

Ici entre en jeu une première charnière qui servira à établir une base solide : la formation technique des cueilleurs et leur apprentissage sur le terrain. Celle-ci vise plusieurs objectifs : répondre aux critères des marchés visés, augmenter l'efficacité des cueilleurs tout en diminuant leurs risques de blessures, assurer des standards réguliers, répondre aux besoins des acheteurs et cueilleurs et enfin les sensibiliser à la préservation des ressources.

Chaque formation est montée en fonction de l'espèce à récolter et est donnée dans diverses municipalités autour de la péninsule afin d'accommoder les intéressés. Elles sont organisées par le coordonnateur pour le développement des ressources naturelles alternatives à la CRÉGÎM et durent de une à trois heures. Dépendamment de l'espèce à récolter, de l'endroit de la formation, du nombre et du rôle des personnes formées, elles peuvent nécessiter une sortie sur le terrain.

La formation approfondie des responsables des postes d'achat est primordiale, particulièrement lorsqu'une nouvelle ressource est intégrée ou qu'un nouveau marché est développé. Ces occasions permettent aussi l'échange et la collaboration entre les divers intervenants du milieu incluant les revendeurs. Comme exemples concrets et positifs de coopération entre les intervenants, nous avons engagé, dans le cadre du développement des champignons forestiers, une personne qualifiée comme formateur et ensuite réalisé et distribué un guide technique sur les principaux champignons sauvages comestibles pour lesquels il existe un marché. Ressource abondante et malheureusement encore méconnue des Québécois ; les champignons sauvages ont été ajoutés, avec un fulgurant succès, à la gamme d'aliments sauvages déjà récoltés en Gaspésie.

DES RETOMBÉES EN RÉGION

Les efforts d'organisation présentés précédemment semblent porter fruits. En effet, deux nouvelles entreprises spécialisées dans la récolte de divers aliments sauvages ont vu le jour en 2006: Les Bleuets Sauvages de la Gaspésie et Gaspésie Sauvage. La première entreprise est spécialisée dans les bleuets, mais touche également à d'autres aliments sauvages. Une quinzaine de cueilleurs ont suffisamment travaillé au courant de l'année pour être éligibles à l'assurance emploi. Aussi, grâce à l'étroite collaboration de divers intervenants avec l'entreprise Gaspésie Sauvage, les champignons sauvages comestibles sont devenus une ressource récoltée de manière commerciale sur le territoire gaspésien. Les champignons sont vendus frais en saison et vendus séchés le reste de l'année. À elles deux, ces entreprises ont permis l'embauche de plus de 120 cueilleurs autonomes sur l'ensemble de la péninsule Gaspésienne.

À la suite de l'apparition d'entreprises régionales spécialisées dans les aliments sauvages, des efforts sont consentis afin d'augmenter la consommation régionale en premier lieu. Le tourisme étant un axe de développement important en Gaspésie il semble logique et conséquent de proposer nos produits du terroir aux visiteurs. Conséquemment, plusieurs entreprises locales de transformation agroalimentaire se montrent de plus en plus intéressées à transformer nos petites fraises, bleuets, champignons, boutons de marguerite, etc., en produits de consommation tels que les confitures, marinades... Dans cette optique de développement local, les restaurants, épiceries et commerces spécialisés ont été approchés pour inciter l'utilisation de ces produits régionaux pour la vente au détail, en saison pour les éléments frais et tout au long de l'année pour ceux transformés. Des activités de promotion se poursuivront durant la prochaine année afin de poursuivre ces efforts.

QUELQUES DÉFIS

Bien qu'il semble possible de créer des emplois avec les connaissances actuelles, le niveau de connaissances demeure encore limitatif selon l'échelle visée. Certaines ressources retrouvées en grande quantité sur le territoire, ont un marché limité (noisettes, boutons floraux) ou quasis inexistant (viorne trilobée, cerise à grappes). De plus, l'approvisionnement est basé sur la récolte spontanée en milieu naturel. Ceci peut permettre l'atteinte de certains marchés à forte valeur ajoutée si le réseau d'approvisionnement est très bien développé. Mais cela peut être limitatif pour stabiliser l'approvisionnement et assurer la survie d'une entreprise qui désire se spécialiser dans les aliments sauvages, malgré les avantages apportés par la superficie de la péninsule gaspésienne. L'aménagement de la ressource en milieu naturel pour favoriser la production ou la mise en culture, sont des avenues d'approvisionnement pour lesquelles les informations actuelles sont limitées. Un autre des aspects limités par les connaissances sont les méthodes de récolte. Les méthodes actuelles ne sont peut être pas, dans certains cas, optimales ce qui a peut avoir un impact à court et long terme sur la ressource et sur l'efficacité du cueilleur et son salaire.

Pour de maintes raisons, il importe également de sensibiliser les propriétaires de lots boisés aux activités de cueillette d'aliments. En Gaspésie, la proximité de la forêt privée par rapport à la forêt publique en fait des secteurs de récolte souvent privilégiés par les cueilleurs. Cet aspect peut malheureusement amener des conflits d'utilisation, amenés par le non-respect de la propriété privée. D'un autre côté, on observe un intérêt croissant des propriétaires pour l'aménagement multiressources de leur lot boisé. La faune, le récréotourisme et plus récemment, l'agroforesterie sont des avenues explorées par les propriétaires pour diversifier leurs activités et revenus. Ainsi, en coordonnant les activités de sensibilisation, d'acquisition et de transfert de connaissances aux propriétaires, il est possible d'amener de nombreux avantages pour l'ensemble des utilisateurs. Ainsi, un propriétaire pourra décider de favoriser certaines espèces de fruits sauvages (ex. : bleuets) par des aménagements. Une collaboration entre propriétaires et cueilleurs deviendra donc souhaitable et possible : du côté du propriétaire, celui-ci pourra décider de faire récolter ses ressources. Pour le cueilleur, cela pourra représenter des zones de récolte stables. Bien sûr, ces interactions pourront évoluer en différents modes et à différentes échelles de coopération.

La présence de ressource et de marché est certes essentielle mais un autre élément important dans le développement d'un réseau de cueillette durable est relié à l'aspect économique. En effet, pour voir apparaître des activités de récolte commerciale, l'ensemble de la filière doit y trouver sont compte, en commençant par les cueilleurs. Puisque le cueilleur est payé à forfait, soit en fonction de quantité récoltée, on utilise souvent un taux horaire ou journalier minimal pour établir le prix par unité de poids. Bien que cette approche puisse servir à établir un prix de référence, elle n'est pas systématiquement appliquée puisque d'autres facteurs peuvent influencer le prix. Après tout, le jeu de l'offre et de la demande existe également dans ce domaine.

Ce qui importe, c'est de mettre en place une structure qui permette à des personnes intéressées de se procurer un salaire décent en tenant compte du prix aux consommateurs selon le marché visé. La méthode de récolte utilisée est donc importante puisqu'elle influera sur l'efficacité des cueilleurs et donc sur l'aspect économique. Cet aspect met encore une fois l'importance des formations.

CONCLUSION

Les démarches gaspésiennes visent à donner les outils nécessaires aux entreprises et aux cueilleurs afin de favoriser la diversification de l'économie régionale basée sur des ressources naturelles alternatives. Ainsi, les actions réalisées visent principalement à appuyer le milieu dans la mise en place de structure et d'outils favorisant un approvisionnement et un accès aux marchés.

Bien que l'approche présentée soit adaptée à une réalité propre à la Gaspésie, il n'en demeure pas moins que des éléments essentiels doivent être respectés pour arriver à un développement d'activité de récolte. Entre autres, ce développement nécessite une étroite collaboration entre les intervenants, les promoteurs et les cueilleurs. De part la nature, plutôt parallèle des activités de cueillette, il importe de démontrer aux personnes impliquées les avantages d'une collaboration et la transparence des intentions. Ces démarches doivent également s'effectuer en tenant compte des activités déjà en place. Dans cet ordre d'idée, il importe de ne pas chercher à mettre en place une structure trop lourde ou trop rigide et encore moins essayer de le faire rapidement.

Finalement, les efforts de structuration doivent être menés de façon à ne pas créer de dépendance face aux aides gouvernementales, mais plutôt en visant la mise en place d'une structure autonome. L'intégration d'entrepreneurs possédant des objectifs de développement similaire à ceux de la région dans les démarches est donc importante puisqu'une fois la structure en place, la durabilité de ce secteur économique reposera principalement sur leurs épaules. Bien que les appuis régionaux présentés soient récents, les résultats sont suffisamment positifs pour maintenir ces efforts.

FRAMEWORK FOR EVALUATING SPECIALTY CROPS

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Abstract: Within BC, the term 'specialty crop' refers to a new crop, a new use for an established crop, or an established crop new to another region. Specialty crops are generally not considered part of mainstream agriculture (e.g., tree fruits, grains, etc.), and many may have non-traditional use areas, e.g. functional foods, florals, etc. As compared with traditional agricultural commodities, there are generally few marketing structures in place, and there may be relatively little information regarding crop management. Potential crops considered for agroforestry systems often fall into the specialty crop category.

A framework was designed to aid producers and professionals in decision making when considering specialty crops. It is set up as a series of questions surrounding factors to be considered prior to production. Questions are grouped into three consideration areas: 1) questions about the crop plant; 2) questions about crop management; and, 3) questions about the product.

The framework is designed to aid users in assessing where the information gaps occur, which can then be used to assess the crop against their degree of acceptable risk in pursuing crops of interest. A response of 'yes' or 'no' to each question indicates further considerations for the user. A response of 'unknown' indicates further investigation is needed. A non-exhaustive resource list provides a starting point for users to begin searching for information pertinent to their plant of interest, products and the question being considered within the framework.

Key Words: Specialty crops, decision-aid tool, assessment framework.

SECTION 6

La production de biomasse sur courtes rotations

Biomass Production on Short Rotation

KEYNOTE SPEAKER

WOODY BIOMASS FEEDSTOCKS: AGROFORESTRY AND THE ENERGY CRISIS

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BIOMASSE FORESTIÈRE : AGROFORESTERIE ET CRISE ÉNERGÉTIQUE

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Abstract: Wood biomass from the forest and farmed short-rotation woody biomass energy crops offer a significant renewable alternative, and environmentally more acceptable replacement options to diminishing fossil-based energy supplies. Woody biomass is available year-round from multiple sources, so end users are not dependent on a single source of material. This ensures a consistent feedstock supply, reduces the risk of fluctuations in price, and limits the need for complicated and expensive long-term storage of material.

Across North America annual forest growth is generally greater than annual harvests. Much of this growth is in low-value timber due to decades of high-grading and loss of pulp markets. The dynamics of the forest industry over the past few decades provides a prime opportunity to use this woody biomass sustainably for the production of biofuels, bioproducts and bioenergy, while simultaneously improving the management of forests.

Short-rotation woody biomass crops, willows, hybrid poplars and others have been studied and developed for commercial deployment for over twenty years in North America. Not only do these SRWC provide biomass feedstocks, but also multiple environmental and rural development benefits associated with agroforestry and remediation efforts with their production and use. The large-scale deployment of SRWC will create thousands of rural jobs, and produce an array of environmental benefits.

Résumé : La biomasse forestière et l'exploitation de plantations forestières énergétiques à révolution courte représentent des solutions de rechange renouvelables et attrayantes. Elles sont plus acceptables sur le plan environnemental puisqu'elles permettent de réduire le recours aux énergies fossiles. Plusieurs sources peuvent aider à générer une biomasse forestière accessible à l'année, libérant ainsi les consommateurs de leur dépendance envers une source unique d'énergie. Voilà de quoi assurer l'approvisionnement en matière première, la diminution des risques de fluctuation des prix et le besoin moins important d'un stockage à long terme de la matière première, un processus à la fois complexe et coûteux.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

La croissance annuelle de la forêt dépasse celle des récoltes annuelles en Amérique du Nord. La majeure partie de cette croissance revient à la fibre ligneuse de faible valeur, résultat de décennies d'écrémage et d'exploitation axée sur la pulpe. La dynamique du secteur de la forêt au cours des dernières décennies a créé l'occasion de nous tourner vers la biomasse forestière pour produire des biocarburants, des bioproduits et de la bioénergie tout en améliorant la gestion des forêts.

En Amérique du Nord, au cours des vingt dernières années, l'exploitation, entre autres, de plantations forestières énergétiques à révolution courte comme les saules et les peupliers hybrides a fait l'objet d'un examen approfondi et leur potentiel de commercialisation a été développé. Si ces exploitations forestières énergétiques à révolution courte représentent une source de biomasse forestière, leur production et leur utilisation procurent également plusieurs avantages reliés à l'agroforesterie et au processus d'assainissement sur le plan de l'environnement et du développement des communautés rurales. Le déploiement à grande échelle de l'exploitation de plantations forestières énergétiques à révolution courte permettra de créer des milliers d'emplois et de produire d'importantes retombées environnementales.

APPLICATION OF AGROFORESTRY PRINCIPLES FOR SHORT ROTATION FORESTRY IN A WILLOW (*SALIX* SPP.) CLONAL TRIAL IN SOUTHERN ONTARIO, CANADA

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Abstract: Results from experiments conducted at the University of Guelph's Agroforestry Research Station over the last 20 years suggest two distinct zones across a 15 m wide tree-intercropping alley. The first zone – the competitive zone – is the area within 2 m of the tree row. The second zone – the complementary zone – is the remaining area in the centre of the alley, which is 11 m wide. The competitive zone is characterized by competition for nutrients, moisture and light. The complementary zone is characterized by favourable growing conditions where the following processes are enhanced: nutrient cycling, nitrogen mineralization, soil organic carbon addition, earthworm activity, and carbon assimilation. In addition, there appears to be lower soil temperature, low evapotranspiration, and reduced wind turbulence within the complementary zone. During the spring of 2006, three willow varieties from SUNY-ESF (SV1, SX67 and 9882-41) were planted in an established 'complementary zone' where tree rows are 20 years old. As a control, the same varieties were established on an adjacent piece of land without established tree rows. Plots are 50 m by 10 m, contain five double-rows (0.75 m and 1.5 m inter-row distances), and are replicated four times for each variety in each field. The willows will be coppiced at the end of the first growing season, and following a three-year harvesting cycle thereafter. It is hypothesized that the favourable growing conditions prevailing in the complementary zone, as influenced by the presence of mature trees in an agroforestry set-up, will enhance short-rotation biomass yields when compared with conventional (control) yields.

Key Words: Short rotation forestry, willow, *Salix* spp., agroforestry, intercropping.

USE OF SORGHUM-SUDAN AS A KILLED COVER CROP IN AFFORESTATION

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Abstract: Commercial horticulture is increasing the use of killed cover crops as an inexpensive method of mulching sites. We tested the use of a killed cover crop for afforestation plantings. We planted two plots of Sorghum-Sudan in mid-summer of 2001. This was cut with a sickle bar mower is spring 2002. The control plots were prepared with conventional tillage. Hybrid poplar cuttings were planted in spring 2002. We conducted no weed control on the treatment plots. The control plots were maintained using periodic conventional tillage and supplementary hand weeding. No difference in growth rate was seen although survival was higher in the treatment plots. Although this is just a preliminary test, it illustrates the potential of future research and use. As the cost and labor associated with conventional weed control is significant, the potential cost savings and environmental benefits of using a killed cover crops may be high.

Key Words: Cover crops, afforestation, hybrid poplar.

AGROFORESTRY DEMONSTRATION SITE NETWORK: GROWTH AND YIELD MEASUREMENTS

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Abstract: Since 2002, the Saskatchewan Forest Centre (SFC) has been instrumental in establishing an Agroforestry Demonstration Site Network across Saskatchewan. This demo network, to a larger degree, deals with hybrid poplar, conifer and mixed species plantations. Silvopasture, riparian habitat renewal, stooling beds, vegetation management and clonal trials are all part of the network. Individually, these sites have been established by or with funding from various federal and provincial government departments, University research and higher learning, agroforestry related groups and organizations and a dedicated SFC Agroforestry Unit.

Growth and yield measurements were undertaken for the first time in the fall of 2006. The results obtained were as different as the methods of establishment, clonal selection and vegetation management. The sites selected were exclusively hybrid poplar (Walker, Hill, Northwest, Assinaboine), conifers (Red Pine, Scots Pine, Siberian Larch) and mixed species plantations. Sites using different vegetation management regimes (chemical, mechanical, combination, mulches (e.g., plastic, sawdust), no management and age variation (rising 1 - 4 years) were measured. The variation in results of the growth and yield Measurements provide an invaluable need for a continued expansion of the Demonstration Network to look at different spacing, vegetation management and quality control options. The need by the general public to be able to see and understand agroforestry and afforestation is partly accomplished by pictures and field tours of the Saskatchewan Forest Centre Agroforestry Demonstration Site Network.

Key Words: Demonstration site, growth, yield, measurements.

HARVESTING SHORT-ROTATION WILLOW WITH A CUTTER-SHREDDER-BALER

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Abstract: A novel harvester was designed specifically to cut, shred and bale short-rotation willow. The harvester includes four rotary saws of 559 mm diameter (1.97 m wide cut considering blade overlap), a 1.55 m wide hammer-type shredder and an agricultural round baler with a chamber width of 1.22 m and variable diameter up to 1.5 m. Short- rotation willow can be cultivated in plantations (15,000 cuttings/ha) and harvested every three years with yields of 10 to 20 t dry crop/ha/annum, 100,000 shoots/ha, heights up to 7 m, and diameters up to 75 mm. It is a potential feedstock for energy and fibre, already used on a large scale (>1,000 ha) in some European countries. Current harvesting is done either with modified sugar-cane harvesters which collect billets (about 200 mm long) or modified forage harvesters which collect wood chips (about 25 mm long). Billets and chips represent handling and storage challenges, and require machines which cost in the order of $500,000. The proposed round baler platform may be more suitable for small scale plantations; it also facilitates natural drying during storage and represents an investment cost of about $60,000. In 2006, the prototype formed more than 90 willow bales, up to 1.5 m in diameter and with a density of 150 kg dry crop/m³ (bale mass near 600 kg at 45% moisture). The baling capacity ranged from 8 to 12 t wet/h. When time for bale wrapping, unloading, and turning at end of rows were included, effective capacity ranged from 5 to 8 t wet/h.

Key Words: Willow, harvest, baling, cutting, shredding, SRIC (short-rotation intensive culture).

Résumé : Une récolteuse novatrice a été conçue afin de couper, broyer et mettre en balles le saule en rotation courte. Le prototype inclut quatre scies rotatives de 559 mm de diamètre (une largeur de coupe de 1,97 m considérant le chevauchement), un broyeur à marteaux de 1,55 m de largeur et une presse agricole formant des balles rondes de 1,22 m de largeur avec un diamètre variable jusqu'à 1,5 m. Le saule en rotation courte peut être cultivé en plantations (avec un taux d'établissement de 15 000 boutures à l'hectare) et récolté sur une base triennale avec des rendements de 10 à 20 t de matière sèche (MS)/ha/an, environ 100 000 tiges/ha, des hauteurs de tiges jusqu'à 7 m et des diamètres jusqu'à 75 mm. Ce type de plantation peut fournir de l'énergie et de la fibre; elle est déjà établie à grande échelle (>1 000 ha) dans certains pays européens. La récolte y est faite avec l'un de deux types de machines, soit une récolteuse de canne à sucre modifiée qui coupe la plante en bâtonnets (200 mm de longueur), soit avec une fourragère automotrice modifiée qui hache la plante en copeaux (25 mm de longueur). La manutention et l'entreposage de bâtonnets ou copeaux de saule présentent certains défis; de plus, les récolteuses européennes coûtent environ 500 000 $ chacune. La récolteuse proposée est mieux adaptée à de petites plantations à un coût abordable (environ 60 000 $); la balle ronde facilite aussi le séchage naturel durant l'entreposage. En 2006, le prototype a servi à récolter plus de 90 balles, jusqu'à 1,5

m de diamètre chacune et avec une masse volumique de 150 kg MS/m³ (une masse de 600 kg à 45 % de teneur en eau). La capacité de formation des balles a varié entre 8 et 12 t humides/h. En incluant le temps de ficelage, décharge et virage au bout des rangs, la capacité réelle variait entre 5 et 8 t humides/h.

Mots-clés : Saule, récolte, pressage, fauche, broyage, SRIC (culture intensive à rotation courte).

INTRODUCTION

Short rotation intensive culture (SRIC) of willow has been suggested as a means of maintaining or enhancing crop production on marginal and abandoned agricultural land (Labrecque and Teodorescu 2003). SRIC may also provide considerable environmental benefits as a sink for excess greenhouse gas, industrial waste and municipal sludge (Perttu and Kovalik 1997) and as a source of biomass for energy and the chemical industry (Morris and Ahmed 1992).

Various willow plantation designs have been proposed. European spacing is typically 0.75 m between two rows in a pair and 1.5 m between pairs of rows, with plantation densities of about 16,000 cuttings per ha, i.e. about 556 mm between plants along a row (Paulson 2005). Seedlings in eastern Canada have been planted in six rows 1.5 m apart and spaced 3.0 m between groups of six rows (Labrecque and Teodorescu 2003). The interval between plants along a row was 300 mm, therefore providing a density of 19,050 plants/ha. Hilton et al. (2005) indicated that harvesting must be considered at the plantation stage. Figure 1 illustrates the two main plantation designs and the impact they can have on field traffic with tractors, implements and self-propelled harvesters.

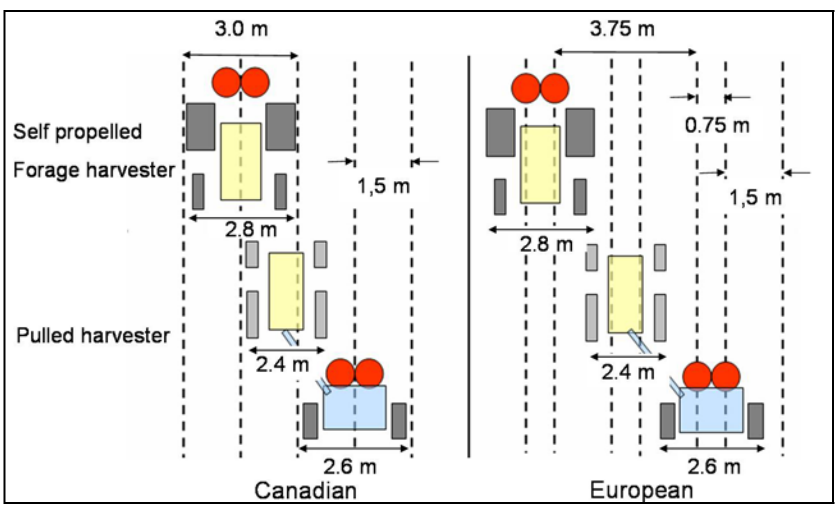

Fig. 1: Machinery traffic in a willow plantation with Canadian and European spacings.[1]

At three years of age, willow stems measure up to 6 m high and have a base diameter up to 80 mm. Because of stem multiplication and resprouting, there can be more than 100,000 stems per

[1] This figure is in colour in the electronic version of the Proceedings (CD)

ha. According to Hytönen (1994), willow stems should be cut about 100 mm above the ground to maintain good regrowth for the next cycle. Observations in the United Kingdom indicated that willow shoots can span sideways up to about 620 mm at a cutting height of 100 mm (Savoie 2005). Therefore, a minimum distance 310 mm should be left between the center of the row and the outside of the harvester's tires. The cutter head width has to cover at least this same distance on each side of the harvested rows' centerline.

Willow can be harvested in different forms: full length stems, chips, bales or bundles. Each form has different characteristics for handling and drying. A literature review on the various methods of harvesting willow was carried out (Lechasseur and Savoie 2005). Meetings with researchers involved in large-scale willow production and harvesting, notably in New York State (Volk 2005) and the United Kingdom (Paulson 2005), provided up-to-date information.

Chipping with self-propelled forage harvesters is currently being done in the United Kingdom and Sweden to provide large quantities of biomass for co-firing in industrial coal burning plants. The chips are harvested and stored in large stacks at a typical moisture content of 40 to 50%. Natural drying is limited during the storage. Although the field harvester may be expensive (over $500,000 CAN), it is justified for the large area (as much as 1000 ha) and volume (close to 30,000 t DM) handled annually by a single machine.

Smaller machines to bunch and tie stems together or to compress them into bales have been less successful than the self-propelled forage harvester-chipper. However, they could serve a useful purpose of natural drying, as suggested by Hilton (2000). A baling system is also very convenient for storage on the farm and handling with conventional equipment (tractor, loader). In comparison, wood chips are not as practical to store in small piles on the farm.

As willow production might grow become more important in Canada over the next two decades, harvest machinery must also keep pace to handle potentially large volumes of biomass. The present work was initiated to provide up-to-date technology related to willow harvesting. The objective of this project was to develop a willow harvester that could contribute both to experimental and early commercial needs to remove the crop quickly and efficiently from the field, at a reasonable cost.

The research project was oriented towards the development of a baler system for long-stem willow. The main design criteria for a new harvester had to consider cutting speed, handling the cut willow stems and compression into a bale. The following sections describe the prototype details and first-year field evaluation.

PROTOTYPE DEVELOPMENT

The new concept proposed for willow harvest integrates a cutter, a shredder and a baler working simultaneously in the same machine. The computer aided design drawings were completed from January to March 2006; the manufacturing process took place from March to June 2006. The design criteria were described initially by Savoie et al. (2006). The actual construction and evaluation of the prototype are explained below.

Baling mechanism

A round baler is a relatively economical harvesting platform (about $30,000 CAN for a new machine). It has a low power requirement in the range of 40-50 kW. The machine is light and provides good floatation on soft soils. A round baler with a variable compression chamber can form a compact core and different bale diameters from 0.90 to 1.50 m. The baler used for this prototype was a BR 740 (CNH, New Holland, PA). A number of modifications described below were made to the baler.

The hay pickup and the twine wrapping system were removed to increase space under the baler where a new shredder and the cutter head were positioned. The original baler wheel axle was moved forward (about 350 mm) to improve weight distribution. The shredder and the cutter head added an extra 800 kg in front of the baler. To pull the harvester in offset position from the tractor's drive line, the original tongue was replaced by a central swing pivot tongue. A hydraulic cylinder allowed offsetting the baler by 2.35 m on each side of the tractor's line of travel (Fig. 2). The swing pivot tongue was equipped with a swivel gear box (Gehl model 3512) for better maneuverability in restricted areas like headlands.

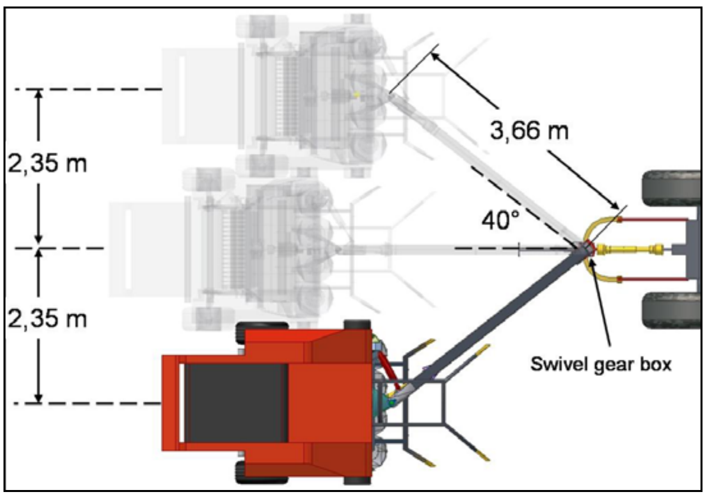

Fig. 2: Aerial view of baler offset.[1]

The frame of the baler was reinforced to support the extra weight of the cutter bar and the shredder. The six original narrow belts were replaced by a single full length belt of 1143 mm width by 8.5 m length. The full width belt was intended to retain all the stems and broken sticks within the compression chamber.

Shredding mechanism

A shredder was incorporated to break up willow branches just enough to make them very pliable prior to entering the compression chamber. The shredder was basically a 1.5 m long rotor with 12

[1] This figure is in colour in the electronic version of the Proceedings (CD)

hammers (Orsi Model WHO 1550, Italy). Each hammer weighed 1.7 kg and was 150 mm wide. The rotor diameter was 200 mm and the hammers' rotating diameter was 450 mm. The hammers acted as flails on the rotor and were located at about 125 mm center-to-center from each other with a 90° angular offset (Fig. 3). The rotor speed was 2200 RPM; the direction of rotation was such that hammers pulled the stems above the rotor. The peripheral speed of the hammer was about 52 m/s.

An adjustable shear bar was installed on the shredder's inside wall to adjust the size of the output woody residues of stems (Fig. 3). Steel metal sheeting and tubing were used to build the frame. The hood was rebuilt to fit the area available under the baler and the cutter bar.

Cutting mechanism

The cutter head was attached in front of the shredder. It consisted of four disk mower modules (John Deere, low-profile modular cutterbar) that were modified to receive four 560 mm diameter saws. These modules were chosen because of their small thickness which minimized the inclination angle (about 13° from the horizontal plane) to neatly cut willow stems close to the stumps.

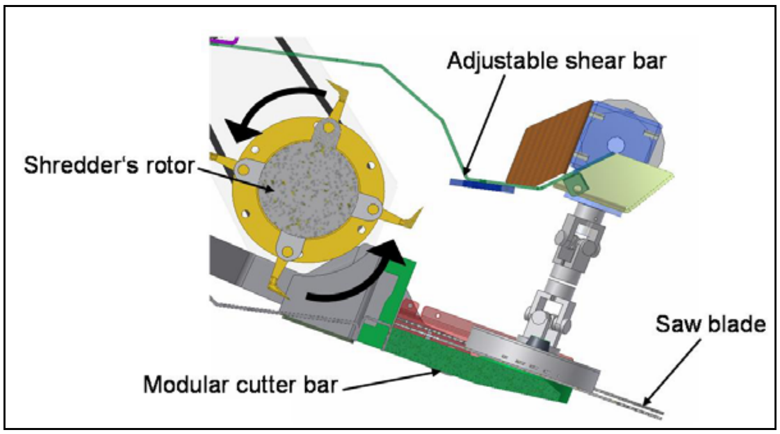

Fig. 3: Cross-section of cutting and shredding mechanisms.[1]

The distance center-to-center was 457 mm between each pair of saws and 495 mm between the two pairs (Fig. 4). The horizontal overlap was 103 mm within a pair of saws and 65 mm between the two pairs. The vertical offset between the saw blades was 9.5 mm. The saws were made from 4.75 mm thick steel sheet by laser cutting. Each original saw blade had 60 teeth. The tip speed was 88 m/s at a rotational speed of 3000 RPM.

The saw blade tip height was adjustable between 100 mm and 400 mm above the ground. There was also an adjustable depth wheel on each side to maintain a constant cutting height as shown in Fig. 4.

[1] This figure is in colour in the electronic version of the Proceedings (CD)

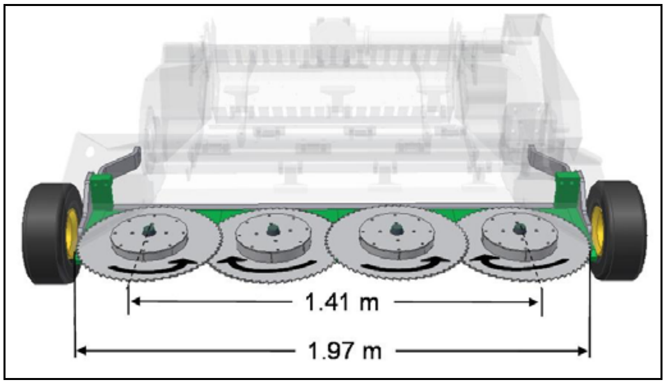

Fig. 4: Front view of cutter head.[1]

Double push bar system

A double push bar system was designed with a dual function: to force the upper part of the stems forward just in front of the saw blades and to protect the power transmission components from the flow of freshly cut material. By pushing the stems forward, the upper bar improved the free-cutting action of the blades as a result of an increased opening of the kerf (the cutting groove). Once the stems were cut, they acted as a spring. The stem base rotate upwards and toward the top of the shredder near the shear bar. Then, the whole stem was grasped by the hammers and pulled through the shredder. The truncated V shape of the push bars was intended to bring the outlying stems towards the middle of the harvester.

The push bars were adjustable vertically to change the force according to stem size and yield. They were also stretchable horizontally to improve harvest efficiency in different plantations. The upper push bar could reach a total width up to 2.1 m.

FIELD METHODOLOGY

Harvest trials

The harvester prototype was evaluated at five different dates and three locations in 2006. On June 19-20, the harvester was moved a first time to Cazaville (Quebec), about 380 km south-west of the research laboratory in Quebec City. The plantation was privately owned; the willow stems were in their third growth cycle, last harvested in 2002. On July 24, the harvester was moved again to the same site for a second trial. On August 30-31, the harvester was evaluated in Huntingdon, 20 km east of Cazaville, on another privately owned plantation; the willow stand was a semi-abandoned plantation about 6 years old and last harvested around 2000. On November 8 and 9, the harvester was evaluated near Syracuse, NY at the Lafayette willow plantation of the State University of New York (SUNY). On November 27-29, the harvester was again moved to the Cazaville site for the fifth and last trial in 2006. The Cazaville and Huntingdon plantations were composed of willow rows 1.5 m apart; the baler harvested one row

[1] This figure is in colour in the electronic version of the Proceedings (CD)

at a time on these two sites. The SUNY plantation was formed of pairs of rows 0.75 m apart and spaced 1.5 m from other pairs of rows; the baler harvested two rows simultaneously at SUNY.

Field measurements

The harvester was operated with a rented tractor, ideally with a minimum of 100 kW power and 4 hydraulic circuits. A second tractor with a clamp was used to lift and move individual bales. Each bale was weighed on a platform scale (1000 kg full range; precision +/- 0.2 kg). Each bale was measured for three circumferences (+/- 10 mm). The wet density was calculated as the ratio of wet mass to volume.

Each bale was harvested by moving at a normal speed chosen by the tractor operator along a row of willows. The forward speed was expected to be between 1 and 3 km/h, but had to be adjusted to the crop yield and sometimes to the tractor power available. For each bale, two stakes were put in the ground to mark the beginning and end of the row length which was measured precisely (+/- 0.1 m) after harvest. Time to harvest each bale was clocked (+/- 1 s). Any delay (e.g. turning to another row, stopping for any reason) was noted, and subtracted from the total time to estimate the actual harvest rate to form each bale.

During the fifth trial, an experimental design was planned to compare willow bale harvest as a function of bale diameter and compression belt tension. Planned bale diameters were small and large (about 1.2 and 1.5 m). Planned belt tension levels were the lowest practical adjustment and the highest practical adjustment. The two tension levels were established by trial and error to ensure a well-formed bale, in the case of low tension, and to avoid overstressing the bale chamber components, in the case of high tension. In principle, low tension and high tension would produce low and high density bales, respectively. The four treatment combinations were: 1) small diameter bale and low belt tension; 2) large diameter and low belt tension; 3) small diameter and high belt tension; 4) large diameter and high belt tension. Each combination was repeated four times randomly during the process of harvesting 16 bales. Prior to harvesting each bale, the belt tension was adjusted according to the planned level and the operator was instructed to stop baling when the appropriate diameter was reached as indicated on the bale size monitor located inside the tractor cabin.

To measure moisture content, three willow stems were selected randomly along a row just prior to harvest of each bale (or every other bale) and cut with a manual saw. Each stem was cut in small pieces of about 100 mm long, put in a perforated paper bag and placed to dry in an oven. The total wet and dry mass of each stem was weighed (+/- 0.1 g). The method was the same as the one used to measure moisture in forages (ASABE 2006); the willow samples were dried in the oven at 103°C for 24 hours.

Field loss was the ratio of willow mass not collected over the original willow yield. During the fifth trial, residues between two rows spaced 1.5 m apart and over a length of 1 m were collected at random locations, put in a bag and oven-dried to estimate dry matter loss. This loss was compared to the total yield prior to harvest which was estimated by cutting all the stems in a row segment (typically 1.5 m long) and repeating the measure several times in the field.

RESULTS

Table 1 presents a summary of baling capacity for five field trials carried out in 2006. The average baling capacity was 7.9 t/h (wet matter). This does not include idle time for wrapping and unloading bales in the field, or turning time and other inefficiencies. The field efficiency of such a willow harvester is expected to be similar to the efficiency of a round baler to harvest forage, i.e. typically 65% (ASABE 2006). The average field harvest capacity would be about 5 t/h with the current prototype, but this could be improved to at least 9 t/h with minor improvements because baling capacities above 14 t/h were already observed in good working conditions (high yield and relatively uniform plantation). Figure 5 shows the prototype at the end of the first year of operation.

Table 1: Summary of the five field trials.

Trial	Date	Place	Bales harvested	Average yield † (t/ha)	Area capacity (ha/h)	Baling capacity (wet mass) Actual (t/h)	Baling capacity (wet mass) Maximum (t/h)
1	June 19-20	Cazaville	8	74.1	0.14	6.1	6.1
2	July 24	Cazaville	11	47.8	0.26	9.22	13.1
3	Aug. 30 to Sept 1	Huntingdon	29	NA	0.28	7.1*	11.8
4	Nov 8-9	Syracuse NY	25	76.5	0.28	9.72	14.3
5	Nov.27 and 29	Cazaville	19	NA	0.30	7.52	11.1
		Total	92	Average	0.25	7.9	11.3

†Yields were not measured during third and fifth harvest trial because of excessive variation in the field.

Table 2 provides results from the two-factor factorial harvest carried out in November 27-29, 2006. Bale diameter averaged 1.08 m for small bales and 1.38 m for large bales. Average bale width was 1.22 m. High belt tension in the compression chamber significantly ($p = 0.033$) increased the dry density of bales compared to low belt tension (138 vs. 128 kg DM/m³).

Table 3 presents a summary of harvest capacity during the fifth trial. As expected, more time was required to harvest small bales than large bales. The forward speed was similar for all treatments, averaging 2.0 km/h. The area capacity was also similar for all treatments (average of 0.30 ha/h). The statistical test did not show significant difference between harvest capacities. The average harvest capacity was 7.5 wet t/h and the average harvested yield was 25.4 wet t/ha (12.8 t DM/ha).

Table 2: Willow bale characteristics (average of 4 bales per treatment, Nov. 27-29, 2006).

Treatment		Circumference	Bale	Volume	Bale	Density	
Belt tension	Bale diameter	(m)	diameter (m)	(m^3)	mass (kg)	(kg/m^3) Wet	(kg/m^3) DM
Low	Small	3.38	1.07	1.11	288	259	131
Low	Large	4.08	1.35	1.74	411	248	125
High	Small	3.45	1.10	1.16	311	269	136
High	Large	4.40	1.40	1.88	523	278	140

Table 3: Time to form a single bale, capacity and harvested yield (Nov. 27-29, 2006).

Treatment		Baling	Forward	Capacity		Harvested
Belt tension	Bale diameter	time (s)	speed (km/h)	(ha/h)	(t/h) wet	yield (t/ha) wet
Low	Small	153	2.05	0.31	7.73	25.6
Low	Large	255	2.05	0.31	6.92	23.2
High	Small	160	1.87	0.28	7.45	26.6
High	Large	272	2.12	0.32	7.97	26.1

Due to frost and the beginning of snow, only 4 samples were collected to estimate field loss. The mean field loss was 4.9 t DM/ha (standard deviation of 0.42 t DM/ha). Since the harvested yield averaged 12.8 t DM/ha, this would imply an average loss of 28%.

The most visible fraction of harvest loss comes from the bale chamber. Small particles fall out on each side of the compression belt and between the rollers. The bale chamber should be better sealed to minimize particle loss. Reducing the intensity of shredding could also have a beneficial effect on loss reduction. Other visible losses come from the cutter head. Several stems are pushed too far away: they are either not cut and trampled over by the harvester or pushed sideways after being cut and never fed into the shredder.

Cost of harvester

The total material and manufacturing cost of the harvester was initially about $42,800 CAN. The main purchased components were a three-year old baler ($23,000), the modular cutterbar ($5,100), the shredder ($2,600), the swivel gear box ($3,200) and the full-length compression belt ($900). Other material purchases included pulleys, transmission belts, bearings etc. More than a hundred steel parts was laser cut or machine bended externally at a cost of $5,800. Labor and design costs were not included. After the initial field trials, an extra $6,500 was need for the various improvements. The total material and manufacturing cost for the prototype by the end of the first year (Fig. 5) was $49,300. A video of the harvester in operation can be viewed on the following site: ftp://public:public@echo.grr.ulaval.ca/videos_saules/

Fig. 5: Willow harvester in November 2006.

CONCLUSION

Willow grown in plantations may become an important source of biomass either for energy or fiber products. A review of past and recent work on willow harvesting has shown a need for an efficient, low-cost baler-type harvester to produce bales that can be handled easily, stored on the farm, and left to dry naturally during storage. The paper describes the development of a working prototype and its field testing in five different trials in 2006.

The prototype clearly demonstrated the feasibility of cutting stems with saw blades, feeding them through a shredder and forming bales in a compression chamber continuously, with a single harvester. A total of 92 bales were collected at various diameters between 0.99 to 1.54 m. The wet matter density of bales varied from 222 to 300 kg/m³ during the five trials. On a dry matter basis, the range was from 111 to 167 kg DM/m³. An increased compression belt tension significantly increased density. Moisture content of willow at harvest ranged from 44 to 51%.

At the end of the season when most mechanisms worked well, the continuous harvest rate of the baler ranged between 8 and 12 t wet/h. When idle time, turning time and time to wrap bales are included, the actual harvest rate would likely range between 5 and 8 t wet/h (2.5 and 4 t DM/h). Losses of broken particles left in the field were estimated at about 28% of original yield (trials 2 and 5). Several improvements could be considered such as a non row sensitive cutter head, a less aggressive shredding mechanism and a better sealed bale chamber to minimize small particle loss.

The prototype was best operated with a minimum tractor size of 100 to 120 kW and four hydraulic outlets. The material cost for the prototype development totalled about $50,000; this represents about one tenth the capital cost of a self-propelled willow-chipper harvester which is currently the only machine available to harvest willow over large areas of several hectares.

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AGROFORESTRY SYSTEMS FOR BIO-ENERGY GENERATION IN CANADA

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Abstract: The performance, productivity and adaptation of biomass willow clones in agroforestry systems are being determined. In determining the feasibility of these systems, their environmental benefits, including protection of soil, water and biodiversity, will also be determined. The study focuses on willow biomass production in alley-cropping and riparian buffer systems. We have hypothesized that using riparian buffer strips for willow biomass production provides energy alternatives through the use of the produced biomass but also leads to other environmental benefits such as reduced erosion and nutrient leaching and that alley-cropping systems can be designed that optimize resource use efficiency so that biomass production is increased and net GHG emissions are reduced compared to monoculture systems of woody or herbaceous species. Project sites are located in Sasaktchewan, Ontario, Quebec and Prince Edward Island.

Key Words: Riparian buffer, alley-cropping, willow, biomass.

THE POTENTIAL OF WESTERN CANADIAN SHELTERBELT SPECIES FOR SHORT ROTATION INTENSIVE CROP BIOMASS PRODUCTION

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Abstract: The use of short rotation intensive crop (SRIC) woody biomass is gaining popularity in the world as the economics of fossil fuels change. *Salix* and *Populus* have been considered to be best for SRIC biomass production in temperate regions. However there exists little information which rules out other species which are commonly used in western Canada for agroforestry. Several species may have the potential to be used as SRIC as they are know to vigorously re-grow after full or partial winter coppice. To determine the potential for SRIC candidates the study examined 17 commonly used shelterbelt species in western Canada including *Salix acutifolia* (acute willow) and *Populus deltoides* hybrid "Walker". Two-year-old plants were coppiced in the spring of 2006 and biomass re-growth was measured in the fall. By comparison, the study examined the biomass of three-year-old uncoppiced plants of the 17 species from the plantation. In this way, a relative measure of coppice re-growth was determined for each species. Initial results suggest that acute willow had the highest initial biomass and biomass reestablishment. Of the non-typical SRIC candidate species, *Sambucus racemosa* (red elder) and *Prunus pensylvanica (*pincherry) showed the most promise.

Résumé : La production de biomasse ligneuse par culture intensive sur courtes rotations (CICR) ne cesse de gagner en popularité à l'échelle mondiale à mesure que le marché des combustibles fossiles évolue. Les espèces de *Salix* et de *Populus* sont considérées comme celles convenant le mieux à la production de biomasse CICR dans les régions tempérées. Cependant, la documentation établissant qu'il faut exclure les autres espèces couramment utilisées en agroforesterie dans l'Ouest du Canada est lacunaire. Plusieurs espèces pourraient être utilisées en CICR, car elles sont reconnues pour rejeter vigoureusement après une coupe totale ou partielle de rajeunissement pratiquée en hiver (recépage). Afin de déterminer le potentiel de CICR d'espèces candidates, l'étude a examiné 17 espèces couramment plantées dans les brise-vent de l'Ouest du Canada, y compris le *Salix acutifolia* (saule à feuilles aiguës) et le *Populus deltoides* hybride "Walker". Des sujets de deux ans ont été recépés au printemps 2006, puis la repousse de la biomasse a été mesurée durant l'automne. L'étude a évalué à des fins de comparaison la biomasse produite par des sujets de trois ans non recépés des 17 espèces de la plantation, ce qui a permis d'obtenir une mesure relative de la repousse des sujets rajeunis de chaque espèce. Selon les premiers résultats, le saule à feuilles aiguës avait la biomasse initiale et le taux de régénération les plus importants. Parmi les espèces candidates non traditionnellement utilisées en CICR, le *Sambucus racemosa* (sureau rouge) et le *Prunus pensylvanica* (cerisier de Pennsylvanie) se sont avérés les plus prometteurs.

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INTRODUCTION

The use of purpose-grown biomass as a source of fuel is gaining acceptance as North America attempts to lessen its dependency on fossil fuels. Currently, purpose-grown woody biomass crops are comprised of willow (*Salix*) and hybrid poplar (*Populus*) species which have been selected for their fast growth and the ability to re-grow after harvest (Volk et al. 2004) Other sources of biomass include forestry and agricultural residue, wood waste from manufacturing and processing, purpose-grown grasses and other typical agricultural crops such as corn or cereals.

Agriculture and Agri-Food Canada's PFRA Shelterbelt Centre at Indian Head, Saskatchewan since 1901, has provided hardy tree and shrub materials to western Canadian farmers through the Prairie Shelterbelt Program. The prairie shelterbelt program currently provides 28 species of trees and shrubs including native and non-native species. Since the start of the program, approximately 650 million trees and shrubs have been distributed. Work has been done (Kort and Turnock 1999) to estimate the amount of carbon and biomass in existing shelterbelts. However, this work only examined biomass in older existing shelterbelts and did not examine shelterbelt species in their first years of growth. Based on the biomass estimates by Kort and Turnock (1999) and the number of trees that have been distributed across western Canada, there is a potential for a significant amount biomass to be harvested from existing shelterbelts. As shelterbelts reach a mature age, a possible rejuvenation method is to coppice the old material allowing the roots to regenerate new top growth.

Although work in western Canada on woody biomass energy production research has also focused on willow (*Salix*) and hybrid poplar (*Populus*) species, the literature provides little information on suitable alternatives to these species. This study focused on the biomass production from non-typical woody biomass crops. Seventeen common shelterbelt species were selected to be tested for their potential use as short rotation intensive biomass crops. A greenhouse study was also undertaken to examine biomass growth of five of these shelterbelt species.

METHODS

Field study

The seventeen species for coppice re-growth analysis were established in the spring of 2003 as a plant quality trial for plants used in the Prairie Shelterbelt Program. The site is located at the AAFC-PFRA Shelterbelt Centre, in Indian Head, Saskatchewan Latitude: 50° 30' N Longitude: 103° 40' W Elevation: 604.10 m and is located in the black soil zone. The average annual precipitation is 435mm and the average annual rainfall is 324mm. The average number of frost-free days is 123. In 2005, the site received an annual precipitation of 463mm with 345mm occurring during the growing season. Typically the area receives 124 frost-free days. In 2005, the site had 680 growing-degree days and 832 growing-degree days in 2006.

The site contained ten rows of five-plant plots at 0.5 m spacing between plants and 2.5 m spacing between rows with an east-west orientation. The site was maintained as a plant quality site for the first two years and was regularly cultivated to prevent weed competition. The species studied are listed in Table 1.

Table 11: Species selected for the field study, common name, Latin name, growth form and origin

Common Name	Latin Name	Form	Origin
Red elder	*Sambucus racemosa* L.	Shrub	Native
Acute willow	*Salix acutifolia* Willd.	Tree	Introduced
Walker poplar	*Populus deltoides* hybrid "Walker"	Tree	Introduced
Pincherry	*Prunus pensylvanica* L. f.	Shrub	Native
Dogwood	*Cornus sericea* L.	Shrub	Native
Hedge rose	*Rosa gallica* L.	Shrub	Native
Buffaloberry	*Shepherdia argentea* Nutt.	Shrub	Native
Sea buckthorn	*Hippophae rhamnoides* L.	Shrub	Introduced
Villosa lilac	*Syringa villosa* Vahl.	Shrub	Introduced
Hawthorn	*Crataegus arnoldiana*	Shrub	Native
Mongolian cherry	*Prunus fruticosa* L.	Shrub	Introduced
Green ash	*Fraxinus pennsylvanica* Marsh.	Tree	Native
Manitoba maple	*Acer negundo* L.	Tree	Native
Caragana	*Caragana arborescens* Lam.	Shrub	Introduced
Ussurian pear	*Pyrus ussuriensis* Maxim.	Tree	Introduced
Chokecherry	*Prunus virginiana* L.	Shrub	Native
Trembling aspen	*Populus tremuloides* Michx.	Tree	Native

In the spring of 2006 the centre plant in each five-plant plot was selected to be coppiced. All above-ground woody biomass from the coppiced plant was collected, bagged and oven-dried to determine the oven-dry biomass content and initial vigour. This was replicated five times for each species. During the growing season, the site was mowed and cultivated between the rows to prevent weed competition. Surrounding plants not used in the study were removed to limit competition. At the end of the 2006 growing season, selected plants were coppiced and the woody biomass was collected, bagged and oven-dried to determine oven-dry biomass content and post-coppice vigour. Also at the end of the 2006 growing season, three-year-old plants were harvested to examine the biomass of un-coppiced plants. The biomass was collected from all species, oven-dried and weighed. This was replicated five times for each species if the plants were available. A vigour index was calculated by dividing the biomass harvested in the fall, which gave an estimate of the plant's ability to produce biomass after coppice, by the biomass harvested in the spring of 2006, which was an estimate of how well the plants were growing before coppice. The index has no units and gives an indication of biomass growth after coppice based on the past growth. Calculations were done to estimate un-coppiced biomass growth by subtracting the mean spring 2006 biomass from the mean fall un-coppiced biomass. The estimate of un-coppiced biomass growth was then subtracted from the mean coppiced growth and then divided by the biomass harvested in the spring of 2006 to calculate a coppice effect index. The data was examined in Minitab to look for statistical differences among the species. An analysis of variance was used with the Tukey's test to show significant difference among the species.

Greenhouse study

Five species considered to have good potential for biomass production based on their growth rates in shelterbelts, were studied in the greenhouse and are listed in Table 2.

Table 12: Species selected for the greenhouse study, common name, Latin name

Common Name	Latin Name
Red elder	*Sambucus racemosa*
Acute willow	*Salix acutifolia*
Walker poplar	*Populus deltoides* hybrid "Walker"
Pincherry	*Prunus pensylvanica*
Manitoba maple	*Acer negundo*

Dormant seedlings of each species were selected for uniform size and were grown in pots. The initial mass of the seedlings was recorded by destructively sampling 10 similar seedlings of each species. The seedlings were washed to remove soil from the roots, oven-dried and then weighed. Four seedlings of each of the species were planted in pots for a total of 20 pots. Seedlings were grown for 42 day in the greenhouse using a 21-hour photoperiod and a light intensity of 800 watts. The day temperature was 25 °C with a night temperature 22 °C. At the end of the 42 days, the seedlings were destructively sampled and the woody biomass was oven-dried and weighed. The initial biomass was subtracted from the final biomass to give an estimate of the biomass increase over the 42 days.

RESULTS

Field study

The calculated vigour index rated *Populus deltoides* hybrid Walker with the largest biomass increase while *Populus tremuloides* had the lowest. This indicated that *Populus deltoides* hybrid Walker's coppice was the greatest in relation to its starting biomass. The 2006 spring results indicated that *Salix acutifolia* had the highest biomass growth while *Prunus virginiana* had the lowest biomass growth (Table 3). For the fall coppice harvest of biomass *Sambucus racemosa* had the highest amount of biomass regrowth and *Populus tremuloides* had the least. For the un-coppiced plants, *Salix acutifolia* had the highest total biomass and biomass growth estimated for the season while *Populus tremuloides* had the least biomass for total and seasonal growth. For the coppice effect index, that is the difference between the coppiced growth and the un-coppiced growth for the 2006 growing season divided by the 2006 starting growth, *Sambucus racemosa* had the most positive response to coppice while *Populus deltoides* hybrid Walker had the most negative response.

Table 3: Pre-coppice and end-coppice dry weight biomass and calculated vigour index for the plants in the field study. The highest and lowest values in each column are in bold font.

	Vigour index (A)	Pre-coppice biomass (g) (B)	Coppiced biomass (g) (C)	Un-coppiced biomass total (g) (D)	Un-coppiced biomass growth (g) (E)	Coppice effect index (F)
	(C/B) Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	(D-B)	(C-E)/B)
Populus deltoides hybrid "Walker"*	**6.92 (1.27)**	45.7 (4.8)	306.8 (59.4)	657.6 (95.0)	611.8	**-6.7**
Sambucus racemosa	3.52 (0.75)	256.9 (45.1)	**895.6 (230.3)**	1032.0 (161.5)	775.0	**0.5**
Fraxinus pennsylvanica	3.50 (0.56)	33.5 (8.0)	91.1 (21.2)	244.7 (63.9)	211.2	-4.1
Prunus virginiana	3.23 (0.91)	**23.5 (5.9)**	55.4 (9.7)	201.1 (61.2)	177.6	-5.2
Syringa villosa	2.58 (0.63)	49.2 (16.4)	101.8 (23.6)	296.0 (59.3)	246.8	-2.9
Acer negundo	2.10 (0.50)	39.9 (8.2)	92.8 (25.9)	162.6 (38.2)	122.7	-0.7
Pyrus ussuriensis	1.87 (0.22)	31.1 (8.9)	57.1 (17.3)	210.2 (75.0)	179.1	-3.9
Crataegus arnoldiana	1.85 (0.24)	51.2 (6.1)	99.2 (25.3)	218.2 (38.3)	167.0	-1.3
Cornus sericea	1.56 (0.33)	125.6 (20.0)	190.6 (40.5)	508.1 (82.1)	382.5	-1.5
Salix acutifolia	1.52 (0.41)	**573.3 (102.4)**	740.2 (147.1)	**1590.3 (382.5)**	**1017.0**	-0.5
Shepherdia argentea	1.48 (0.38)	85.9 (9.7)	137 (50.6)	464.1 (82.2)	378.2	-2.8
Caragana arborescens	1.40 (0.25)	64.6 (15.7)	78.8 (12.7)	237.2 (39.7)	172.6	-1.1
Prunus pensylvanica	1.32 (0.27)	195.3 (12.8)	265.7 (63.5)	783.2 (108.1)	587.9	-1.9
Prunus fruticosa	1.24 (0.56)	68.7 (21.8)	50.7 (15.0)	362.7 (68.5)	294.0	-3.5
Rosa gallica	1.02 (0.19)	191.7 (12.3)	195.9 (36.2)	365.8 (65.5)	174.1	0.1
Hippophae rhamnoides	0.85 (0.17)	88.6 (24.1)	66.5 (12.3)	418.3 (91.9)	329.7	-3.0
Populus tremuloides	**0.59 (0.24)**	33.6 (7.6)	**18.8 (7.9)**	**118.7 (8.0)**	**85.1**	-2.0

* *Populus deltoides* hybrid "Walker" in this study was taken from another planting which was 1 year younger.

When the data is extrapolated to annual tonnes per hectare based on 1 plant per m^2 *Sambucus racemosa* and *Salix acutifolia* produced the largest amount of biomass (Table 4).

Table 4: Estimated annual biomass produced by each species.

Species	**Biomass (ODT ha^{-1} yr^{-1})**		
Latin Name	Max	Min	Mean
Sambucus racemosa	14.66	2.38	6.89a
Salix acutifolia	11.37	2.49	6.35a
Populus deltoides hybrid	5.17	1.79	3.18b
Prunus pensylvanica	4.47	1.29	2.63bc
Cornus sericea	2.91	0.95	1.80bc
Rosa gallica	3.19	0.94	1.59bc
Shepherdia argentea	3.30	0.46	1.46bc
Hippophae rhamnoides	2.60	0.26	1.03bc
Syringa villosa	1.78	0.39	1.00bc
Crataegus arnoldiana	1.96	0.42	0.86c
Prunus fruticosa	1.77	0.15	0.86c
Fraxinus pennsylvanica	1.34	0.23	0.86c
Acer negundo	1.77	0.02	0.81c
Caragana arborescens	1.20	0.47	0.79c
Pyrus ussuriensis	1.20	0.21	0.62c
Prunus virginiana	1.45	0.33	0.61c
Populus tremuloides	0.47	0.04	0.29c

Greenhouse study

The greenhouse study indicated that *Sambucus racemosa* had significantly higher biomass growth over the 42 day period then the other species selected (Table 5).

Table 5: Mean increase in biomass over 42 days of the seedlings in the greenhouse.

		Biomass (g)	
Species	**n**	**Mean**	**SE**
Sambucus racemosa	4	25.5a	1.5
Salix acutifolia	4	15.8b	0.2
Populus deltoides hybrid "Walker"	4	11.8c	0.1
Acer negundo	4	9.7c	2.5
Prunus pensylvanica	4	7.8c	0.9

DISCUSSION AND CONCLUSION

In agriculture as in forestry there is an existing woody biomass resource that can be harvested for thermal, ethanol or other energy conversion options. Much of this biomass exists in shelterbelts across western Canada. A sustainable harvest of existing shelterbelts in western Canada could provide significant biomass supplies. However, as biomass needs increase there will be a requirement for intensive biomass production systems. Based on this study, there are several current shelterbelt species that have the potential to be used as a short rotation intensive biomass crop.

As a non-typical biomass species, *Sambucus racemosa* showed the greatest potential for biomass growth in both the field study and in the greenhouse. An interesting factor of *Sambucus racemosa* was its response to coppice with an increase in biomass after coppice. This may suggest that even young *Sambucus racemosa* has greater growth after coppice then without coppice, resulting in shorter rotations and a faster growing crop then *Salix* or *Populus*. The shorter rotation may also benefit *Sambucus racemosa* biomass production as older plants may be diverting resources to berry production rather then biomass production. With the exception of *Rosa gallica*, all other species in the study had more estimated biomass growth in the 2006 growing season if left un-coppiced, which may suggest that these shelterbelt species require a longer rotation, for example *Populus deltoides* hybrid Walker had the most negative response to coppice and is known to be productive in a longer rotation. The biology of *Sambucus racemosa* which includes reproduction by both seed and vegetative propagation, the species' response to coppice and the initial growth rates, increase its potential for use in SRIC. Limited knowledge on the quality of the biomass produced as a fuel, the lifespan and economics of a *Sambucus racemosa* SRIC systems and availability of suitable varieties for SRIC could limit its immediate use in SRIC.

Another of the potential candidates for SRIC was *Prunus pensylvanica* which had the ability to produce biomass. However, coppice effect based on the coppice effect index showed a negative impact on this species which may suggest that it may require a longer rotation. As with *Sambucus racemosa,* there is limited knowledge about the use of *Prunus pensylvanica* in SRIC systems and more work is required.

The *Salix acutifolia* and *Populus deltoides* hybrid "Walker" clone used in this study are typical clones for shelterbelt use in western Canada but were not developed especially for SRIC systems. However, both *Salix acutifolia* and *Populus deltoides* hybrid "Walker" in the field and greenhouse studies showed that they do have the potential to be used in SRIC systems. These plants have been proven to be hardy to the western Canadian climate and provide a good benchmark for the testing of new *Salix* and *Populus* clones as well as other species specifically developed for SRIC.

The species with the lowest potential for SRIC were *Populus tremuloides* and *Prunus virginiana* which are native to the region. This may be due to the low initial vigour for both species in the younger plants used in this study. It could also be due to a negative response to coppice in the case of *Prunus virginiana* as it received low ratings in the coppice effect index.

As SRIC becomes more interesting to western Canadian producers, more research needs to be done to find suitable species and varieties. Production, processing and utilization systems also need to be developed and refined so that SRIC is an economic and environmentally suitable option.

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HYBRID POPLAR CROP DENSITY

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Abstract: The volume of high value wood produced in short-rotation-intensive-culture (SRIC) hybrid poplar crops depends primarily on crop density. Choice of density and rotation length depends on crop development, rate of growth and financial considerations:

- Differentiation of growth rates between trees in a clonal crop starts at age two to four years;
- Differentiation of growth rates is independent of crop density;
- DBH growth peaks at age three to four and is independent of crop density;
- Rate of DBH growth depends on crop density; trees grown at lower densities have better and more sustained DBH growth.

Forintek Canada Corp. simulated potential clear and knotty lumber recoveries from a range of tree sizes. Results were used to evaluate volume and value recovery for seven crop densities, ranging from 434-1077 stems per hectare, represented by 13-year old density trials.

The discounted cash flow method was used to determine:

- Incremental net present value recovery by crop density for knotty and clear wood;
- Crop density recommendations for high value poplar crops.

Financial results indicate that hybrid poplar crops can be grown at crop densities that are lower than pulpwood densities now in general use in Canada, while generating similar or slightly better value per hectare, especially when trees are pruned for clear lumber and veneer recovery. Critical to success is to maximize tree growth in the earliest years by improved weed control, use of improved clonal material and of superior planting stock.

Key Words: Hybrid poplar, crop density.

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COMPETITION INTRASPÉCIFIQUE CHEZ LE PEUPLIER HYBRIDE

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Résumé : Les processus éco-physiologiques qui affectent la réaction des clones de peuplier hybride (*Populus* spp.) à la densité des peuplements sont peu connus. Dans une perspective agroforestière, il se peut qu'on doive faire varier l'espacement entre les plants ou la densité des blocs de plantations par rapport aux espèces compagnes. Ainsi, il devient impératif de mieux comprendre la compétition intraspécifique chez le peuplier hybride par l'évaluation des variations morphologiques et physiologiques liées à la diminution de l'espacement entre les arbres et des rapports de biomasse entre différentes parties selon le degré de compétition. Ces informations sont essentielles dans le choix des clones utilisés et dans la gestion de l'espacement entre les arbres pour maximiser la productivité. Trois parcelles expérimentales ont été installées en 2003 selon un même dispositif (blocs aléatoires) contenant deux clones de peuplier hybride, le 747215 (*P. balsamifera*, *P. trichocarpa*) et le 915319 (*P. maximowiczii*, *P. balsamifera* et trois différents espacements entre les arbres: 1 1m, 3 3m et 5 5m. Les mesures effectuées portent sur la caractérisation morphologique (cime et branches) et physiologique: (photosynthèse (An), respiration, conductance stomatique (Gs), concentrations en éléments nutritifs et en protéines solubles et insolubles, sur 9 feuilles situées à différents emplacements de la cime : trois en bas, trois à mi-hauteur et trois au sommet). La présentation portera sur les changements morpho-physiologiques induits par la réduction de l'espacement entre les arbres.

Mots-clés : Écophysiologie, peuplier hybride, acclimatation.

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TOWARDS AGROFORESTRY IN GERMANY – PRODUCTION OF ENERGY WOOD ON FALLOW GROUNDS

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Abstract: Due to increasing energy prices for fossil fuels the production of renewables on agricultural lands attracts strongly rising attention during the last few years in Germany. However, with respect to a number of specific management treatments (e.g., fertilization, use of pesticides, soil compaction, watering) and ecological indicators (e.g., C-sequestration, trace gas emissions, fauna and flora diversity) woody plants might be a serious alternative to common annual plants for energy production like canola or corn. The given paper will elucidate the potential of wood production on agricultural land in Germany. It will focus on short, medium and longer rotation periods, mainly with poplar and willow, and will concentrate on the question how woody plantations in agriculture should be designed to improve biodiversity and other ecological indicators.

Key Words: Fallow ground, energy wood, poplar, willow, rotation periods.

HARMONISATION DES USAGES DU TERRITOIRE AGROFORESTIER : L'EXEMPLE INTÉRESSANT DU PROJET PILOTE DES APPALACHES

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Résumé : L'aménagement et l'utilisation du territoire constituent des enjeux importants dans plusieurs régions du Québec. Les territoires péri-urbains et agroforestiers à l'intérieur desquels se juxtaposent différentes activités socio-économiques, telles la foresterie, l'agriculture et la villégiature, sont parfois le lieu de conflits d'usage mais aussi d'une sous-utilisation des terres.

La région agroforestière des Appalaches a vu s'implanter depuis plusieurs années une industrie porcine source de deux impacts importants : l'épandage réglementé de lisier sur les terres agricoles et l'extension de cette activité en zones forestières adjacentes après déboisement. Par ailleurs, cette région compte de nombreuses terres en friche qui offrent un potentiel de boisement intéressant. Est-il possible, dans ce contexte, de concilier boisement et valorisation du lisier de porc?

C'est dans cette perspective qu'un projet de R et D a été lancé en 2003 avec l'appui de six partenaires afin de répondre à différents objectifs en matière de développement durable :

- valorisation du lisier de porc comme source de fertilisant en plantation de peuplier hybride et évaluation des risques environnementaux associés à cette approche;
- boisement et valorisation de friches herbacées ou embroussaillées à des fins de production de bois et de captage de carbone;
- bénéfices multiples pour les propriétaires.

Ce projet pilote implanté dans quatre municipalités et auquel collaborent neuf propriétaires permettra d'évaluer scientifiquement l'impact de quatre régimes d'azote provenant de lisier de porc sur différents éléments à caractère forestier, agricole, environnemental et économique. L'affiche décrit les grandes lignes du projet pilote et certains résultats obtenus à ce jour.

Mots-clés : Agroforesterie, peuplier hybride, lisier de porc, aménagement du territoire.

Abstract: Land development and use are important issues for many regions of Québec. In urban periphery and agroforestry areas where several socio-economic activities such as forestry, farming and vacation development take place, usage conflicts sometimes arise but also land may be under-used.

In recent years, a pig production industry has developed in the Appalaches agroforestry region, with two significant consequences, namely the regulated spreading of pig slurry on farmland, and an extension of the activity into forested areas following deforestation. The region has several areas of open land that offer considerable potential for afforestation. In such a context, would it be possible to reconcile afforestation with slurry development?

A research and development project was launched in 2003, with support from six partners, in order to meet a number of sustainable development goals:

- Development of pig slurry as a source of fertilizer for hybrid poplar plantations and assessment of the associated environmental risks;
- Afforestation and development of open land for timber production and carbon sequestration purposes;
- Multiple benefits for landowners.

The pilot project was implemented in four municipalities with nine landowners. It will provide a scientific assessment of the impact of four pig slurry-based nitrogen regimes on various forestry, farming, environmental and economic factors. The poster describes the principal elements of the pilot project and presents some of the results obtained so far.

Key Words: Agroforestry, hybrid poplar, pig slurry, land management.

INTRODUCTION

L'utilisation et l'aménagement du territoire constituent des enjeux importants dans plusieurs régions du Québec et plus particulièrement dans les zones péri- urbaines et en forêt habitée. Plusieurs créneaux structurent en effet le tissu socio-économique des communautés locales afin de répondre aux besoins de secteurs d'activités créateurs de richesses : industries, agriculture, foresterie, villégiature, etc. L'occupation du territoire doit généralement intégrer à la fois les droits individuels attachés à la propriété, mais aussi les besoins plus collectifs qui intègrent différents aspects à caractère environnemental, biologique et sociologique (voir Fig. 1).

PROBLÉMATIQUE

Située au sud de la ville de Québec, la région de Chaudière-Appalaches couvre un territoire agroforestier qui soutient une communauté locale et régionale diversifiée. Plusieurs secteurs d'activités économiques contribuent à la création et au maintien de l'emploi; parmi ceux-ci, l'agriculture et la foresterie, de par les caractéristiques bio physiques du territoire, constituent des secteurs d'activité créateurs de richesse.

Fig. 1 : Paysage agroforestier typique du Québec.

Des inventaires réalisés récemment indiquent que des superficies relativement importantes de friches herbacées ou arbustives sont présentes sur le territoire et sont peu valorisées pour créer une valeur ajoutée. Il s'agit généralement de petites superficies enclavées entre des secteurs agricoles et des massifs forestiers. Ces terres, généralement de bonne qualité au plan de la fertilité et accessibles, font l'objet d'intérêts divergents et sont source de conflits entre les agriculteurs et les forestiers:

- <u>Les agriculteurs</u> ont besoin de superficies importantes pour permettre le développement d'activités agricoles, plus particulièrement celle de la production porcine. Cette industrie est source de nuisance puisque les producteurs doivent épandre le lisier ou purin sur leurs terres à l'intérieur d'un cadre réglementaire restrictif. Depuis 2002, le Règlement sur les eaux agricoles (REA) sous la responsabilité du ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) a été renforcé, plus particulièrement la charge maximale applicable en phosphore (P_2O_5). Cette réglementation fait en sorte qu'il faut davantage de superficies d'épandage pour respecter la norme.

- <u>Les forestiers</u> dans le secteur agroforestier, sont à la recherche de superficies accessibles et de bonne qualité afin d'accroître la production de fibres par le boisement plus spécifique d'essences à croissance rapide tel le peuplier hybride (PEH). En effet, le bilan forestier actuel pour la région des Appalaches indique que la demande en fibres de peupliers rejoint actuellement la possibilité forestière à rendement soutenu.

OBJECTIFS DU PROJET PILOTE

Initialement, ce projet a été mis sur pied dans le cadre de l'Initiative d'évaluation de la faisabilité du boisement en vue de captage de carbone. Cette initiative, élaborée dans le cadre du Plan d'action du Canada sur les changements climatiques de 2002 a été mise en place au Québec par le Service canadien des forêts du ministère des Ressources Naturelles du Canada en partenariat avec le ministère des Ressources naturelles et de la Faune du Québec (MRNF). Comme la région des Appalaches est la plus affectée au Québec par le surplus de lisier de porc selon les données obtenues du MAPAQ en 2000, l'Agence de mise en valeur des forêts privées des Appalaches a été sélectionnée en 2002 pour assurer la mise en œuvre du projet pilote.

Compte tenu des conflits d'usage liés aux friches décrites précédemment et de l'importance de démontrer l'harmonisation des usages agricoles et forestiers dans les friches, ce projet ciblait deux objectifs : d'une part, démontrer scientifiquement la faisabilité de cultiver du peuplier hybride sur des friches avec un apport de lisier de porc comme source d'azote sans produire d'impacts négatifs sur l'environnement et, d'autre part, d'examiner certains enjeux socio-économiques d'une telle approche.

Pour réaliser ce projet intégrateur et constituer une équipe multidisciplinaire, plusieurs intervenants ont été retenus outre l'Agence de mise en valeur des forêts privées des Appalaches : le Service canadien des forêts pour les aspects socio-économiques, les bilans de carbone, les analyses statistiques et le financement, le MAPAQ pour l'élaboration des calendriers d'amendement en azote, l'Université Laval et le Réseau Ligniculture Québec pour l'encadrement scientifique et technique du projet et le MRNF pour le volet forestier, environnemental et le financement du projet. Soulignons que les organisations ont offert un support en ressources humaines afin de réaliser ce projet.

MATÉRIEL ET MÉTHODE

Volet biologique et environnemental

Deux dispositifs expérimentaux ont été implantés, le premier en 2003 et le second en 2004, à l'intérieur desquels respectivement quatre et neuf blocs ont fait l'objet d'une expérimentation. Comme le montre la Fig. 2, chaque bloc était divisé en quatre planches, chacune étant associée à une dose de lisier (0, 40, 60 et 80 kg N/ha) appliquée annuellement. Chaque planche était subdivisée en quatre parcelles à l'intérieur desquelles trois clones de peuplier ont fait l'objet d'un suivi ainsi qu'une parcelle dans laquelle des herbacées servaient de témoin.

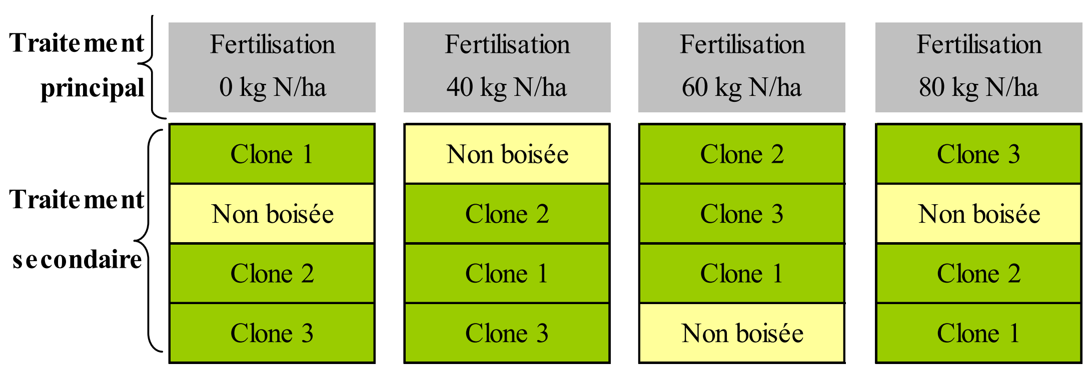

Fig. 2 : Schéma caractéristique d'un bloc expérimental.

Des mesures de référence ont été prises avant l'application du lisier de porc (voir Fig. 3). Des inventaires annuels ont été réalisés afin de mesurer les effets associés aux traitements principaux et secondaires. Globalement, les variables suivantes ont fait l'objet d'une évaluation :

1. Hauteur (m) et diamètre (cm) des arbres (au sol et au DHP lorsque possible); analyse foliaire : poids unitaire (g) et concentrations en éléments minéraux (N, P, K, Ca et Mg (mg/kg));

2. Sols : pH, P, K, Ca, Mg, Al et Na (mg/kg), texture et type de sol : dans les rangées et entre les rangées distinctement;

3. Trois prélevés de solution de sol au cours de la saison avec des lysimètres à des profondeurs de 20 et 40 cm après épandage de lisier et suite à une période de pluie; mesures de $P/PO4^{-3}$, N/NH^{-4}, N/NO^{-3} (ppm; Fig. 4).

Les superficies moyennes des sites expérimentaux variaient entre 1,1 hectare et 2,7 hectares. Les traitements sylvicoles usuels étaient réalisés pour l'ensemble des blocs selon les exigences de l'Agence de mise en valeur des forêts privées des Appalaches afin de permettre une croissance optimale des peupliers hybrides. Pour chaque variable, un modèle statistique a été élaboré, validé et ajusté afin de tenir compte de certaines particularités observées lors du suivi. L'analyse des données a été réalisée à l'aide de la procédure MIXED de SAS.

Fig. 3 : Application de lisier de porc entre les rangs de peuplier hybride.

Fig. 4 : Opération requise pour l'utilisation des lysimètres.

Volet socioéconomique

Une enquête scientifique a été réalisée auprès de 411 propriétaires de terres non boisées sur lesquelles il ne se fait pas d'agriculture, plus particulièrement des friches et des pâturages. Une sous-population était constituée de propriétaires de terres non boisées également producteurs de porcs. La méthode utilisée est une approche par sondage téléphonique. Plusieurs éléments ont été pris en compte lors de l'enquête et plus spécifiquement les volets suivants :

1. Caractéristiques des terres susceptibles d'être boisées au sens du protocole de Kyoto;
2. Intérêt des propriétaires pour le boisement;
3. Intérêt des propriétaires pour le boisement d'essences à croissance rapide;
4. Phénomène du déboisement;
5. Caractéristiques socio-économiques des propriétaires.

Les données colligées lors d'une première pré-enquête en mars et avril 2005 et lors de l'enquête principale en janvier et février 2006 ont été traitées statistiquement à l'aide du logiciel SPSS, version 11.5.

RÉSULTATS PRÉLIMINAIRES

Volet biophysique et environnemental

Les analyses statistiques préliminaires obtenues du traitement des données colligées du dispositif expérimental de 2003 indiquent peu de différences de hauteur et de diamètre des tiges de PEH entre les quatre traitements de fertilisation azotée (Fig. 5 et Fig. 6). Trois ans après la mise en terre des plants du premier dispositif expérimental, les arbres fertilisés étaient semblables morphologiquement. Par contre, les clones présentent des croissances significativement différentes, et ce, tant pour la hauteur que pour le diamètre au sol. Sur le plan des analyses foliaires, trois ans après traitements, l'application de doses différentes de lisier de porc a produit des effets significatifs sur le N, le K et le Ca mais aucun sur le P et le Mg. Les clones de peuplier présentent des différences significatives à ce chapitre sauf pour l'élément phosphore.

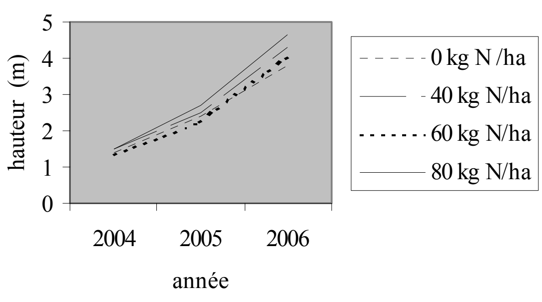

Fig. 5 : Croissance en hauteur du peuplier hybride.

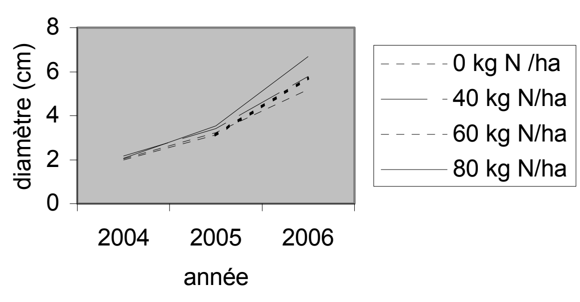

Fig. 6 : Croissance en diamètre du peuplier hybride.

Sur le plan de la biomasse, les résultats préliminaires indiquent que les masses foliaires des peupliers ont été significativement différentes entre les traitements de fertilisation ainsi qu'entre les clones. Finalement les analyses faites des solutions de sol obtenues des lysimètres (P/PO4-3, N/NH-4, N/NO-3) présentent des tendances variables selon la profondeur et le jour du prélèvement. Globalement cependant, la dose de lisier a un effet significatif sur les concentrations en P/PO4-3.

Volet socio-économique

Les résultats préliminaires de l'enquête font ressortir des éléments intéressants qui mettent en perspectives certains aspects du milieu agroforestier. Ainsi, 83 % des répondants au sondage ont confirmé posséder une terre en friche et 23 %, un pâturage. Les propriétaires ont dans 60 % des cas plus de 50 ans et sont retraités pour 25 % d'entre eux. Au plan forestier, la moitié des propriétaires seraient intéressés à planter des peupliers hybrides moyennant certaines formes d'aide financière. L'ajout d'un volet fertilisation au lisier pour augmenter la vigueur et la croissance des arbres, mais sans impact sur l'environnement, ne modifierait pas ou augmenterait leur intérêt pour la plantation de peupliers hybrides dans 83 % des cas.

DISCUSSION – CONCLUSION

Trois ans après l'application de lisier de porc à différentes concentrations à l'intérieur de plantations de peuplier hybride cultivées sur des friches herbacées, les résultats préliminaires obtenus sur le plan environnemental demeurent encourageants bien qu'il demeurerait important de porter une attention plus particulière aux concentrations en phosphore dans les eaux de surface. Les données du second dispositif implanté en 2004 et constitué de neuf blocs permettront de mieux préciser les tendances préliminaires observées.

Sur le plan biologique, bien qu'aucun effet n'ait été décelé sur la hauteur et le diamètre des tiges de PEH, les effets réels observés sur la masse foliaire indiquent que les arbres semblent bien répondre à court terme aux traitements de fertilisation. Les suivis à moyen terme permettront de confirmer l'effet des amendements et du clone sur le gabarit des plants.

L'analyse socio-économique effectuée auprès des propriétaires, un aspect généralement peu étudié dans le domaine de la foresterie, met en perspective certains éléments importants à prendre en compte dans un éventuel programme national de boisement des friches. L'aide financière associée à la remise en production de ces terres mais aussi la fiabilité des épandages sur le plan environnemental constituent des éléments importants pour les propriétaires.

Réalisé dans un cadre agroforestier, ce projet de recherche et de développement qui met à contribution cinq partenaires issus des milieux national, provincial, universitaire et régional a fait ressortir l'importance de bien définir les objectifs initiaux et de coordonner efficacement différentes interventions de nature agroforestière afin d'en maximiser les retombées socio-économiques.

Ce projet de R et D reflète bien le concept de l'agroforesterie puisque les cinq critères qui le sous-tendent sont respectés, à savoir la mise en œuvre d'actions humaines, intentionnelles, intensives, interactives et intégrées. La poursuite à moyen terme du projet permettra de préciser le potentiel de développement durable de l'approche mise à l'essai par le biais de ce projet pilote.

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HYBRID POPLAR CROP MANUAL FOR THE PRAIRIE PROVINCES

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Abstract: The 'Hybrid Poplar Crop Manual for the Prairie Provinces' is a compendium of current knowledge about the planning, establishment and management of 'short-rotation-intensive-culture' (SRIC) hybrid poplar crops. SRIC hybrid poplar crops are managed as agronomic crops on farmland in British Columbia and the Prairie Provinces. To meet rapidly growing interest in this agronomic crop from farmers, land owners and corporations, this Manual for the Prairie region consolidates relevant information into one document.

Information was compiled based on the author's expertise, supplemented with the vast knowledge of local experts and practitioners in the field. This Manual is available in a Web-based format through the Websites of the Saskatchewan Forest Centre (www.saskforestcentre.ca) and the Poplar Council of Canada (www.poplar.ca).

The organization of the Crop Manual follows a logical planning sequence, reflected in seven modules, preceded by an introduction with basic information:

1. Site requirements and selection;
2. Clone selection and deployment;
3. Stock procurement;
4. Crop density, spacing & layout;
5. Site preparation;
6. Crop planting;
7. Crop maintenance & improvement.

There are three support modules on growth & yield, diseases & insects, and economic analysis. Modules are linked to appendices and a glossary of terms. External Web links allow expansion of the information base. Navigation features allow users to move around the document with ease.

Key messages are:

- Use of proven clones (require additional new clones);
- Plant only high quality sites;
- Ensure intensive tending, especially weed control.

Key Words: Hybrid poplar crop manual, crop manual, hybrid poplar, poplar, manual.

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SECTION 7

Biodiversité et aspects fauniques de l'agroforesterie

Biodiversity and Wildlife in Agroforestry

AVIAN FAUNA IN WINDBREAKS INTEGRATING SHRUBS THAT PRODUCE NON TIMBER FOREST PRODUCTS

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Abstract: Avian diversity was studied during spring and fall of 2005 and 2006, in 12 year-old windbreaks integrating or not shrubs that produce non-timber forest products (NTFP) in farmlands of eastern Québec, Canada. The main objectives were: (1) to determine whether the NTFP's shrubs increase bird abundance, richness and diversity; (2) to attest if the NTFP attract detrimental birds; (3) to determine the habitat variables that best explain the use of windbreaks by birds. Traditional windbreaks (n = 7) integrated American Larch (*Larix laricina* (Du Roi) Koch.) alternating with Ashes (*Fraxinus pennsylvanica* Marsh or *Fraxinus americana* L.), while the windbreaks integrating shrubs that produce NTFP (n = 7) included Elderberries (*Sambucus Canadensis* L.) and Highbush Cranberries (*Viburnum trilobum* Marsh.) instead of *L. laricina*. No difference was found in terms of bird abundance, diversity and richness between the two types of windbreaks, except for the richness during the spring that was greater in windbreaks without NTFP, probably due to the fact that Larches provide greater tree cover. In both windbreaks types, the great majority (> 94%) of the birds encountered were non detrimental. Bird use was influenced by the presence of ditches along the windbreak.

Key Words: Avian diversity, bird richness, bird abundance, indigenous shrub, NTFP, windbreak.

Résumé : Au cours des printemps et automne 2005-2006, la diversité aviaire de haies brise-vent de 12 ans intégrant ou non des arbustes porteurs de produits forestiers non ligneux (PFNL) a été évaluée dans des exploitations agricoles de l'est du Québec, au Canada. Les objectifs de l'étude étaient de : (1) déterminer si la présence de PFNL dans les haies brise-vent augmente l'abondance, la richesse et la diversité aviaire; (2) vérifier si les PFNL sont une source d'attraction pour la faune aviaire nuisible et (3) déterminer les caractéristiques des haies qui expliquent le mieux la présence des oiseaux. Les haies traditionnelles (n=7) comportaient des mélèzes (*Larix laricina* (Du Roi) Koch.) en alternance avec des frênes (*Fraxinus pennsylvanica* Marsh ou *Fraxinus americana* L.), alors que les haies avec PFNL comportaient des sureaux blancs (*Sambucus canadensis* L.) et des pimbinas (*Viburnum trilobum* Marsh.) à la place des mélèzes. L'abondance, la diversité et la richesse aviaires se sont révélés similaires dans les deux types de haies, à l'exception de la richesse aviaire printanière qui était plus élevée dans les haies sans PFNL, probablement à cause du plus grand couvert arboré offert par les mélèzes. Dans les deux types de haies, la grande majorité des oiseaux observés (> 94 %) étaient non nuisibles. La présence de fossés de ferme le long des haies influence l'utilisation des haies par les oiseaux.

Mots-clés : Abondance aviaire, arbuste indigène, diversité aviaire, haie brise-vent, PFNL, richesse aviaire.

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INTRODUCTION

In the last decades, the intensification and specialization of agriculture has drastically transformed the agrarian landscape (Bélanger and Grenier 2002). The consequences were largely damageable to forests and natural hedgerows still remaining on the farmstead. The loss of woodlots, hedgerows, field margins and ditches (Agger and Brandt 1988), as a result of agricultural modernization (Meeus 1993), has lead to landscape fragmentation that is the first cause of biodiversity losses in rural areas (Saunders et al. 1991). Birds are both indicators and targets of the changes that are observed in agricultural practices. Their behavior, distribution, seasonal phenology and demography track closely onto the spatial and temporal scales of agricultural intensification (Ormerod and Watkinson 2000).

Windbreaks are foreseen to constitute a promising avenue to restore and sustain the ecological processes affected by land fragmentation. In Québec, more than 2500 km of windbreaks were established between 1989 and 1994 (Pesant 2005) and this trend continues because of economical supports from governments to farmers. In spite of their many advantages, windbreaks are still perceived as a loss of cultivable space (Kort 1988) and a source of damaging birds, insect pests and weeds. Thus, they are often removed (Jobin et al. 2001) or too severely mowed and pruned. However, according to Jobin et al. (2001), windbreaks can implement avian diversity without sacrificing that much of a cultivated land.

It was then suggested that introducing shrubs that produce non-timber forest products (NTFP) into windbreaks could compensate for crop losses by generating incomes for the farmers. NTFP are defined as products of biological origin other than wood derived from forests, other wooded land and trees outside forest (FAO 2004). In Québec, five indigenous shrubs that produce NTFP were studied and were identified as potentially marketable and profitable (Rousseau 2001). Those shrubs bear fruits that are of interest for rural development because of their transformation potential into products with high added value. Their cultivation could also reduce pressure on natural forests where harvesting is carried out without any organized method (Rousseau 2001).

In many studies carried out in USA, Canada and UK, windbreaks were strongly favorable to birds, but the impact of shrubs that bear fruits on avian fauna has not been studied in Québec. Therefore, the main objectives of this study were: (1) to determine whether the NTFP's shrubs increase bird abundance, richness and diversity; (2) to attest if the NTFP attract detrimental birds; (3) to determine the habitat variables that best explain the use of windbreaks by birds.

MATERIAL AND METHODS

Twelve year-old windbreaks were studied in the La Pocatière area (47°04' N to 47°43' N, 69°18' W to 70°06' W), on the east side of the St. Lawrence River, Québec, Canada. Because one of the windbreaks was long enough to be separated into two sample units, surveys were carried out in fourteen 350 m long one-row windbreak sections with a width of ~ 2 m, and with at least 10 m long buffer zones at both extremities. Traditional windbreaks (n=7) were composed of *L. laricina*. alternating with *F. pennsylvanica* or *F. americana*, while the windbreaks integrating shrubs that produce NTFP (n=7) included *S. canadensis* and *V. trilobum* instead of *L. laricina*.

Each windbreak was bordered by crops or pastures and some of them were located along ditches or irrigation channels that dried out or presented weak flows in the summer.

Survey of structural composition

Surveys of windbreak structural composition were conducted in July 2005. The structural arrangement of each windbreak was systematically characterized by walking along them and noting several variables: tree height, shrub height, number of tree and shrub species, distance between each component of the windbreak, presence of branches on the ground (after pruning), presence of openings in the vegetative layer and number of dead trees and shrubs. Tree cover was calculated using tree height and width in relation to their proportion in the windbreak. Crops adjacent to windbreaks were similar in both windbreak types, mostly pasture. Ditches were encountered alongside both types of windbreaks. Most of them were weak flow ditches. All characteristics were then compiled for further analysis, adding environment variables such as presence of ditches and nature of adjacent crops.

Bird surveys

In 2005, bird surveys were conducted between May 18 and June 4 and between September 13 and 21 while, in 2006, they were conducted between June 5 and 19 and between August 28 and September 6. Each windbreak was visited 7 times for each survey period and each visit occurred at different moments of the day. In spring, surveys were carried out during the breeding season while, in fall, they coincided with the period of maturation of the fruits. In spring, visual and song identification took place from 5h00 am to 10h00 am, the most active period of the day (Emlen 1977; Robbins 1981). In fall, observations were conducted during all daytime hours. Climatic conditions were standardized and noted, so that no surveys were carried out under heavy rain or strong wind.

Data analysis

Structural composition- The study was conducted with a 7 replicates sample design. The structural composition of the two treatments was compared using a one-factor ANOVA (PROC MIXED; SAS Institute 1988). When variables did not meet normality and variances were not homogeneous, the non-parametric Wilcoxon test was used (PROC NPAR1WAY; SAS Institute 1988).

Birds- For each windbreak, a summation of the 7 observation dates was made. Bird richness was defined as the total number of birds species encountered, while the abundance corresponds to the number of birds encountered for each species. The total abundance refers to the summation of all the species abundances. An index of relative importance (RI) for each bird species encountered was calculated for the two types of windbreaks (Yahner 1983). This index integrates the spatial, temporal and abundance characteristics to assess the constancy of occurrence of birds. The RI values were ranked as follows: high ($300>RI \geq 150$); moderate ($150> RI \geq 83$); low ($83> RI \geq 60$); negligible ($RI < 60$).

The Shannon index (Zar 1984), one of the most widely used in ecology (Greig-Smith 1983) and in agroforestry (Rojas et al. 2001) was used as an index of diversity. All data were analyzed combining 2005 and 2006 data using a two-factors analysis (PROC MIXED; SAS Institute 1988) because no interaction was found between treatment and year. When the number of observations was low (< 5) for a given species, a logistic regression was performed. Differences were considered significant at $\alpha = 0.05$. Birds were assigned to two classes according to their potential impacts on crops and NTFP. *Corvus brachyrhynchos* Brehm*, Agelaius phoeniceus* L. and *Sturnus vulgaris* L. are considered detrimental in North America (Timm 1988). Because of their scavenger behaviour, their attraction for small fruits or their impacts on sanitation aspects (feces), Ring-billed Gull (*Larus delawarensis* L.*)*, Cedar Waxwing *(Bombycilla cedrorum* L.) and Common Raven (*Corvus corax* L.) were also considered detrimental (Johnson and Beck 1988). All other species encountered were considered non detrimental. To determine which of the structural and environmental variables best explained bird abundance and richness, a multiple regression analysis (PROC REG; SAS Institute 1988) was performed.

RESULTS

Structural composition

Distances between trees were greater in windbreaks without NTFP (data not presented). Mean height of the tree stratum was higher in windbreaks without NTFP (7.21 m vs 5.58 m), although the shrub stratum was higher in windbreaks with NTFP (1.55 m vs 0.75 m). Tree cover percentages were greater in windbreaks without NTFP (74.9% vs 59.6%). A mean of 7.29 different tree and shrub species, planted or not, were found in windbreaks with NTFP, compared to 6.14 species in the traditional windbreaks. Number of gaps in the herbaceous stratum and number of live trees and shrubs were similar in both windbreak types.

Spring birds

Abundance and richness - In spring 2005 and 2006, 655 birds belonging to at least 11 species and 818 birds of at least 13 species, respectively, were encountered (Table 1). Similar diversity indices were obtained in windbreaks of both types (Table 1).

Table 1: Abundance (total number of birds), richness (total number of species) and diversity (Shannon index) in windbreaks with or without NTFP in spring 2005 and 2006

	Spring 2005		Spring 2006	
	With NTFP (n=7)	Without NTFP (n=7)	With NTFP (n=7)	Without NTFP (n=7)
Abundance	300	355	372	446
Richness	≥5[1]	≥10[1]	≥5[1]	≥9[1]
Diversity	0.40 [a]	0.53 [a]	0.46 [a]	0.65 [a]

[1] Species number is minimal because of unidentified sparrows
[a] Data followed by the same letter are not significantly different (Hutcheson Test, t= -0.049 and t= -0.07)

Analyses showed no interaction between year and treatment, allowing a combined analysis of the 2 years. Spring abundance showed no significant difference between both windbreak types (Table 2). Spring richness was greater in windbreaks without NTFP (Table 2).

Table 2: Bird abundance (number of bird observations), bird richness (number of species) and number of non detrimental birds (number of bird observations) in windbreaks with or without NTFP (means of spring 2005 and 2006)

	With NTFP		Without NTFP		
	Mean	S.E.	Mean	S.E.	P value
Bird abundance	47.64	4.72	60.57	6.59	0.2404
Bird richness	3.00	0.23	5.07	0.45	0.0006**
Number of non detrimental birds	44.93	4.71	52.50	4.82	0.4283

**Very significant difference at a level of $P \leq 0.01$

Detrimental birds- Four detrimental bird species were observed during spring: American Crow (*Corvus brachyrhynchos* Brehm), Red-winged Blackbird (*Agelaius phoeniceus* L.), Ring-billed Gull (*Larus delawarensis* L.) and European Starling (*Sturnus vulgaris* L.). The total number of non detrimental bird observations represented 94.1% of all the observations: 95% in windbreaks with NTFP and 93.3% in windbreaks without NTFP (Table 2). Non detrimental bird abundance did not differ from one windbreak type to the other (Table 2).

Bird species abundances- For the species that were analyzed including both years, bird species abundance showed no difference between windbreak types, except for American Goldfinch that had a moderate index of relative importance (RI) (data not presented) and a greater abundance in windbreaks without NTFP in comparison with windbreaks with NTFP (Table 3). Both windbreaks types were visited by the same dominant species presenting a high index of RI (data not presented): Song Sparrow (*Melospiza melodia* (Wilson)) and Savannah Sparrow (*Passerculus sandwichensis* (Gmelin)).

Fall birds

Abundance and richness- In fall 2005 and 2006, 455 birds of at least 9 species and 872 birds of at least 10 species, were respectively encountered. They were identified to the species, except for 277 and 403 sparrows. Many sparrows were not identified because of many factors at that time of year: dense foliage cover, birds' lower propensity to sing, lack of strong territorial behaviour, presence of less easily identified juvenile birds, and migratory flows. Shannon index indicates that windbreaks with or without NTFP have a similar diversity (Table 4).

In fall, there was no interaction between year and treatment, allowing a combined analysis of the 2 years. Fall abundance showed no significant difference between both windbreak types (Table 5). Fall richness did not differ from one windbreak type to another (Table 5).

Table 3: Bird species abundances (number of bird observations per windbreak section of 350 m) in windbreaks with or without NTFP (means of spring 2005 and 2006)

	With NTFP		Without NTFP		
Species (Latin names)	Mean	S.E.	Mean	S.E.	P value
Song Sparrow (*Melospiza melodia* (Wilson))	14.14	2.05	14.86	1.87	0.8455
Savannah Sparrow (*Passerculus sandwichensis* (Gmelin))	20.43	3.76	19.29	3.47	0.8629
American Crow (*Corvus brachyrhynchos* Brehm)[1]	1.64	0.87	1.29	0.42	0.5586
American Goldfinch (*Carduelis tristis* L.)	0.36	0.29	4.29	1.04	0.0006**
Red-winged Blackbird (*Agelaius phoeniceus* L.) [1]	0.64	0.51	2.14	1.57	0.4125
Northern Harrier (*Circus cyaneus* L.) [1]	0.00	0.00	0.21	0.11	0.0902
American Black Duck (*Anas rubripes* Brewster) [1]	0.29	0.16	0.36	0.25	0.7851
Eastern Phoebe (*Sayornis phoebe* (Latham)) [1]	0.00	0.00	0.57	0.44	0.1763

**Very significant difference at a level of $P \leq 0.01$

[1] A logistic regression was used to realize comparisons between windbreak types for these species.

Table 4: Abundance (total number of birds), richness (total number of species) and diversity (Shannon index) in windbreaks with or without NTFP in fall 2005 and 2006

	Fall 2005		Fall 2006	
	With NTFP	Without NTFP	With NTFP	Without NTFP
Abundance	223	232	359	513
Richness	≥6[1]	≥7[1]	≥9[1]	≥6[1]
Diversity	0.51 [a]	0.45 [a]	0.44 [a]	0.43 [a]

[1] Species number is minimal because of unidentified sparrows

[a] Data followed by the same letter are not significantly different according to the Hutcheson Test (t=0.030 and t= 0.0022)

Table 5: Bird abundance (number of bird observations), bird richness (number of species) and number of non detrimental birds (number of bird observations) in windbreaks with or without NTFP (means of fall 2005 and 2006)

	With NTFP		Without NTFP		
	Mean	S.E.	Mean	S.E.	P value
Bird abundance	41.50	8.12	53.21	12.26	0.4488
Bird richness	2.86	0.33	2.93	0.25	0.8406
Number of non detrimental birds	40.93	8.17	51.93	12.15	0.4870

Detrimental birds- Three detrimental bird species only were observed during fall: American Crow, Cedar Waxwing (*Bombycilla cedrorum* L.) and Common Raven (*Corvus corax* L.). Total number of non detrimental bird observations represented 98% of all the observations: 98.5% in windbreaks with NTFP and 97.6% in windbreaks without NTFP. Non detrimental bird abundance did not differ from one windbreak type to another (Table 5).

Species abundances- For the species that were analyzed including both years, bird species abundance showed no difference between windbreak types (Table 6). In both windbreak types, Savannah Sparrow was the dominant species, presenting a high index of RI (data not presented).

In windbreaks without NTFP, Song Sparrow presented a high index of RI, while in windbreaks with NTFP, the index of RI was low in 2005 and moderate in 2006 for this species (data not presented).

Table 6. Species abundance (number of bird observations per windbreak section of 350 m) in windbreaks with or without NTFP (means of fall 2005 and 2006)

	With NTFP		Without NTFP		
Species (Latin names)	Mean	S.E.	Mean	S.E.	P value
Song Sparrow (*Melospiza melodia* (Wilson))	5.36	1.88	10.43	4.56	0.2581
Savannah Sparrow (*Passerculus sandwichensis* (Gmelin))	10.43	3.56	12.43	2.73	0.5055
American Crow (*Corvus brachyrhynchos* Brehm)	0.29	0.16	1.29	0.54	0.0861

Habitat model

Multiple regression habitat modelling was carried out year by year to describe habitat variables that best explained the use of windbreaks by birds, and results were similar for both years. In spring 2005 and 2006, the presence of ditches explained the largest amount of variation for bird abundance, whereas distance between trees in a row, and bare soil and mulch coverage, explained the largest amount of variation for bird richness (Table 7). As it was mentioned before, distance between trees in a row was greater in windbreaks without NTFP, which could explain the greater richness found in those windbreaks during the springs. In fall 2005, the number of tree and shrub species explained the largest amount of variation of bird abundance and richness (Table 8). In fall 2006, the type of crops in the east side of the windbreak (pasture) explained the largest amount of variation for bird abundance, while no variable could explain the variation of bird richness.

Table 7: Habitat model in relation to bird abundance and richness in windbreaks with or without NTFP in spring 2005 and 2006

Estimated values	Year	Habitat model[1]	Total model R^2
Total abundance	2005	Ditches (0.5471)	0.5471
	2006	Ditches (0.4738)	0.4738
Richness	2005	Distance between trees in a row (0.5070) + bare soil and mulch (0.1657)	0.6727
	2006	Distance between trees in a row (0.3482) + bare soil and mulch (0.3095)	0.6577

[1]Characteristics explicating habitat model were retained at $P \leq 0.05$

Table 8: Habitat model in relation to bird abundance and richness in windbreaks with or without NTFP in fall 2005 and 2006

Estimated values	Year	Habitat model[1]	Total model R^2
Total abundance	2005	Number of tree and shrub species (0.6310)	0.6310
	2006	Type of crop in the east side of the windbreak (0.6878)	0.6878
Richness	2005	Number of tree and shrub species (0.5959)	0.5959
	2006	-	-

[1] Characteristics explicating habitat model were retained at $P \leq 0.05$

CONCLUSION

In this study, windbreaks were not particularly attractive to detrimental birds, which is encouraging for the promotion of windbreaks integrating shrubs producing fruits with economical potential. In fact, this study shows that shrubs bearing NTFP did not improve avian diversity in general. Introduction of NTFP did not create different habitats. Both windbreak types consisted of a single row linear tree structure driving similar bird abundance and richness. However, windbreaks integrating shrubs that produce NTFP constitute an inspiring initiative in the search to conciliate economic, environmental, agronomical and ecological needs to maintain sustainable agriculture in Eastern Québec. Integrating a diversity of plant species, a diversity of windbreak types and creating a tree network could be profitable to enhance bird diversity at a regional scale.

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SHRUBS AND TREES IN STREAM BANKS: A FACTOR REDUCING MUSKRAT (*ONDATRA ZIBETHICUS*) DEPREDATION IN AGRICULTURAL AREAS

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Abstract: In agricultural areas, the digging of tunnels and burrows by muskrats (*Ondatra zibethicus*) into stream banks is a major cause of damage and has a negative impact on water quality. In an attempt to reduce muskrat abundance and therefore, depredation, we evaluated the influence of riparian vegetation characteristics on population density. Intensive field investigations lead to the selection of 39 homogenous 100-meter long stream sections. Among these, 13 had woody riparian vegetation (mean width: 7.17 m; SD: 3.13) dominated by rough alder (*Alnus rugosa*), red osier dogwood (*Cornus stolonifera*) and willow (*Salix* sp.). The other 26 sites had herbaceous riparian vegetation (mean width: 3.38 m; SD: 1.39) dominated by reed grass (*Calamagrostis* sp.). Muskrat abundance was measured in each section by using submersed funnel traps (4 trap-nights per site) in early October. A total of 131 muskrats were captured: their abundance differed significantly (Student's t-test p: 0.0138) between riparian classes. Herbaceous riparian habitats were more attractive for muskrats: they sustained 4.35 (SD: 3.76) individuals per site against 1.39 (SD: 2.36) in woody riparian sites. In addition to known beneficial impact on soil conservation and stream bank protection, woody riparian vegetation strongly influences muskrat distribution and could efficiently reduce depredation in agricultural areas. Mechanisms involved are investigated from a management perspective.

Key Words: Stream bank, muskrat, agriculture, depredation, habitat, management, submersed funnel trap.

Résumé : En milieu agricole, les rats musqués (*Ondatra zibethicus*) construisent leurs terriers dans les berges causant ainsi des dommages aux rives et provoquant des impacts sur la qualité de l'eau. Afin de diminuer la déprédation causée par les rats musqués et pour contrôler leur abondance, nous avons évalué l'effet de la composition de la bande riveraine sur les densités de rats musqués. Des inventaires sur le terrain de parcelles d'échantillonnages de 100 mètres linéaires de cours d'eau ont été effectués dans le but de ne conserver que des parcelles qui ne divergeaient que de la composition de la bande riveraine. Au total 39 parcelles ont été sélectionnées. Sur ce nombre, 13 parcelles avaient une bande riveraine ligneuse (largeur moyenne : 7,17 m; ET: 3,13) dominée par des Aulnes rugueux (*Alnus rugosa*), des Cornouilliers stolonifères (*Cornus stolonifera*) et des Saules arbustifs (*Salix* sp.). Les 26 autres parcelles avaient une bande riveraine herbacées (largeur moyenne : 3,38 m; ET: 1,39) dominées par le graminée-roseau (*Calamagrostis* sp.). L'abondance des rats musqués, au début octobre, a été évaluée dans chaque parcelle à l'aide de cages sous-marine (effort de capture de 4 nuits/piège). Au total 131 rats musqués ont été capturés et leur abondance est significativement différentes (*t* de Student p : 0,0138) entre les deux types de bandes riveraines. Les cours d'eau à bande riveraine herbacée supportent davantage de rats musqués (4,35 rats musqués; ET: 3,76) que les cours d'eau à bande riveraine ligneuse (1,39 rats musqués; ET: 2,36). En plus d'améliorer la qualité de l'eau et la protection des berges, le maintien et l'aménagement de bandes riveraines ligneuses réduisent l'abondance de rats musqués dans les petits cours d'eau.

Mots-clés : Bande riveraine, rat musqué, agriculture, déprédation, habitat, aménagement, cage sous-marine.

INTRODUCTION

The muskrat (*Ondatra zibethicus*) is a commonly found rodent native to North America and introduced in Europe and Asia at the beginning of the twentieth century.

This mammal exhibit semi-aquatic habits and its presence is influenced by the hydrology. In streams, muskrats find shelter in burrows they dig in stream banks (Messier and Virgl 1992). They are vegetarian and eat mostly aquatic plants (Messier et al. 1990; Virgl 1997; Connors et al. 2000). Movements of muskrat mostly takes place less than 100 metres away from their burrows.

Small streams in agricultural landscapes are habitats where muskrats can regularly be found (Brooks and Dodge 1986). Farmers have become aware of depredation problems such as stream bank damage and reduced water quality in these streams, which they associate to the presence of muskrats. In agricultural landscapes, stream bank protection measures are not well respected and understood neither they are adequately enforced. Thus existing stream banks are largely made of herbaceous plants and the ligneous vegetation is absent in many places.

The objective of this study was to determine if the riparian vegetation type (herbaceous or ligneous) had an effect on the abundance of muskrats. The hypothesis being that aquatic habitats surrounded with stream banks composed of herbaceous plants sustained a greater number of muskrats than streams with ligneous banks.

MATERIALS AND METHODS

Study area and sampling plots selection

The study area is located on the south shore of the St. Lawrence River, 150 km east of Quebec City and covers a 366 km^2 area. Two small watersheds, which are dominated by agricultural activity, are included in the study area.

The selection of sampling plots took place according to a stratified sampling plan based on the nature of the stream bank (herbaceous or ligneous). From the totality of small permanent flow streams, 100-metre long sampling plots were selected. These plots include the streambed and both stream banks. For each selected plot, the same type of stream bank had to be found on the entire length of the 100-metre plot, and that, and on both banks. In order to avoid any disturbance, there also had to be a minimum of 100 metres of same type of stream bank, downstream and upstream of the sampling plot.

Fieldwork was planned in two phases and took place in 2006. The first phase consisted of a complete characterization and standardization of the sampling plots. The second phase, consisted of the trapping of muskrats in order to evaluate their abundance in each plot.

First phase: Characterization of the sampling plots

An inventory of different characteristics affecting the abundance of muskrats took place in September on all selected plots. The objective was to identify sampling plot that differed from one another only by the composition of their stream banks. In each plot, a description of the stream bank was done (composition and width). The height, the slope and granulometry of the stream banks, the water velocity, the depth and the width of the stream were measured. Based on the values of these different parameters, only the plots that diverged solely on the composition of the stream bank (non-ligneous versus ligneous) were selected.

The inventory also included a description of the emerging aquatic vegetation (composition and abundance) and the description of indicators marking the presence of muskrats (tracks, feces, feeding ground, burrows).

Second phase: Trapping

The trapping of muskrats occurred, one month later, in October. Trapping took place on the plot differing only in the composition of their stream banks. Trapping was done in 39 plots, 26 of which had herbaceous stream banks and 13 ligneous.

The traps used were submersed funnel traps (Fig. 1). In each plot, two traps were installed at 33 metres intervals (one trap 33 metres away from the beginning of the plot and a second one at 66 metres). The traps were left there for two nights and visited everyday. The capture effort was four trap-nights for each plot.

Fig. 1: Submersed funnel trap

RESULTS AND DISCUSSION

In the study area, the mean width of the non-ligneous plot is significantly smaller (3.38 m, SD: 1.39) than in the ligneous plot (7.17 m, SD: 3.13; Student's t-test $p < 0.0001$). In the majority of non-ligneous stream bank plots, the stream bank is composed essentially of graminaceae plants (*Calamagrostis* sp.) In ligneous plots, the most commonly found shrubs are rough alders (*Alnus rugosa*), some red osier dogwood (*Cornus stolonifera*) and some willow (*Salix* sp.).

For all sampling plots, 131 muskrats were captured. Of that number, 113 came from the 26 herbaceous plots, while 18 were taken from the 13 plots with ligneous stream banks. The hypothesis, that streams with herbaceous stream banks offered a better habitat for muskrats, was accepted. The plots with herbaceous stream banks supported a mean number of muskrats three times higher to the ligneous stream bank plots. There are a significant greater number of muskrats in the non-ligneous stream bank plots (4.35 muskrats, SD: 3.76) than in the ligneous plots (1.39 muskrats, SD: 2.36; Student's t-test $p= 0.0138$).

The difference in the abundance of muskrats between both habitats can be explained by a combination of three factors: the availability of food resources, the difficulty of digging burrows in the bank and the absence of their main predator, the American mink (*Mustela vison*).

The availability of aquatic vegetation influence the abundance of muskrat in that habitat (Bélanger 1986; Blanchette 1987; Prescott and Richard 2004). They are vegetarian and eat the leaves, stems and most flavourful parts of aquatic plants (Prescott and Richard 2004). During the field inventory of the plots, we noted that the aquatic vegetation in the ligneous stream bank plots was less dense and diverse that the herbaceous stream banks. From a nutritional standpoint, the latter represented a best quality environment. This differential abundance in aquatic vegetation between both habitats is attributable to the width and composition of each stream bank. A diminution in the light intensity reduces the growth of aquatic vegetation (Daniel et al. 2006; Hrivnak et al. 2006). The height and density of the vegetation that make up the stream bank, determine the intensity of shade; a ligneous stream bank being more likely to block sunrays than the herbaceous one (Belt et al. 1992; Hrivnak et al. 2006). Moreover, the retention of agricultural contaminants from nonpoint sources is highly influenced by the width of the stream bank (Lowrance et al. 1984; Laroche 2005). The width of the ligneous stream banks being greater, it allows a larger amount of nutrients to be retained. If these nutrients were found in the aquatic environment, they would enhance aquatic vegetation growth (Daniel et al. 2006; Thiebaut 2006).

The second factor influencing the low abundance of muskrats in the ligneous stream bank plots is attributed to the physical difficulty of digging burrows in these banks; the roots of shrubs and trees offering physical resistance to digging than herbaceous plants. The widespread root system of ligneous vegetation forms a physical barrier for the muskrats when they dig their burrows. The roots of shrubs and trees provide greater stability to the banks, as opposed to the herbaceous plants (Hansen 1992; Wynn et al. 2003). To be successful at limiting the density of muskrats, the stream bank must be dense and mostly made of ligneous plants. To be effective, shrubs and trees must be present in the stream bank slope, not only on the top. Furthermore, we believe that varieties of shrubs and trees with strong root system are appropriate at limiting the abundance of muskrats.

The third factor decreasing the abundance of muskrats in streams with ligneous stream banks is predation pressure. The American mink and humans are the two major predators for muskrats (Aleksiuk 1986). The mink is found most frequently in forests and under-brushes located close to rivers and lakes (Prescott and Richard 2004). Just like the muskrat, it is a semi-aquatic mammal. Therefore, the development of ligneous stream banks would encourage the presence of minks as they use this habitat as migration corridors or hunting grounds.

CONCLUSION

In agricultural landscapes, muskrats can cause depredation, which are problematic for farmers. This study has showed that riparian vegetation type had a significant effect on the abundance of muskrats.

Muskrats seem to be more attracted in streams with herbaceous banks than streams with ligneous banks. The presence of a ligneous stream bank would limit their abundance by a combination of three factors: aquatic vegetation is less abundant, greater difficulty for digging their burrow in banks with strong root systems and the enhancement of the predator, the mink.

Therefore, in addition to offering better protection on water quality and the stabilisation, the management of stream banks with ligneous vegetation limits the abundance of muskrats and their depredation in agricultural areas.

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INFLUENCE DE L'INTÉGRATION DE PRODUITS FORESTIERS NON LIGNEUX SUR LA FRÉQUENTATION DES MICROMAMMIFÈRES DANS LES HAIES BRISE-VENT ET LES BANDES RIVERAINES

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Résumé : Bien que les bandes riveraines et les haies brise-vent présentent de nombreux avantages environnementaux, les producteurs agricoles voient souvent l'implantation de ces aménagements comme une perte d'espace de production ou comme un milieu favorisant la prolifération des mauvaises herbes et d'une faune nuisible. Il y a une dizaine d'années, des haies brise-vent incluant des arbustes indigènes porteurs de produits forestiers non ligneux (PFNL) ont été implantées à La Pocatière dans l'optique de rentabiliser l'espace cultural perdu par la récolte de petits fruits. Cette initiative a été reproduite il y a quatre ans dans des aménagements de bandes riveraines. Les PFNL font ici référence à toute substance biologique, autre que le bois d'œuvre et d'industrie, susceptible d'être extraite d'écosystèmes naturels ou de plantations aménagées, utilisées à des fins domestiques ou commerciales.

Les objectifs du projet consistent à évaluer la richesse et l'abondance des micromammifères associés à des aménagements de haies brise-vent et de bandes riveraines intégrant ou non des PFNL et à vérifier si la présence de PFNL augmente la présence de faune nuisible. Les résultats démontrent que la richesse et l'abondance des micromammifères ne diffèrent pas entre les deux types de haies brise-vent et de bandes riveraines. Il ressort également que la proportion de micromammifères nuisibles n'est pas différente entre les deux types de bandes riveraines. Cependant, la proportion de campagnol des champs est plus élevée dans les haies brise-vent avec PFNL que dans les haies brise-vent sans PFNL. Une analyse plus poussée de la structure végétale des haies devrait permettre d'expliquer ces résultats.

Mots-clés : Haies brise-vent, bandes riveraines, produits forestiers non ligneux, micromammifères.

ACTION CONCERTÉE POUR METTRE EN VALEUR LA BIODIVERSITÉ DANS LE BASSIN AGRICOLE DE LA RIVIÈRE BOYER SUD – 2005-2010 (PROGRAMME FFQ-UPA)

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Résumé: Ce projet conjoint consiste à poursuivre la démarche de restauration des habitats fauniques en aménageant des bandes riveraines, des haies et des milieux humides pour assurer le maintien de la biodiversité dans le bassin de la Boyer Sud. En impliquant tous les intervenants du milieu agricole, municipal, scolaire, universitaire, environnemental et gouvernemental, dans une telle démarche, ce projet s'inscrit dans une approche intégrée par bassin favorisant la collaboration et le transfert de connaissances pour retrouver un équilibre agriculture-faune primordial.

De nombreuses études réalisées dans le bassin de la Boyer ont porté sur les bandes riveraines, la stabilisation des berges, la faune et ses habitats aquatiques et riverains. Grâce à la réalisation de plusieurs cahiers du propriétaire (46 d'ici cet hiver) et d'ententes de conservation, les besoins d'intervention se précisent dans ce bassin de 65 km2 cultivé à 68 % par 90 producteurs agricoles dont les productions animales sont à 47 % porcine et 42 % laitière.

L'altération physique du paysage en vue d'accroître les zones agricoles et l'intensité de l'agriculture dans le bassin de la rivière Boyer, notamment par le drainage des zones humides et le déboisement a grandement affecté la conservation de la biodiversité. L'accent est mis sur l'importance des boisés et la conservation de corridors fauniques en réponse à la fragmentation des habitats en combinaison avec la promotion des bonnes pratiques agroenvironnementales pour limiter la pollution diffuse responsable de l'érosion et de l'eutrophisation des cours d'eau. Déjà plusieurs aménagements fauniques ont été réalisés et des kilomètres de bandes riveraines ont été plantés. Et ça continue!

Mots-clés : Bassin versant, restauration, cohabitation agriculture-faune, concertation.

FUNCTIONAL EDGE WIDTH OF AVIAN SPECIES IN WOODY AGRICULTURAL HABITATS

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Abstract: Woody edges on farms provide habitat for birds that in turn function as natural predators of insect pests. Earlier research determined that a majority of avian foraging activity in crop fields was within 50 m of field edges. The purpose of this research was to determine the primary area within the 50 m region where birds most actively forage, thus clarifying conservation options and further defining the role of birds in suppression of pest populations. In east central Nebraska, 12, 100 m by 50 m plots were established in crop fields planted to either corn (*Zea mays* L.) or soybean (*Glycine max* L. Merr.) and adjacent to a shelterbelt or woody riparian buffer. Field edges were surveyed using 30-min, 300 m transects (2-3/site) in 2006 and plots were monitored with 30-min point counts (9/site in 2005, 10-14/site in 2006). Perches and feeders containing mealworms (*Tenebrio molitor* L.) were strategically placed within the plots. A total of 44 bird species were identified during the transect surveys. Of these, 21 were observed foraging in crop fields and primarily within 20 m of the woody edge. Fifty-six percent of the birds arrived from and departed to the adjacent shelterbelts, while 76% arrived from and departed to the adjacent woody riparian buffers. Results of this study suggest that farmers interested in improving avian foraging in their crop fields should consider conservation practices within the 20 m region immediately adjacent to the woody edge.

Key Words: Birds, shelterbelts, riparian buffers, agroecosystems.

INFLUENCE DE L'UTILISATION DES PRODUITS FORESTIERS NON LIGNEUX DANS LES HAIES BRISE-VENT SUR LES POPULATIONS DE CARABIDÉS (COLEOPTERA : CARABIDAE)

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Résumé : Il est reconnu que les haies brise-vent présentent de nombreux bénéfices environnementaux et peuvent contribuer à l'amélioration de la biodiversité. Dans ce contexte, il devient important d'identifier des aménagements qui conjuguent ces effets positifs avec une certaine rentabilité économique pour le producteur agricole. Il y a une dizaine d'années, des haies brise-vent incluant des arbustes indigènes porteurs de PFNL ont été implantées dans la région de La Pocatière (Québec) dans l'optique de rentabiliser l'espace cultural perdu par la récolte de petits fruits.

Dans ce projet, huit haies brise-vent matures ont été sélectionnées dans cette région afin d'évaluer l'abondance et la richesse des carabes associés à deux types de haies brise-vent, avec ou sans PFNL. L'évaluation des populations d'insectes a été effectuée à l'aide de pièges fosses au cours des étés 2005 et 2006. Les insectes récoltés ont ensuite étés identifiés jusqu'à l'espèce. Les pièges, disposés près des haies brise-vent et dans les champs adjacents, ont permis de vérifier le déplacement des insectes et l'évolution des populations dans le temps. Les résultats préliminaires semblent démontrer que le nombre d'individus et d'espèces ne diffère pas entre les deux types de haies brise-vent.

Mots-clés : Haies brise-vent, produits forestiers non ligneux, biodiversité, Carabidés.

ASSESSING POTENTIAL IMPACTS AGROFORESTRY ON BIODIVERSITY AND WILDLIFE HABITAT SUITABILITY IN THE PRAIRIE PROVINCES OF CANADA

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Abstract: Agroforestry is poised to expand across the Canadian prairie provinces, yet the pros and cons of this practice for biodiversity are unknown. Therefore, we reviewed literature reporting on hydrologic and biodiversity response to agroforestry, focusing on block planting, alley-cropping, riparian buffers and shelterbelts. Hydrological effects depended on many factors, but generally, where water supply is compromised (e.g., some grasslands) plantings could reduce available water to wetlands. Conversely, plantings in forested areas can increase infiltration rates and decrease peak flow rates; riparian buffer strips also intercept run-off of non-point source pollutants. General conclusions about effects on biodiversity were more difficult to make, being somewhat confounded by the relative contribution of generalist species to estimates of biodiversity, often at the expense of more sensitive specialist species. However, some hybrid poplar stands provide habitat for small and medium-sized mammals in the Northwestern US, but not in the US Midwest, while some large mammals used extensive block plantings in the Northwest. Bird species richness and abundance was higher in hybrid poplar than arable land, but lower than in natural or semi-natural woodlands. Willow coppice in the Northeastern US and Europe has high avian and plant species richness, but most species are typical of early successional habitat. While invertebrate biodiversity was higher in alley-cropping than arable land, and willow coppice is rich in invertebrates, hybrid poplar may reduce habitat supply for Carabid beetles. Although potentially detrimental to grassland species, agroforestry plantings could increase connectivity among blocks native habitat in forest-dominated areas. Despite these conclusions, relatively little information exists for making sound decisions on landscape planning of agroforestry. To fill this information gap, we recommend conducting field studies on biodiversity and hydrology in the prairie provinces of Canada.

SECTION 8

Aspects socio-économiques et environnementaux de l'agroforesterie

Socioeconomic and Environmental Aspects of Agroforestry

KEYNOTE SPEAKER

AGROFORESTRY SYSTEMS AND THE INVISIBLE PRESENT: ECOLOGICAL GOODS AND SERVICES
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SYSTÈMES AGROFORESTIERS ET PRÉSENT INVISIBLE : BIENS ET SERVICES ÉCOLOGIQUES

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Abstract: Ecological goods and services are defined as logical benefits resulting from the 'normal' functioning of an ecosystem. Maximum production of such goods and services is associated with non-stressed agroecosytems, which within the context of agroforestry, would constitute a variety of temporal and spatial configurations of trees on the farming landscape. Humans benefit from the maintenance of these goods (e.g. fresh water) within the ecosystem, and the 'flow' of these services (e.g. greenhouse gas mitigation) to other systems.

Agroforestry systems, regardless of type, are capable of providing numerous ecological goods and services, of a range of complexities, over long periods of time. Indeed, agroforestry systems can be designed and engineered to provide specific quantities of particular goods and services. Nonetheless, the universal application of ecological principles to agroforestry system design and management is nearly impossible as a result of the many varied types of systems in existence – from riparian management systems that link terrestrial and aquatic systems to more traditional systems that integrate perennial plants with annual crops, with or without animals. The broad geographical range over which agroforestry systems may be successfully implemented and the scale at which interactions occur – from landscape to individual plant – also complicates the development of an universal understanding of nutrient and energy flows and the relationship of these to system productivity.

In natural systems, a long-term ecological approach has proven useful to understand the importance of i) slow processes that occur on the scale of decades to centuries, ii) processes with high annual variability, iii) rare and unique events, iv) subtle processes and v) complex processes with many interacting factors. A long-term ecological research perspective holds much potential for understanding agroforestry systems, since the temporal context provided by engaging in such research can aid us greatly in understanding large-scale changes in ecosystem processes, such as the provision of goods and services, revealing the secrecy inherent in what has been termed 'the invisible present'.

Environmental benefits and factors that constrain their production are discussed for a variety of agroforestry systems using an ecosystem ecology framework. Such an approach to understanding the structure and function of agroforestry systems and the relationship of these parameters to net

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primary productivity is a strong foundation upon which to evaluate the production of ecological goods and services, over long periods of time.

Résumé : Les biens et services écologiques sont les retombées logiques découlant d'un écosystème fonctionnant « normalement ». La production maximale de ces biens et services provient d'agroécosystèmes non stressés qui, dans le contexte de l'agroforesterie, constitueraient une variété de configurations tant temporelles que spatiales des arbres au sein d'un milieu agricole. La population tire profit de la conservation de ces biens (p. ex., disponibilité en eau fraîche) au sein de l'écosystème et du « flux » de ces services (p. ex., atténuation des gaz à effets de serre) vers d'autres systèmes.

Les systèmes agroforestiers, sans égard à leur typologie, ont le potentiel de fournir plusieurs biens et services écologiques d'une grande complexité et sur de longues périodes. En effet, les systèmes agroforestiers peuvent être conçus de manière à fournir des quantités précises de biens et services particuliers. Néanmoins, la mise en application universelle des principes écologiques à la conception et à la gestion de systèmes agroforestiers est quasiment impossible étant donné la présence d'une grande variété de types de système ; des systèmes de gestion riparienne établissant le lien entre les systèmes terrestres et aquatiques aux systèmes plus courants qui intègrent les plantes vivaces aux cultures annuelles, avec bétail ou non. La vaste gamme de profils géographiques qui peut accueillir l'implantation de systèmes agroforestiers et la portée des interactions que ces derniers provoquent – du paysage à la plante – limitent l'acquisition d'une connaissance universelle des nutriments et des flux d'énergie, ainsi que de leur influence sur la productivité du système.

Une approche écologique à long terme aux systèmes naturels a démontré qu'elle permettrait de saisir l'importance 1) des lents processus qui s'étendent sur des décennies, voire des siècles ; 2) de la grande variation des processus ayant lieu au cours d'une année ; 3) d'événements uniques et rares ; 4) des processus plus subtils et 5) des processus complexes impliquant plusieurs facteurs. Une approche écologique à long terme présente un plus grand potentiel quant à la compréhension des systèmes agroforestiers, étant donné que le contexte temporel inhérent à ce type de recherche peut nous aider à mieux saisir les modifications qui se produisent à grande échelle au sein des processus des écosystèmes, dont le ravitaillement en biens et services écologiques, révélant du coup l'aspect caché dans ce qu'il est convenu d'appeler « le présent invisible ».

Nous traiterons des retombées environnementales et des facteurs qui régissent leur apparition dans divers systèmes agroforestiers dans un cadre de travail de l'écologie des écosystèmes. Cette approche permettant de comprendre la structure et la fonction des systèmes agroforestiers et le lien de ces paramètres avec la production primaire représente de solides assises servant à l'évaluation de la production des biens et services écologiques sur de longues périodes de temps.

MISE EN PLACE D'UN RÉSEAU DE PARCELLES DE DÉMONSTRATION EN AGROFORESTERIE DANS LA MRC DU ROCHER-PERCÉ

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Résumé : Depuis 2005, 12 partenaires locaux, régionaux et provinciaux étudient les rôles que l'agriculture joue dans la région du Rocher-Percé, un milieu rural dévitalisé situé en Gaspésie, au Québec. L'entretien des paysages de ce territoire vanté par les touristes et le maintien d'un dynamisme rural sont des composantes remarquables de sa multifonctionnalité. Pourtant, les contributions positives de l'agriculture sont menacées par sa régression constante, due principalement à sa faible rentabilité économique. Le reboisement par des résineux constitue pour plusieurs propriétaires l'alternative à la friche ou au prêt gratuit de leur terre à un agriculteur. Il s'en suit une fermeture des paysages et un accès aux terres réduit pour l'agriculture. Puisqu'elle combine sylviculture et agriculture sur les mêmes parcelles, l'agroforesterie est envisagée comme une nouvelle alternative permettant d'atteindre les objectifs de valorisation du patrimoine foncier d'un propriétaire tout en maintenant une activité agricole.

En 2006, 7 sites de démonstration ont été mis en place chez des agriculteurs. Des rangées d'arbres nobles (chênes, frênes, ormes et pins) sont disposées en bordure de parcelle agricole ou en plein champ en conservant toujours un espacement entre les rangées suffisant pour que l'agriculture y soit pratiquée. Les arbres sont donc présents en faible densité (50 à 200 arbres par hectare) et l'accent est mis sur une sylviculture permettant d'en tirer une qualité maximale (utilisation de paillis de plastique et de protecteurs, taille de formation et élagage). Ces sites permettront d'étudier *in situ* le fonctionnement des systèmes agroforestiers et de stimuler leur utilisation dans la région.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

Mots-clés : Agrosylvopastoralisme, bois nobles, développement rural, Gaspésie, multifonctionnalité, paysage.

Abstract: Since 2005, 12 local, regional and provincial partners have been studying the different roles of agriculture in the Rocher-Percé region, a devitalized yet tourist friendly area situated on the Gaspé Coast in Quebec. The maintenance of the territory's landscape and the preservation of its rural vitality are noteworthy components of the agriculture's multifunctionality. However, the positive contribution of agriculture is threatened by its constant regression that is mainly due to its low economic profitability. For landowners, conifer plantation represents an appealing economic alternative to fallow land or gratuitous loans to a farmer. Unfortunately, this leads to the closure of landscapes and restricted access to land for agriculture. Since agroforestry combines sylviculture and agriculture on the same parcel, it is considered an innovative alternative that increases the value of an owner's property while maintaining agricultural activities.

In 2006, 7 demonstration sites were implemented by farmers. High-value trees (oak, ash, elm and pine) are arranged in borders along a parcel or within the field with adequate space between each row to carry out agricultural activities. Trees are therefore present at low densities (50 to 200 trees per hectare) with an emphasis on sylviculture in order to reach maximum quality (use of plastic mulch and protectors, shaping and pruning). These sites will allow the study, in situ, of agroforestry systems and stimulate their use in the region.

Key Words : Agrosylvopastoralism, Gaspé peninsula, high-value timber wood, landscape, multifonctionality, rural development.

INTRODUCTION

La municipalité régionale de comté (MRC) du Rocher-Percé est une division géographique administrative située au sud-est de la péninsule gaspésienne (Annexe). Cette MRC est essentiellement rurale. Les principales activités, la pêche et l'exploitation des ressources forestières, sont aujourd'hui en crise. Une agriculture à petite échelle s'y pratique dans ses extrémités est et ouest. Dans son ensemble, le milieu est fortement dévitalisé et la MRC est classée parmi les plus pauvres au Québec. Elle jouit pourtant d'une bonne réputation touristique, notamment en raison de sa culture maritime.

En 2005, un projet intitulé « Mise en valeur de l'espace rural de la MRC du Rocher-Percé par la reconnaissance de la multifonctionnalité de son agriculture » a été mis en place par 12 partenaires locaux, régionaux et provinciaux afin d'explorer de nouvelles avenues pour redynamiser ce milieu en déclin. Il vise le développement d'une agriculture multifonctionnelle, c'est-à-dire qui offre des biens et services multiples, dépassant la seule production marchande. L'agriculture n'y est pas vue comme une fin en soi mais plutôt comme un moyen de rendre l'espace rural plus vivant et plus attractif. Une attention particulière est portée aux paysages, témoins des activités humaines qui se pratiquent sur le territoire.

L'AGROSYLVOPASTORALIME POUR LA MISE EN VALEUR DU TERRITOIRE

Une agriculture en régression

Globalement, l'agriculture dans la MRC montre des signes de dévitalisation : le nombre d'exploitations est en diminution et les agriculteurs dénoncent un contexte économique difficile qui rend l'avenir incertain. Sur les 32 agriculteurs recensés dans la MRC, 19 élèvent des bovins de boucherie. Leurs pratiques sont très extensives et les champs de foin occupent la plus grande partie de l'espace cultivé qui totalise 3270 ha environ. Une enquête menée par De Baets (2007) a révélé la fragilité du système d'accès aux terres. En effet, environ 60% des terres utilisées pour la culture du foin n'appartiennent pas aux agriculteurs et seules des ententes verbales reconduites chaque année leur y offrent un accès. Les agriculteurs ont donc tendance à réduire au minimum leurs investissements sur ces terres, tandis que les propriétaires ne trouvent comme avantage dans ce système que l'entretien de leur terrain et la satisfaction d'appuyer un agriculteur.

Une étude des paysages agricoles réalisée par Baumgartner (2007) met de l'avant les marques visibles de la régression de l'agriculture. Les champs laissés à l'abandon sont nombreux (la superficie des terres en friche recensées est d'environ 1430 ha). Même parmi ceux qui sont encore cultivés, on remarque des traces de déclin telles que l'absence d'entretien des clôtures et des bâtiments.

Une tendance notable est le reboisement d'une partie des terres agricoles avec des plantations de résineux. On estime à environ 800 ha la superficie reboisée depuis moins de 10 ans, ce qui est considérable vue la superficie agricole totale. Cette tendance au reboisement s'explique notamment par le support financier fourni par l'industrie forestière et le gouvernement qui permet au propriétaire de se constituer un capital forestier pour des dépenses minimes ou nulles. Ce reboisement entraîne une fermeture et une homogénéisation des paysages qui modifie considérablement l'identité du milieu rural de la MRC.

Une alternative : les systèmes agroforestiers multifonctionnels

Dans l'optique du maintien d'une agriculture qui, entre autres bénéfices au milieu, entretient les paysages, les systèmes agrosylvopastoraux semblent constituer une alternative des plus intéressantes. Tels qu'envisagés ici, ces systèmes combinent sur les mêmes unités de terrain la sylviculture d'arbres nobles, la culture de plantes agricoles et l'élevage.

L'intérêt supposé de ces systèmes tient dans leur multifonctionnalité particulièrement adaptée au contexte de la MRC. En combinant l'agriculture - et éventuellement l'élevage - à la sylviculture, ils offrent la possibilité de maintenir une présence agricole souhaitée tout en satisfaisant des propriétaires désireux de voir leur terre leur rapporter ou, tout au moins, de préparer la formation d'un capital « sur pied ». Si on utilise des essences de bois noble, des plantations à faible densité (200 arbres par hectare) sont susceptibles de rapporter autant qu'une plantation classique de résineux. De plus, dans une optique sylvicole, le suivi de ces arbres devrait être facilité par l'agriculture adjacente, ce qui ouvre potentiellement la porte à des activités actuellement très peu répandues dans la MRC (sylviculture intensive d'arbres nobles). Si le paysage doit s'en trouver quelque peu modifié, il devrait néanmoins conserver l'ouverture et l'entretien recherchés et peut-être acquérir de nouveaux attributs qui le rendront encore plus appréciable.

DE LA THÉORIE À LA PRATIQUE : MISE EN PLACE DE PARCELLES DE DÉMONSTRATION

Objectifs poursuivis

L'objectif principal qui sous-tend la mise en place d'un réseau de parcelles de démonstration est la validation de l'intérêt des systèmes agrosylvopastoraux dans le contexte de la MRC du Rocher-Percé. Cette validation touche autant les aspects techniques et économiques que sociaux. Elle se fera par l'acquisition de données in situ. Les systèmes implantés permettront de préciser un choix d'essences d'arbres adaptées aux conditions du milieu ainsi que les modalités de plantation et d'arrangements spatiaux. Ils serviront également à définir les coûts associés à leur mise en place, ce qui permettra d'établir des scénarios de financement. Enfin, ces systèmes permettront d'évaluer leur acceptabilité sociale, que ce soit auprès des agriculteurs ou des propriétaires.

Une approche progressive est visée dans le cadre de ce projet. Bien que la finalité soit d'utiliser ces systèmes pour renforcer le lien entre propriétaires terriens et agriculteurs, la démarche présentée ici n'est que la première partie du processus. Ainsi, il a été décidé de travailler d'abord avec les agriculteurs afin de vérifier s'ils seraient prêts à développer ce genre de systèmes. L'implication de propriétaires non agriculteurs pourra être entreprise par la suite. Une approche participative impliquant autant que possible les agriculteurs dans la mise en place des systèmes devrait favoriser leur éventuelle adoption. De plus, en mettant à profit le partenariat du projet sur la multifonctionnalité de l'agriculture dans la MRC du Rocher-Percé, de nombreux acteurs locaux oeuvrant dans le développement du milieu se retrouvent impliqués dans ce projet, ce qui permet à la fois une validation plus pointue et une appropriation progressive du concept par ces acteurs qui seront susceptibles d'appuyer son développement. Enfin, la mise en place de systèmes sur des sites visibles répartis sur le territoire agricole de la MRC devrait favoriser la diffusion de l'information auprès des différents usagers du territoire.

Caractéristiques des systèmes implantés

En 2006, des travaux ont été entrepris pour mettre en place 7 systèmes agrosylvopastoraux. Quatre d'entre eux sont en fait des systèmes agrosylvicoles car il n'y a pas d'activité d'élevage directement associée. La mise en place de ces systèmes a consisté à planter des arbres nobles sur ou en bordure de champ ou de pâturage. Afin de faciliter ce premier contact avec l'agroforesterie pour les agriculteurs, ce sont 6 haies en bordure de champ et 1 système intercalaire qui ont été implantés pour cette première série d'essais.

Les essences d'arbres choisies sont le chêne rouge (*Quercus rubra*), le pin blanc (*Pinus strobus*), le frêne de Pennsylvanie (*Fraxinus pennsylvanica*) et l'orme d'Amérique (*Ulmus americana*). Les critères ayant conduit à ces choix sont la forte valeur potentielle du bois de ces arbres, leur compatibilité avec une sylviculture intensive pratiquée en milieu ouvert et leur caractère indigène à la Gaspésie.

Tous les arbres plantés sont protégés par un paillis de plastique afin de limiter la concurrence de la végétation herbacée. Pour 6 des 7 systèmes, le paillis de plastique a été placé en bande sur toute la longueur des haies. Les Figures 1 et 2 illustrent deux des systèmes implantés sur paillis de plastique posé en bande.

Fig. 1 : Haie simple en bordure de champ à St-Isidore (système n°4). Photographie : Bertrand Anel.

Fig. 2 : Haie double de frênes de Pennsylvanie en bordure de pâturage à Cap d'Espoir (système n°7). Photographie : Bertrand Anel.

Pour un des systèmes implantés, les arbres sont protégés par des paillis de plastique de format individuel (Fig. 3). Cette approche a été rendue nécessaire par l'impossibilité de travailler le site avec un tracteur, mais cet essai s'est montré très intéressant dans la mesure où il limite les travaux mécaniques.

Fig. 3 : Jeune orme d'Amérique protégé par un paillis de plastique individuel (système n°9). Photographie : Bertrand Anel

Le Tableau 1 résume les principales caractéristiques des 7 systèmes implantés en 2006. On remarquera que les travaux doivent être poursuivis en 2007, notamment en ce qui concerne la plantation des chênes rouges.

Tableau 1 : Principales caractéristiques des systèmes agrosylvopastoraux implantés dans la MRC du Rocher-Percé en 2006.

Numéro de référence du site	Arbres plantés en 2006 (Arbres à planter en 2007)				Nombre de haies		Espacement entre les arbres (m)	Longueur totale des haies (m)
	CHR*	FRP*	ORA*	PIB*	Simples	Doubles		
1	(35)	35		70	1		4	560
2	(95)	95	63	62	4	1	5-6	125
3	(74)			76	2		3	450
4	(35)			35	1		4	280
7	(50)	64		49		1	6	490
9		159 (15)	176 (15)		5		5	1750
10	(21)			21		1	6	125

(* CHR = chêne rouge, FRP = frêne de Pennsylvanie, ORA = orme d'Amérique, PIB = pin blanc)

La visibilité des systèmes a été recherchée autant que possible, en tenant compte de l'impact qu'auront les arbres nouvellement plantés sur le paysage. Toutefois, chacun des sites a également des caractéristiques propres. Ainsi, dans le système n° 9, les arbres ont été plantés dans la zone réglementaire de retrait des animaux des cours d'eaux. Pour l'agriculteur, il s'agit de la mise en valeur d'un espace autrement perdu. Le système n°1 a, quant à lui, été implanté dans un milieu semi-urbain et les arbres devraient avoir un rôle positif sur la cohabitation entre les usages agricoles et résidentiels sur le territoire.

Bien que ne constituant pas un dispositif expérimental au sens scientifique du terme, un dispositif de suivi a été mis en place. Il permettra dans le temps de mesurer la croissance des différentes essences d'arbres et de mener des comparaisons sur des éléments tels que les différents protecteurs mis en œuvre pour limiter les attaques de rongeurs.

Dans le cadre des activités du projet sur la multifonctionnalité de l'agriculture dans la MRC du Rocher-Percé, un autre système agroforestier a été mis en place en 2006. Il s'agit d'une plantation de sureau blanc (*Sambucus canadensis*) réalisée sur une superficie de 3 ha dont 2 ha qui combinent des productions céréalières et maraîchères à celle de sureau. Les objectifs de cet essai sont multiples, mais nous retiendrons ici qu'il offre un exemple visible de culture agroforestière intercalaire. Les Figures 4 et 5 illustrent ce système dans lequel les rangées de sureau sont espacées de 15 m. L'impact de la parcelle sur le paysage a été particulièrement prise en compte.

Fig. 4 : Parcelle intercalaire de sureau en vue aérienne. En arrière-plan, le village de Val d'Espoir (Percé). Photographie : Raoul Beaudin

Fig. 5 : Détail de l'association sureau - orge. Photographie : Bertrand Anel.

Des résultats encourageants

Le premier constat qui s'impose suite à cette première étape de mise en place des systèmes agrosylvicoles est l'intérêt croissant rencontré chez les agriculteurs. Si ceux-ci ont pu paraître réticents lorsque le projet leur a été présenté, ceux qui ont décidé d'implanter des systèmes chez eux n'ont pas tardé à démontrer leur satisfaction pour cette forme de mise en valeur de leurs terres. Il s'agit d'un point très important dans le processus d'adoption. Le fonctionnement du projet, qui a permis de rémunérer les agriculteurs pour les travaux accomplis une fois un seuil de participation minimum dépassé, a certainement joué favorablement en ce sens.

La mise en place des systèmes s'est révélée relativement simple. Sur un sol préparé adéquatement, la pose du paillis de plastique et la plantation des arbres sont des opérations faciles à mettre en œuvre.

Les coûts d'implantation se sont aussi révélés modérés. Des travaux réalisés par Bernier et al. (2007) démontrent que cet investissement devrait trouver une rentabilité lorsque les arbres seront récoltés pour la valeur de leur bois.

CONCLUSION

À la suite de cette année de mise en place, le bilan du projet est positif. Les premières données recueillies semblent confirmer l'hypothèse de départ proposant l'agrosylvopastoralisme comme moyen de mise en valeur de l'espace rural de la MRC Rocher-Percé et l'implication directe des acteurs concernés s'est avérée concluante en termes d'appropriation des concepts. Toutefois, il ne s'agit que d'une première étape et les résultats du suivi de la survie et de la croissance des arbres seront déterminants.

Les systèmes implantés en 2006 devront être complétés en 2007. En effet, il n'a pas été possible d'obtenir plus tôt les plants de chênes rouges. De plus, 4 nouveaux systèmes devraient être installés : 2 systèmes de haies en bordure de champ et 2 systèmes intercalaires. Dans le cas des systèmes intercalaires, il est intéressant de noter que ceux-ci seront développés sur des terres actuellement en friche, ce qui permettra d'acquérir des données techniques et économiques sur leur reconversion.

Il est également prévu de travailler sur la diversification des haies implantées. Jusqu'à présent, seuls des arbres ont été plantés. Il semble toutefois très intéressant de compléter les haies avec des arbustes. Ceux-ci devraient avoir un effet positif sur la structure des haies et sur la croissance des arbres. Sous un angle économique, si ces arbustes portent une production de petits fruits, par exemple, les haies pourraient générer un revenu qui renforcerait leur rentabilité, comme le laisse penser le modèle développé par Bernier et al. (2007). D'un point de vue technique, l'implantation de tels arbustes devrait être très simple là où des paillis de plastique posés en bande sont déjà en place.

Le suivi de la croissance des arbres, de l'intérêt des agriculteurs et de la rentabilité économique sera poursuivi. Si l'ensemble des données recueillies confirme l'intérêt de ces systèmes, des approches pourront être entreprises auprès des propriétaires de terres, cultivées ou en friche, afin de connaître leur motivation pour l'implantation de tels systèmes. Advenant un intérêt de leur part, il sera alors possible d'entreprendre un maillage entre les agriculteurs et les propriétaires. Toutefois, avant d'entreprendre l'implantation des systèmes agrosylvicoles à grande échelle, des travaux devront avoir été entrepris pour mettre en place les conditions institutionnelles et économique nécessaires. Mais ces travaux dépassent le cadre de ce projet et celui de l'horizon 2007.

REMERCIEMENTS

La réalisation de ces travaux a été rendue possible grâce à la contribution financière, matérielle et humaine des douze partenaires du projet de « Mise en valeur de l'espace rural de la MRC du Rocher-Percé par la reconnaissance de la multifonctionnalité de son agriculture. » Ces partenaires sont : le Centre local de développement du Rocher-Percé, le Ministère de l'agriculture des pêcheries et de l'alimentation du Québec, le Consortium en foresterie Gaspésie Îles de la Madeleine, la Municipalité régionale de Comté du Rocher-Percé, l'Union des producteurs agricoles de la Gaspésie et des Îles de la Madeleine, la Société d'aide au développement des communautés du Rocher-Percé, la Chaire multifacultaire de recherche et d'intervention sur la Gaspésie et les Îles de la Madeleine de l'Université Laval, le Centre local d'emploi du Rocher-Percé, la Fondation communautaire Gaspésie-les-Îles, la Conférence régionale des élus Gaspésie-les-Îles, la Ville de Percé et la Coopérative de solidarité Rocher-Percé.

Nous tenons à remercier le Ministère des Ressources naturelles du Québec pour avoir fourni les arbres plantés dans le cadre de ce projet. Merci aussi au Syndicat du Rocher-Percé de l'Union des producteurs agricoles pour son implication, de même qu'à tous les agriculteurs qui ont participé aux essais.

Enfin, nous tenons à remercier les étudiants qui ont travaillé dans le cadre de ce projet pour leur appréciable collaboration.

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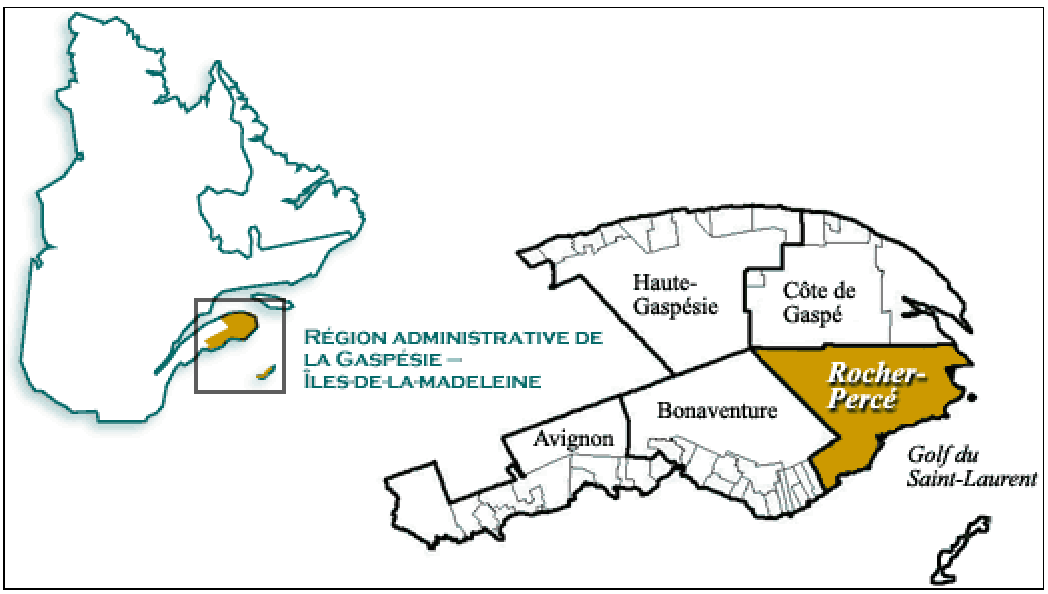
ANNEXE : LA MRC DU ROCHER-PERCÉ



Source : Ministère du Développement économique, de l'Innovation et de l'Exportation (2005)

BIENS ET SERVICES ÉCOLOGIQUES ET AGROFORESTERIE : L'INTÉRÊT DU PRODUCTEUR AGRICOLE ET DE LA SOCIÉTÉ

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Abstract: La présentation porte sur un projet en cours de réalisation qui vise à estimer la valeur sociale des BSE qui découlent des pratiques agroforestières et évaluer la rentabilité de ces pratiques au niveau de l'entreprise agricole. Il vérifie l'hypothèse selon laquelle les produits dérivés de l'agroforesterie ne génèrent pas un revenu suffisant pour inciter l'agriculteur à implanter des pratiques agroforestières et la valeur économique des biens et services environnementaux (BSE) qui découlent de l'agroforesterie justifie l'institution de programmes publics pour en favoriser l'implantation. L'étude se déroule, au Québec, dans deux bassins versant, l'un en zone périurbaine (agriculture intensive) et l'autre en milieu rural (région éloignée).

Les objectifs du projet sont nombreux : évaluer les BSE associés à l'agroforesterie; vérifier si les produits dérivés de l'agroforesterie génèrent un revenu suffisamment élevé pour inciter le producteur agricole à implanter des pratiques agroforestières; vérifier si la valeur sociale des BSE qui découlent de l'agroforesterie justifie l'institution d'incitatifs économiques pour en favoriser l'implantation; Identifier les freins au développement de l'agroforesterie; Identifier les conditions nécessaires au développement de l'agroforesterie; structurer le dialogue à travers un réseau formel d'échange d'information au Québec et au Canada.

PARTENAIRES IMPLIQUÉS
Activa, CÉPAF, Éconova, ÉcoRessources, Université Laval, UPA, Canards illimités, MAPAQ, MDDEP, SCF – RNC, Solidarité rurale.

Key Words: producteurs agricoles, développement, réseautage, programmes, projet pilote, bassin versant, économie expérimentale.

A MODEL FOR THE ENVIRONMENTAL VALUES OF AGROFORESTRY

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Abstract: A new model is being developed to describe and predict the environmental values of agroforestry systems in Canada. Outputs from the model will relate to the agroforestry practice's environmental functions that include the protection of soil, water, air and biodiversity. These will be estimated for various agroforestry scenarios for wind reduction, soil erosion reduction, habitat quality (or other significant biodiversity measures), carbon accumulation and biomass growth. The STELLA-based model will be designed more on an empirical basis and less mechanistically than other models such as WANULCAS. While the model will accept GIS input and will output information on a polygon basis it will still be a non-spatial model. The model is expected to provide output at several scales. It should be able to evaluate individual agroforestry practices at a watershed and regional levels and then be able to estimate cumulative impacts on a regional scale. The value of this model will be twofold. It will be used for determining the environmental impacts of existing agroforestry practices and assessing the impacts of additional agroforestry plantings.

Key Words: Agroforestry modeling, cumulative impacts, biodiversity, pollination buffers.

INTRODUCTION

Study objective

The main objective of our project was to develop a computer model that could be used to estimate environmental values of selected agroforestry systems. The systems used in the model are currently a variety of shelterbelt systems but a broader range of agroforestry systems will be added to the model in the future. The model was designed to predict environmental impacts such as sediment movement, carbon sequestration and biodiversity indices for pollination and predator pests. The model would also need to work at a variety of scales and be able to work in all regions of Canada.

In addition the model was required to consider impacts of various shelterbelt systems on crop yields, model the cost of agroforestry system establishment and maintenance as well as being able to track some economic values associated with harvest of agroforestry systems as they become old enough to consider for harvest.

Background

The model's development was supported by a literature search and development of agroforestry algorithms and relationships (Hunt 2005), as well as a field research component to define some of the biophysical characteristics of various agroforestry systems. The quantified biophysical characteristics were meant to define general agroforestry relationships on one hand and on the other to provide place specific coefficients for the model once it was implemented.

The pollinators considered for the model were native bees. They have been shown by Morandin and Winston (2005; 2006) and Gathmann and Tscharntke (2002) to venture up to 750 metres from their nests. S. Javorek (2007, pers. comm.) found that natural bee nests increased in abundance with the increase of uncultivated habitat. Predatory carabid beetles also use shelterbelts as refugia (C. Naronah, 2007, pers. comm.) Although they can disperse throughout the agricultural fields, their abundance depends on the presence of uncultivated habitat (S. Javorek, 2007, pers. comm.). Fournier and Loreau (1999) found diversity of beetle species to be dependent on habitat quality.

Model development

The first step for this project was to find a suitable modeling approach. The approaches considered included: the development of a model specifically written and designed for this project; to modify one of several existing agroforestry models; or to modify an existing non-agroforestry model so that it could accommodate the needs of the our environmental values of agroforestry modeling project. We selected the third approach because of the chosen model had dynamic modeling ability and the relative ease with which it could be upgraded to included an agroforestry component. We then worked with the principal architect of a model called A Landscape Cumulative Effects Simulator (ALCES) to have the agroforestry model developed within the bigger model. ALCES is the flagship program of a company called Forem Technologies (2007). ALCES is based on the dynamic modeling language called STELLA (ISEE Systems, Inc.) We used version 9.0.1. ALCES is a spatially stratified model that tracks land use change and a number of environmental indicators but it does not indicate where in a polygon the change takes place. If a GIS based model were used it would identify specifically where changes take place but speed is normally sacrificed when many interaction are being calculated. Data input to the ALCES model can be made directly into appropriate tables or it can be more automated with the use of spreadsheets. Input to some modeled parameters can be manipulated through the use of Graphical Input Devices (GIDs) that allow for user inputs to reflect local knowledge and also allow the model user to easily change coefficients as more knowledge about interrelationships is gained.

ALCES has been developed over the last 8-10 years and started as a cumulative effects model used to help a large Alberta forest company make integrated land use decisions. It has since evolved to model the interactions between many land uses including a range of agricultural uses. While it was developed in Alberta it can be used to model cumulative effects in any location where land use data and area specific coefficients for the modeled parameters are available. When compared to other agroforestry models such as WANUCAS (Van Noordwijk and Lusiana 1999), ALCES would be considered a strategic modeling approach rather than a mechanistic modeling approach. In the absence of complete data sets for environmental related values for agroforestry systems and a complete understanding that defined all the relationships within agroforestry systems in Canada, a strategic model based on known and largely empirical relationships was more appropriate. This approach is meant to allow users to compare the impacts of various shelterbelt and agroforestry systems as well as model the impacts of agroforestry Beneficial Management Practices (BMPs) and incentive programs that might be used to promote environmental benefits.

The agroforestry component of the ALCES model works first through a shelterbelt growth module that models the growth of eight different shelterbelt types. The eight shelterbelt named in Table 1 were chosen to represent the characteristics of shelterbelts that would be expected to be grown on the prairies and likely in other parts of Canada. Selection of the types was based on a combination of expert opinion and the biophysical surveys completed by PFRA in various regions of Canada (unpublished data, 2007). Tree growth, height and biomass, is derived from the Chapman Richards growth model (Zhang 1997) used in conjunction with field data collected by Kort and Michiels (1995). The result of this derived data is then provided to the model to describe values for each 10-year seral stage that each shelterbelt type grows through. Width and length of each of each shelterbelt type can easily be user defined through input tables in the model.

Table 1 provides examples of pollination related coefficients assigned to each of the eight shelterbelt types and then used in the modeling exercise. For pollination buffers, all shelterbelt types were assigned a width of 750 metres, regardless of how tall or complex they are, however. However, different values have been assigned to shelterbelt types for their pollination quality and subsequent impact on the adjacent pollination buffer. Natural belts were assigned a value of 1.0 and conifer belts, due to the relatively low presence of pollen providing plants, received a pollination quality of 0.8. The shelterbelt quality value is multiplied by the buffer value to give a value that describes the relative abundance of pollinators in the buffer area. For example the buffer around a shrub shelterbelt type will have a pollinator bee abundance of 0.48 (0.8 x 0.6). Compared to the open field, the area within the shelterbelt's pollination buffer have a coefficient that is 3 times as large as that for an open field.

Table 1: Pollination coefficients for eight different agroforestry types.

Agroforestry Type	Buffer Width (m)	Shelterbelt quality	Buffer Value	Open field
Shrub	750	0.9	0.6	0.2
Deciduous	750	0.9	0.6	0.2
Coniferous	750	0.8	0.6	0.2
Shrub/Deciduous	750	0.9	0.6	0.2
Shrub/Coniferous	750	0.9	0.6	0.2
Deciduous/Coniferous	750	0.9	0.6	0.2
Shrub/Deciduous/Coniferous	750	0.9	0.6	0.2
Native	750	1	0.6	0.2

In the model an increase in shelterbelt height results in an increase in pollination buffer width until it reaches the maximum width of 750 meters. Figure 1 provides an illustration of how a pollination buffer is modeled around a shelterbelt.

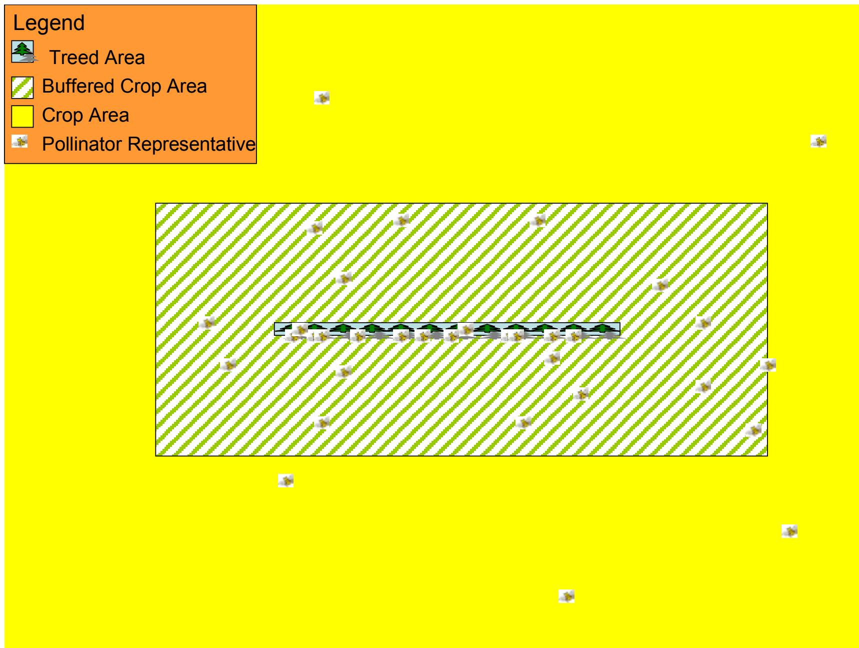

Fig. 1: An illustration of a buffer for pollination.[1]

In the model, the buffered area refers to the area where crop growth is affected by changes in microclimate, is protected from wind, or has enhanced pollination or carabid abundance and changes in species diversity. Each of the eight shelterbelt types is assigned its own buffers for the various parameters and the buffer area varies from one parameter to another. For example, the buffer for native pollinators can be set to reach the maximum width of 750 metres within a specific time but the extent of wind reduction buffer only reaches its maximum width when the shelterbelt reaches its maximum height. Buffer widths and coefficients that described their effectiveness were determined from a combination of literature values and expert opinion. Once again GIDs can be used to adjust how this buffer width grows in relation to age, height and complexity.

One of the advantages of choosing an already functioning model, such as ALCES, is that it included useful components that can add additional modeling power to our intended uses. For instance, the ALCES model includes a meteorological module that can run weather in either a deterministic or stochastic mode. In addition, the model contains a climate change model so that impacts of anticipated climate change could be accounted for. The impact of climate change driven variations in temperature, available moisture, and changes in hydrology will affect crop and tree growth and survivability. These, in turn, may increase the need for environmental benefit of shelterbelts while the ability of the systems to provide the environmental benefits may be

[1] This figure is in colour in the electronic version of the Proceedings (CD)

reduced. While these interactions will present a significant modeling challenge, we plan to build these functions into the agroforestry component of ALCES at a later date.

The agroforestry component of the model also contains a sensitivity analysis component so that impacts of a range of inputs such as growth rates, prices, and various buffer widths could be tested over a predetermined range of values. Outputs from the model are both graphical and tabular. Tabular results can be captured and copied into other programs that allow additional analysis for statistical purposes if desired.

The model allows for testing of various agroforestry configurations at a wide range of scales. The smallest area that can be modeled is one section of land (a square parcel of land of 259 hectares). At the other end the scale it is able to model impacts of regional shelterbelt systems that could be established in different regions of Canada, such as the prairies region or the Atlantic region. Because the model is able to manage as many as 10 biophysical regions at once, it could be used to model shelterbelt impacts for the entire country at one time.

There are several preliminary steps necessary to initialize the model. They include: populating the model with data that describes the biophysical area(s) or landscape(s) to be modeled. This step quantifies the study area for its various uses that include land uses such as different kinds of agriculture, roads, towns and water. Analysis to support this input is typically done with the use of a GIS program and then the data is entered into the model. Future trajectories for various land uses can also be added at this time if cumulative effects are to be modeled. The next step is to develop and provide the model with a description of the agroforestry types that fits each region that the model is to be used for. Because of the model's flexible design it could also be easily used in other countries.

METHODS

Testing the model

In this analysis, agroforestry types were modeled on one of four agricultural areas of Alberta. The area selected for analysis was the Oilseed Landscape type. In Alberta, this area contains 2.1 million hectares or roughly one fifth of the 10.9 million hectares of agricultural area found in the province.

Two scenarios were run in order to compare the impacts of a relatively short term and perhaps a moderate intensity agroforestry establishment program. The comparisons were for the most contrasting kind of agroforestry types in terms of the environmental values they were expected to provide. In scenario 1, the shrub and shrub deciduous shelterbelt type were planted over a period of 6 years at the rate of two shelterbelts per section per year. All shelterbelts were described as being 800 m long. The shrub type of shelterbelt is 3 m wide and the deciduous shelterbelt is also 3 m wide.

In scenario 2, both shelterbelts were multirow and considered to provide be more environmental beneficial. One type of shelterbelt consisted of a mix of shrubs, deciduous and coniferous trees and the other was a wide native shelterbelt consisting of a range of shrubs, hardwoods and softwoods. Both of these shelterbelts were 15 metres wide and, once again they were planted at the rate of two shelterbelts per section per year for 6 years.

After each modeling scenario was created, the model was run as individual runs and then as a comparative run. Running a scenario on a relatively fast laptop computer takes between one and two minutes. The output is provided in both a graphical and a tabular format. Figures 2, 3 and 4 are typical graphical outputs from the model. In the case where our two scenarios were run in comparative manner, 53 graphs were output by the model. The following discussion covers the results found in only a small number of the output graphs.

RESULTS AND DISCUSSION

At this early stage of the model's development two guilds of insects are used to represent shelterbelt impacts on biodiversity. The two guilds modeled guilds are pollinating bees and predatory carabid beetles. While the modeling does not directly predict the amount of pollination that is occurring, or its impact on crop yield, the model does provide an indication of relative amounts of pollination provided by bees that is likely to take place.

Our modeling exercise indicated that large amounts of pollinator buffer could be created with moderate amounts of agroforestry being present on the land. In both scenarios, the 6 years of planting resulted in 12 shelterbelts per section. These shelterbelts occupied roughly 3 ha of area within each section of land. Pollinator buffers reach their maximum size and extent when the shelterbelts have achieved suitable complexity. This is before the shelterbelts reach their mature height or age. We have assumed for now that complexity reaches its maximum value by the time the tree reaches 70% of it maximum height, which is well before its maximum age. Because of these relationships the pollination buffers grow to effectively cover the entire modeled agricultural area of 2.1 million hectares within roughly 20 years.

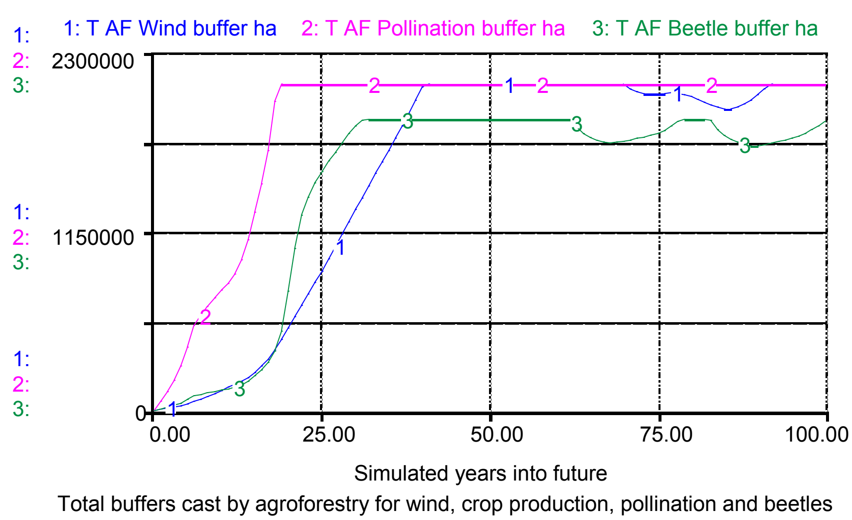

Fig. 2: Total buffer areas for a shrub and deciduous combination.[1]

[1] This figure is in colour in the electronic version of the Proceedings (CD)

By way of comparison it takes nearly 30 years for the beetle buffer area to reach its maximum size and even then it didn't cover the entire study area (Fig. 2). The wind buffer took about 40 years to reach its maximum coverage. The entire area in this case was effectively covered.

Biomass and carbon production is also tracked in the program. Carbon is simply calculated by multiplying the woody biomass by 0.5. At this time the model doesn't calculate and track below ground carbon.

Woody biomass resulting from the shelterbelts could have a number of uses depending on the type of trees that are grown. Some trees and shrubs might best be used for their bioenergy value. In the scenarios shown in Fig. 3 below there were roughly 5 million tonnes of production from the hardwood belts and 2.5 million tones of shrub biomass grown. Conceivably all or some of this production could be chipped and then used by wood fired boiler systems to provide heat for farms and other direct to heat facilities. While the harvest happened over a relatively short time period in this scenario, a different planting and harvest sequence would result in more or less continuous fuel wood production, if this were the desired result. The model could be run to test various scenarios and determine which configuration was optimum for fuelwood or timber production, while not compromising environmental values. One aspect of shelterbelt growth and harvest that becomes obvious is the cyclic nature of production and the resulting environmental values. In the Fig. 3 there is clearly a large decline in hardwood biomass shortly after year 50 but this is slightly offset by the later harvest of the shrub shelterbelts. Similar declines, but substantially less dramatic were seen for pollination and beetle buffers.

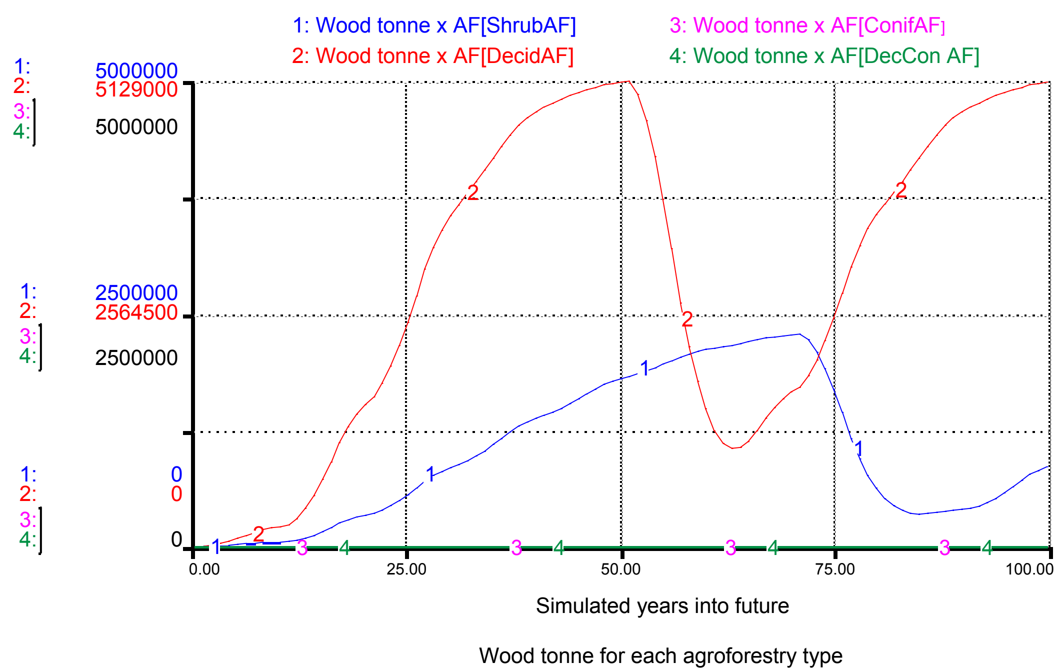

Fig. 3: Wood production for hardwood and shrub shelterbelts.[1]

In scenario 2 both belts were multirow. One type of belt consisted of shrubs, deciduous and coniferous trees and the other was a wide native belt consisting of a range of shrubs, hardwoods and softwoods. The biomass production in this scenario was much greater. The softwood production, which would mostly be White Spruce in this case, was roughly 25 million tonnes. It would likely have a higher dollar value if harvested for timber rather than for fuel wood. The total wood production in this scenario was nearly 53 million tonnes. This is nearly 10 times the wood production than scenario 1. Though the significance of wood production may often be overlooked it can be seen that there are large volumes of fibre and timber that could be produced for a variety of uses. While the model doesn't currently model the growth of short rotation woody crops it could be modified to accommodate it as an agroforestry or shelterbelt type. Its impact could then be evaluated in terms of production, economic impact or to determine how much area of other crops would have to be displaced when there was significant woody biofuel production.

An important consideration when establishing shelterbelts is the impact on crop productivity. The model showed that the cumulative crop production under scenario 1 would be slightly higher than that under scenario 2 (Fig. 4). This is likely due to the larger area taken out of agricultural crop production by the wider shelterbelts in scenario 2. What these scenarios did not consider at this stage however was the large potential yield benefit, resulting from more complex belts, on pollination dependent crops such as canola. There may also be an added benefit from larger numbers of the pest predator carabid beetles. While the model can accommodate these additional and expected positive interactions, of shelterbelts on crop production, it was not tested in our first modeling runs.

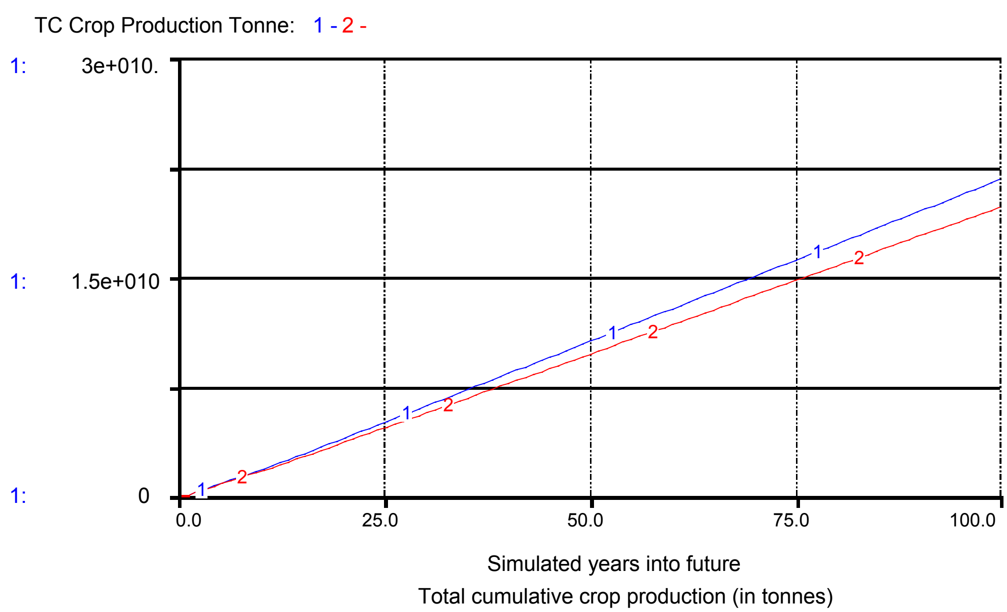

Fig. 4: Cumulative crop production for two shelterbelt scenarios.[1]

SUMMARY

The model does work and produces what appear to be realistic results. It should be noted, however, that these are the very early stages of testing the model. The model can work for

[1] This figure is in colour in the electronic version of the Proceedings (CD)

relatively small areas of land, such as a section of land (259 ha parcel) and it has worked for the agricultural area the size of Alberta, which is about 10 million ha. It also worked for a smaller area called the oilseed production area of Alberta. This was an area of 2.1 million hectares.

At this time there is limited data to verify the relationships we have assigned to the various shelterbelt types and the resulting environmental values but we are still able to obtain apparently credible results. We expect the understanding of these relationships to grow over time and the model will easily be able to accommodate these changes in understanding and knowledge. Because of the way the model is built we will be able to incorporate changes without relying on a programmer to modify underlying computer code. We also expect that the model will be useful in identifying areas of that require additional research.

As we had hoped the model is relatively easy to use though it is best used by those with some agroforestry experience and an understanding of the significance of the relationships between the variables used in the model. The four day introduction to ALCES would also be beneficial for most users. Because our scenarios were confined to only the agroforestry component of the model we did not explore the dynamic modeling features of the model. This would have added complexity to its use but would also provide additional analytical insight. For instance the agricultural land area is often shrinking and losing environmental values as a result of expanding cities, towns, road networks or perhaps too much manure being added. Without the other agricultural components of the model being turned on and interacting with the agroforestry components we have no way of knowing what the net benefit of the agroforestry practices is.

In the near future we hope to add a climate change module, a small mammals and bird guilds to the biodiversity module, and a hydrology component. The hydrology module would model the impact of shelterbelts on snow trapping and runoff.

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INITIAL CARBON QUANTIFICATION AND MODELING IN AGROECOSYSTEMS ON VOLCANIC SOILS OF THE CHILEAN PATAGONIA

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Abstract: During the 1990s, terrestrial ecosystems captured approximately 36% of the total carbon liberated to the atmosphere by combustion of fossil fuels. Consequently, there is a growing interest to study the potential of carbon sequestration in sustainable agro-ecosystems worldwide, including remote regions such as Patagonia, where large areas of degraded pastures and eroded soils are also encountered. The main objective of this project is to investigate and model the potential to sequester carbon in an undisturbed old growth forest stand (*Nothofagus pumilio*), exotic short rotation forest plantation (*Pinus ponderosa*) and degraded grasslands (*Dactylis*, *Holcus*, *Poa*, *Trifolium*) of the Chilean Patagonia. Within these adjacent test sites, soils are volcanic in origin and are classified as Medial, Amorphic and Mesic Typic Fulvudands. Soil samples were analyzed to determine microbial C and N, and rates of respiration. The plant biomass present in each system was calculated using allometric equations. Some of the data obtained were used to calibrate the CO2-FIX model. Preliminary results show that the contents of soil organic carbon are larger than those predicted by the model, which indicates the need to adjust the soil parameters so that the simulations better reflect reality. Once the model is recalibrated, it will be used with an adjacent six-year-old pine-based silvopastoral system to estimate total carbon balance, and the results will be compared with field and lab measurements to construct C cycling models. Hopefully, the results will convince other local ranchers to adopt agroforestry to improve productivity and sustainability of their lands.

Key Words: Carbon sequestration, silvopastoral system, CO2FIX, volcanic soils, *Pinus ponderosa*.

ENVIRONMENTAL SERVICES OF AGROFORESTRY: PHOSPHORUS REDUCTION AND CARBON SEQUESTRATION IN FLORIDA SOILS

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Abstract: Nutrient runoff from heavily fertilized agricultural enterprises is a major environmental problem in the coarse-textured soils of Florida. We hypothesized that agroforestry practices such as silvopasture could address this problem and enhance the environmental quality of the land because of the ability of trees to remove excess nutrients from soils and sequester carbon (C) in the deep soil profile. Two sets of experiments were conducted in two soil orders in Florida, Spodosols and Ultisols, with two major objectives: quantifying water soluble phosphorus (WSP) and estimating the Soil P Storage Capacity (SPSC), and determining the total C and C fractions in soil profiles and tracing the plant sources of C fractions in soil profiles. WSP was consistently higher in treeless pastures, and SPSC was lower in treeless pasture and higher in silvopasture. This suggests greater P storage capacity under silvopasture than treeless pasture, and greater likelihood of P moving out of the soil under treeless pasture than silvopasture. Total soil C in both orders was greater under treeless pastures in the surface horizons, but the stability of C was associated with the smallest soil fraction (<53 µm) which was higher in silvopasture. Stable isotope signature analysis suggested that C3 plants (slash pine) contributed more stable C fraction than C4 plants at soil depths up to 1 m. Thus, the presence of trees in pastures contributed to lower WSP and greater SPSC and more stable C within the soil profiles, indicating the greater environmental benefits provided by silvopastoral systems compared to treeless pastures under similar ecological settings.

Key Words: Coarse-textured soils, nutrient loading, environmental amelioration, silvopasture, subtropical agroforestry.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

GROWING AN AGROFORESTRY INDUSTRY ACROSS SASKATCHEWAN: TREES AND COMMUNITIES

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Abstract: Economic challenges continue to face rural communities on the prairies. These agriculture based areas are looking at reduced prices and increasing costs for products, continuing rural depopulation and loss of services. The Saskatchewan Forest Centre believes that tree production can provide some communities an economically viable way to diversify. Trees link well to other agriculture activities now underway in the province and can provide significant environmental benefits for watersheds, as well as for other development activities a region may be considering.

Within a one hour haul area (100 kilometres) surrounding any community is a land base of about seven million acres. With an average of 1500 to 2000 acres of trees required to support a development (e.g., a sawmill) that employs about 65 people, this takes less than 1 % (0.69%) of the land base. Key elements of a regional development area that could link to this community based strategy include:

- Four large scale hog barns
- 1000 km of riparian area
- Trees on farms, through shelterbelt, roadside and block planting and silvopasture
- Potential use of natural woodlots, and
- Numerous outlying communities.

Tree farming is about diversity: environmental diversity on the field and landscape level, economic diversity for farmers and communities, and social diversity for the region in terms of access to jobs and businesses. It is also about integration. Balanced community economic development is created through integrating varied partnerships and spreading risk. Community stability is the result and sustainable development follows on its heels.

Key Words: Community development, agroforestry, integrated development, crop diversity.

INTRODUCTION

Economic challenges continue to face rural communities on Canada's prairies. These agriculture based areas are looking at long-term reduced prices and increasing costs of moving product to market, continuing rural depopulation and loss of services. The Saskatchewan Forest Centre believes that tree production can provide agricultural-based communities an economically viable way to diversify, for over a 20 year production cycle trees are projected to make more money per acre than comparable annual crops. Trees link well to other agriculture diversification activities

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

now underway in the province and can provide significant environmental benefits for watersheds, as well as for other development activities a community may be considering.

Over a twenty year period, the net revenue from tree production outstrips traditional crop revenue. While so, challenges exist that are tied to industry start-up, community coordination and long term research and development support. This paper describes the regional benefits and revenue potential of establishing an agroforestry industry in Saskatchewan, and describes the benefits that a coordinated community approach can provide. It concludes with a series of next steps that the SFC is pursuing with various partners to realize this vision.

Tree farming is about diversity: environmental diversity on the field and landscape level, economic diversity for farmers and communities, and social diversity for the region in terms of access to jobs and businesses. It is also about integration. Balanced community economic development is created through integrating varied partnerships and spreading risk. Community stability is the result, and sustainable development follows on its heels.

When the agroforestry opportunity is assessed at the regional level, benefits become significant. Multiple provincial objectives could be met and a new economic sector developed. Planting trees as part of a long term community development plan can achieve many local sustainability objectives, including environmental, economic and social benefits.

In 1999, Saskatchewan launched a major expansion of its forest industry. Over the past several years Saskatchewan has seen nearly one billion dollars of investment in the primary forest sector. As a result, the Province is moving towards full utilization of its Crown forest resource. Through a combination of government policy, expected supply pressures and a potential response to the Kyoto Protocol, major opportunities now lie in developing a fibre supply on private lands that would diversify Saskatchewan's rural economy, and in building the associated products and businesses that would add value to this resource.

THE OPPORTUNITY

Saskatchewan has a significant potential to establish trees as a new crop system given its large agricultural land base (about 50% of Canada's agricultural area), relatively low land prices, soil suitability and declining returns from traditional crops. Today, the southern half of Saskatchewan is largely agricultural. Commodity production is focused on grains, oilseeds and specialty crops, with a growing mix of pasture supporting cattle production.

Historically, grain production in Saskatchewan has been a challenge. Distance to market has impacted on profitability. Until the 1980s, the farm economy relied upon the *Western Grain Stabilization Act,* more commonly known as the 'Crow Rate', to subsidize and standardize freight costs. When the Crow Rate was eliminated regionally specific freight costs were developed that reflected more closely the true cost of product movement to market. In the northeast growing region of the province, there were significant losses of revenue for crop production. The result was reduced land prices, and growing trees as a crop becomes economically competitive. The northeast area of Saskatchewan is looking to diversify into many new product areas, to help sidestep the costs of moving grain to market.

When this area was settled much of the land was tree covered. The Parkland forest covered a large portion of the north east agricultural region of Saskatchewan; broadly that area between the Yellowhead highway (#16) and the existing Boreal (Crown-owned) forest. Extending south from the Boreal forest in the aspen parkland transition zone, the Parkland forest was dominated by trembling aspen, birch and balsam poplar. Land conversion to agriculture at the turn of the 20th century significantly reduced the Parkland forest area, and today it is highly fragmented across its former region. Overall, the northeast agricultural region is uniquely situated to be the focus for an agroforestry initiative. Competing crops are few, profits are variable at best and the land area is well suited to tree production, as evidenced by the initial land cover.

Settlement patterns and development across the region is seen as a supporting mechanism. When first settled, government enacted a policy of dispersed farm development, by and large following the patterns of the American west. Farmers were encouraged to homestead on their land rather than concentrating into communities. The result was significant infrastructure across the region, and many small communities to support the dispersed population. Today, there is a fully developed road and human infrastructure which means that competitive, long term agroforestry development would not see the need for high cost for road or infrastructure development in business plans – the tax base provides these services.

Saskatchewan rural population has been declining for decades. Rural areas are looking for mechanisms to diversify the economy and retain their population. Today, small manufacturing facilities and a hog production industry is under development. Agroforestry offers another means by which rural depopulation can be mitigated, and also can be a linking mechanism to the emerging industrial base to provide economic and environmental benefits for the region overall.

ACTIONS TO DATE

Since inception, the Saskatchewan Forest Centre (SFC) has worked with local research institutions and federal and provincial governments to prove the productive and economic capabilities of agroforestry. Initial focus was on five key elements considered as pre-requisites to large scale adoption.

1. First, the productive value of the dominant hybrid poplar variety (Walker poplar) used mostly in shelterbelts was proved. Through several research initiatives, hybrid poplar was shown to be a substitute for apsen in oriented strand board (OSB), had good structural qualities for dimensional products and is good for pulp/paper production. First and foremost, the potential market for the tree was proved (Knudson 2003; 2005).

2. Second, a wide network of demonstration/research sites were established. Today, there are approximately 1500 acres of demonstration sites across Saskatchewan, most within the region of the Parkland forest zone. These sites were able to both establish the research base for variety specific growth and yield measurements and to show farmers the proper (and in some cases improper) methods of tree establishment (Saskatchewan Forest Centre 2007).

3. Optimal site utility and soil capabilities were developed in cooperation with Agriculture and Agri-Food Canada–Prairie Farm Rehabilitation Administration (AAFC-PFRA). It was determined that there are 3.2 million acres of land highly suitable for agroforestry in

Saskatchewan and another 3 million acres that are suitable and moderately suitable. Again, this suitable growing region broadly matches the former Parkland forest region of the province (Schroeder et al. 2003; Coghill 2004).

4. Fourth, a lot of attention has been paid to developing business models and economic analysis to show that tree production is cost competitive to annual crops and will outperform annual crop returns over the same period (20 years). To date, a carbon revenue stream has not been incorporated into future returns (Currie 2003).

5. And finally, a series of models have been developed to apply agroforestry across large land areas of the province. The two that show the most promise are the industrial model (e.g., Alberta Pacific Forest Products have established plantations for their purposes) and the community model (e.g., the Nipawin Biomass Ethanol project). The industrial model has been supported by government through a decision that new facilities will be able to access 80% of wood supply from Crown lands, with the remainder coming from private lands. The community approach involves integration of other regional benefits in long term agroforestry development, and allows the farmer to become an equity participant in the harvest and processing of the timber supply. Of course, both models can co-exist on the same landscape (Bertschi 2007; Currie 2007).

With regard to the economics of hybrid poplar production in Saskatchewan, growth potentials are encouraging. Upwards of 150 cubic metres (m^3) of timber production can be expected in 20 years from an acre of land (approximately 370 m^3/ha). An additional 15-20 m^3 of limbs and branches would be produced and could be utilized in a gasification and/or ethanol facility. In today's terms, approximately $1679 per acre would be realized on the harvest, transport to mill and sale of the wood. If the wood fibre were going to a value added facility (e.g., engineered wood products, veneer mill), the return per acre could be $2119. In comparison, annual crop product revenues are lower, sometimes close to negative (Currie 2007).

Within a one hour haul area (100 kilometres) surrounding any community is a land base of about 7.2 million acres. Within thirty minutes (50 km), there are approximately 1.8 million acres. With a production estimate of 150 m^3 per acre, a sawmill consuming 360,000 m^3 per year would require approximately 2000 – 2500 acres of trees per year to operate. In total, 40,000 to 50,000 acres would need to be planted within the community haul area to support the mill.

Thus, a total land base of less than 1% (0.69%) in a one hour haul distance or 2.8% within 30 minutes would sustain establish a sawmill. About 65 jobs would be created in the sawmill and many more in the harvest/haul industry. The usual spin-off ratio for jobs is 1:1 and is often higher. There is nothing absolute about the estimated acreage. In development, it might be more or less. However, the estimation provides for the development of one illustrative regional model. In this model, approximately $12.6 million would be injected into the local economy from the sale of the trees, with a matching investment amount from the jobs created at the mill.

While this is a laudable goal, the establishment of trees can be linked to other economic and environmental developments in the region to generate much wider regional benefits. Key elements of an integrated development strategy that could link to regional value added facility or sawmill include:

- Integration with large scale hog barns – planting trees around the barns reduces aerosol movement and odour; they also would be a significant user of hog effluent. There could be higher barn density, as more effective aerosol dispersal combined with a small land base required for effluent disposition would result. An added benefit is the production of much higher wood volumes in shorter periods from the ongoing fertilizer application. In Saskatchewan, a 5000 head farrow-to-finish facility would produce enough effluent to irrigate a 640 acre plantation and reduce time to maturity by several years.

- One thousand kilometres of riparian area restoration – watershed restoration can take place while providing farmers revenue upon harvest. Multi-species establishment can be integrated into the overall development plans to reduce erosion, intercept nutrients now lost to the river system and provide longer term revenues from species other than poplar.

- Trees on farms, through shelterbelt, roadside and block planting and silvopasture (trees in combination with livestock) – similar to riparian development, integrated tree production can support other crops or livestock choices.

- Biofuel/ethanol facilities – would utilize tree and farm residuals. Today several ethanol facilities are under consideration in the Parkland region of the province. Several are designed to consume wood fibre as a staple. Work now is underway to identify best suited varieties for energy production, including willow and high density poplar production.

- Potential use of natural woodlots – can advance the industrial development question significantly if there are adequate existing wood supplies. Approximately 900,000 acres of natural woodlots exist in the Parkland area. Many farmers do not consider them a revenue source, and land conversion has continued across the Parkland region. This conversion consists of the terminal sale of the wood to local primary consumers, followed by conversion to ranch or farm lands. With no coordination and a relatively small land base that is not complemented by an active agroforestry program, minimal value is tied to the woodlots. However, when incorporated into a longer term community development plan, these woodlots can sustain a production facility while agroforestry takes hold. Thus, for a community that wants activity to happen sooner than twenty years, woodlots can provide fibre now for investment decisions.

To maximize returns, the SFC has determined that a “total tree use strategy” is required and farmers must manage trees for both volume and value. Successful establishment requires focused farm management over the first few years. To ensure that some of the harvested wood has a higher value, pruning is required. Clear knot-free wood carries a significantly higher value in a veneer market than lower quality wood destined for OSB or pulp. Wood fibre must be produced for multiple end uses – from high value lumber through to using wood residuals for energy production. The present delivered wood cost of $35.00/m^3 could be increased substantially if the tree is managed for value – perhaps generating a delivered wood cost upwards of $65.00/m^3.

Moreover, the community must act together to ensure an adequate volume of wood is available from all participants in 20 years. If the option of utilizing a supply from woodlots does not exist, the actual decision on what facilities would maximize the value of the trees will not be required for perhaps 20 years. The design and investment made at that time needs to be the best fit for the market conditions and opportunities of the day.

THE CHALLENGE

While the potential or a community or investor to develop a local economy based on agroforestry is large, constraints to full implementation do exist. Without considering the use of existing woodlots (not available in some regions), it will take from 15 to 20 years to develop a mature wood supply. The reality is that there are high front end costs. Loan programs and other financial risk sharing programs need development.

It is assumed that large fibre consumers (e.g., OSB and plywood mills) will be indifferent between acquiring wood fibre from the forest or from the farm for the same delivered price. Consolidated large wood processing industries may act oligopolisticly. Hence, it may be necessary for farmers to own part of the processing industry to ensure the returns flow to them.

It is necessary to establish critical production mass in any given region to ensure that a range of services, expertise and local markets are available. The community based model has worked very well in the Nordic countries where individual farmers formed co-operatives to manage the plantations and to take ownership of the industry.

NEXT STEPS

In February 2006, the University of Saskatchewan led a process to develop a growth strategy for agroforestry in Saskatchewan, in response to the Throne Speech of November 2005. In the speech, the province stated a vision to have 10% of the arable land in Saskatchewan planted to trees over the next twenty years. The process brought together major stakeholders in agroforestry in two planning sessions, and delivered a growth strategy for agroforestry that would establish trees as a crop in Saskatchewan and create jobs in a value added sector. The goals identified to attain the vision for agroforestry in Saskatchewan include:

1. Create global industry and market understanding for agroforestry wood products. The capacity for industry analysis and market research in Saskatchewan is underdeveloped. For the Saskatchewan industry to grow, innovative business models that radically alter the traditional roles within the industry are required. Understanding these new models will be fundamental in developing successful market strategies. To be successful, Saskatchewan companies will need to adopt a market-centered strategy guided by a clear understanding of markets, customers and competitors. Support for ongoing market focused research will be required to ensure that establishment and management of the farm-based trees to best match future market expectations.

2. Deliver diverse tree species to create trees that match markets and create products. Implementing agroforestry on private and First Nation lands will challenge the scientific community to produce varieties that can maximize productivity under a variety of soil and climatic conditions. While some of the science issues are related to management of Crown forests, other solutions appropriate to private lands will require the development of unique solutions. Long term support for tree improvement programs will be needed, such as

expansion of the existing demonstration network and establishment of best practices for tree propagation for many of the new stooling bed companies.

3. Develop programs and policies that enable widespread adoption. Today the establishment costs for agroforestry are significant. Risks associated with new crop development include such things as the applicability of farm support programs and crop insurance, to name two. The combined effect of opening these programs to trees as a crop will build confidence in the farm community and help manage the crop life cycle risk (in the same way as any other). The high cost of crop establishment needs to be addressed. A combination of private sector funding and government support through initial stages will be required.

4. Expand extension/communication programs. The development of a robust industry in Saskatchewan is based on knowledge that enables farmers and companies to identify and meet market opportunities in a competitive, economic manner. The opportunities include not only using existing species in ways that produce a higher valued product array but using other species in a manner that maximizes their value. Expansion of extension services is a key element in meeting these needs.

5. Develop community-based clusters and/or value chains. Development of model communities – the community involvement approach. Such a program will work with farm communities and their regions to achieve a critical mass of agroforestry acres such that it would support a significant value added industry within 20 years. Requirements include providing tree cuttings and technology assistance with new varieties, vegetative management and pruning to achieve a high valued tree crop. Creation of an industry focussed on hardwood utilization would be the result and includes the existing poplar, birch and aspen base as well as poplar varieties yet to be developed.

Support for community investment in developing an industry based on tree production in an area should be an important strategy. Communities will need access to the ‘right’ people, for information and for industry development. Assistance for pre-feasibility studies designed to determine suitable land base, existing and needed infrastructure and prospective business creation in the area is required. Many agencies will be needed for involvement in the development guidance process.

Today, community groups are in the formative stages, and are looking for the support identified in the key actions cited above. Foremost, they are looking for an investment model to build confidence that this new crop is economically viable, and for government leadership in research, technology support and program support to enable widespread adoption. The integrated community model, with all its complexities, is seen as a viable way forward to establish agroforestry as an economically viable crop that can deliver significantly more social and environmental returns than Saskatchewan’s traditional crops.

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AGROFORESTRY BOOM IN THE NORTHERN PLAINS OF CHINA: DRIVERS AND IMPACTS

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Abstract: Agroforestry in the northern plains of China has witnessed tremendous expansion over the last 30 years. Shelterbelts, intercropped trees, and small woodlots are found everywhere. Back in the 70s and 80s, farmers planted trees in and around their farm fields primarily for fulfilling their own fuel, fodder, and timber consumption and improving their local environment for agriculture. Since the 90s farmers have been planting trees to produce commercial timber for the regional panel industry. What's behind this new wave of agroforestry development are the backdrop of national timber shortages and thus very high timber prices, and the liberalized policy environment in which farmers are able to make their own choices of land use for their own benefits. It is reported that this agroforestry development has significantly increased farmers' income, improved their employment, and alleviated their poverty, while it has not affected agriculture adversely. Moreover, it has provided large quantities of wood products to national economy. This paper will investigate the driving forces and assess the social and environmental impacts of this agroforestry miracle. It is hoped that the experience and lessons learned from the northern plains of China will be useful to agroforestry and even forestry development in other parts of China and the world.

INTRODUCTION

Agroforestry in the northern plains of China has witnessed tremendous expansion over the last quarter of century. Shelterbelts, intercropped trees, small woodlots, and home gardens are found everywhere. In particular, more and more trees are planted abound and inside of farm fields in the forms of shelterbelts and intercropping. As a result, forest cover in the region has increased from less than 5% in the late 70s to over 15% (China Forestry Statistics 2005).

What are the drivers of this tremendous agroforestry boom and what are its economic and ecological impacts? This paper attempts to answer these questions through a combination of case study and econometric analysis. We will provide a brief account of the demographic and economic context behind the agroforestry boom, using Liangshan county of Shandong province as an example. We will also present a case study of the drivers and impacts of the agroforestry development using Heze municipality of Shandong as yet another example. In another section, we will present our empirical results from econometric analysis. Finally, we will summarize our work and offer some policy implications and future research directions.

We hope that the experience and lessons learned from the northern plains of China will be useful to agroforestry and even forestry development in other parts of China and the world.

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THE STORY OF LIANGSHAN COUNTY

Liangshan, a rural county in southwest Shandong, is a typical site for understanding the specific context of agroforestry development in the northern plains. Like many other places in the region, its population density is high – from more than 300 people per square kilometer by the end of 1970s to over 500 in the mid 1990s. Thus, land has been very limited – for a rural labor force of 147,800 in 1978, the total farmland was only 55,880 ha (see Table 1). And this limited resource further declined to 54,980 ha in 2001, while the labor force swelled to 322,600. Put it differently, farmland per rural worker was 0.38 ha in 1978, and it reduced to 0.17 ha in 2001. The scarcity of land has severely constrained the growth of the local economy, which remains to be agriculture based.

To increase yields, the limited land has been utilized more than once a year – the multiple cropping index, defined as the ration of total sown area over total cultivated area, went up from 143% in 1978 to 190 in 2001. Also, improved seeds have been widely adopted, and irrigation has remained widespread. Further, fertilizers application has intensified from about 50 kg/ha to around 700 kg/ha. However, these technologies have their limitations; farming has been subject to such acute problems as the decline of upper layers of groundwater, the decrease in soil organic content, and the crop susceptibility to pest, disease, and desiccating early summer hot winds (Yin and Hyde 2000). It seems that maintaining a sound natural environment conducive to steady growth of crop production is beyond the reach of modern technologies.

Furthermore, the combination of high input costs and low grain prices meant that once people's subsistence needs are met, heavy dependency on cropping is not conducive to income growth and livelihood improvement. Local farmers have thus made aggressive efforts to diversify their economy by expanding their production activities into animal husbandry, forestry, and other enterprises. It is against this backdrop that agroforestry has been adopted as a major way of adapting to the fundamental constraints of regional biophysical, socioeconomic, and demographical conditions. The ratio of farmland put under the protection of tree shelterbelts went up from less than 30% in 1978 to more than 90%, and the forest cover, over three quarters of which is made up of intercropped trees, rose from 6.4% in 1978 to 15.3% in 2001 (Table 1).

The annual (real) value of grain production per rural worker was around 450 yuan in 1978 and went up to 3,400 yuan in 2001. Similarly, the annual (real) value of grain production per ha was less than 1,200 yuan and rose to around 20,000 yuan in 2001.

The production of annual crops was the dominant means of livelihood in 1978, accounting for 83% of their total agricultural production value; in 2001, it declined to 54%. Accordingly, farmers' living standards have been improved significantly, even though the pace of change is below provincial or national average.

Table 1: Agricultural and agroforestry development in Liangshan county, Shandong.

Year	Rural labor (1,000)	Farm-land (1,000 ha)	Farm-land per worker (ha)	Fertilizer use (kg/ha)	Real value of crop production per worker (yuan)	Real value of crop produc-tion per ha (yuan)	Ratio of crop value over total value	Ratio of farm-land with shelter-belts	Forest cover (%)
1978	148.7	55.88	0.38	50.11	448.69	1193.99	0.83	29	6.4
1979	155.5	55.75	0.36	48.43	475.18	1325.46	0.83	29	6.7
1980	163.2	55.67	0.34	68.26	450.86	1321.80	0.81	31	6.9
1981	167.8	55.61	0.33	86.31	552.26	1666.33	0.83	31	7.0
1982	176.6	55.61	0.31	113.30	588.79	1869.92	0.82	32	7.1
1983	167.2	55.55	0.33	167.41	937.80	2822.51	0.80	32	7.2
1984	171.8	55.53	0.32	185.50	1090.51	3374.05	0.77	43	7.8
1985	184.1	55.48	0.30	180.25	997.88	3311.28	0.76	54	10.3
1986	195.9	55.33	0.28	245.81	950.38	3365.10	0.79	57	12.5
1987	208.1	55.33	0.27	233.16	964.82	3628.99	0.75	61	12.8
1988	211.6	55.20	0.26	248.19	1234.36	4731.70	0.77	62	13.9
1989	221.3	55.18	0.25	251.90	796.61	3194.82	0.74	64	14.3
1990	231.7	55.18	0.24	300.83	757.53	3180.86	0.70	67	14.5
1991	256.5	55.17	0.22	324.43	1526.28	7095.64	0.65	76	14.7
1992	268.1	55.14	0.21	413.49	1497.54	7281.28	0.65	87	14.9
1993	273.9	55.11	0.20	449.98	1731.65	8605.90	0.60	88	14.6
1994	275.6	55.11	0.20	460.87	2793.58	13969.58	0.63	89	13.8
1995	283.4	55.11	0.19	783.84	4539.03	23340.27	0.71	89	14.2
1996	284.4	55.08	0.19	748.00	4807.77	24824.44	0.67	90	14.5
1997	290.6	55.04	0.19	554.14	3836.65	20256.72	0.64	90	14.9
1998	293.2	55.03	0.19	666.95	3455.42	18411.62	0.60	90	15.1
1999	316.5	55.01	0.17	749.00	3247.08	18683.19	0.60	90	15.1
2000	325.8	54.98	0.17	794.83	3247.24	19242.45	0.61	91	14.4
2001	322.6	54.98	0.17	683.89	3408.52	19999.82	0.54	92	15.3

Note: Data were collected from Shandong Agricultural Statistics and Shandong Forestry Statistics.

THE CASE OF HEZE

Situated in southwest Shandong, Heze is a municipality of twelve rural counties. There shelterbelts are established in blocks of 13-30 ha to create a network of trees that reduces the impacts of wind. These grid-like barriers are normally planted 2-4 rows deep (Wu and Zhu 1997). In intercropping, two year-old tree seedlings are planted in farmland, with a spacing of either 3m×6m or 3m×8m. Sometimes, two rows of trees are planted side by side at a spacing of 3m×3m followed by a 10-meter gap for growing annual crops. Poplar has become the most popular species of choice. Poplar seedlings come from genetically improved clonal varieties.

Annual crops are planted in-between the rows of trees. Winter wheat is the first crop planted during the first a few years of the trees' growth. Corn, cotton, and peanuts are grown as the second crops. After 3-4 years of intercropping, the shading effect of tree crowns inhibits the growth of annual these crops. They are then replaced by more shade-tolerant crops like alfalfa, which has the added benefits of fixing nitrogen in the soil and providing food for livestock. Farmers then continue to manage the standing poplar trees, including fertilizer application, pruning, and tilling. After 5-8 years the poplar trees are harvested and logs are transported to nearby processing centers in villagers.

Fig. 1: Two local women kneeling amongst large stacks of wood panels that a housewood wood-products manufacturing enterprise has produced from poplar and paulownia logs.

Before 1978 when the rural reform was initiated in China, forest coverage in Heze was almost non-existent. People had little access to timber for home construction or fuelwood. This scarcity in forest resources and the resulting demand for timber products constituted an initial push for agroforestry development (Zhu 1995). However, before 1978, farmers were unable to make their own production choices under the old economic system. Once the land was decollectivized and the markets were liberalized, the minimal control of local governments over forest management created an atmosphere that favored market-driven forestry development. Timber was sold at open market prices with low taxes. So, farmers responded to this opportunity, and as a result, the forestry sector has flourished (Yin 1994, Yin and Xu 2002).

Local governments also are actively involved in adopting agroforestry systems through financial and technical assistance, and research and development. To farmers interested in planting trees, local governments provide them with seedlings free-of-charge. Also, governments offer financial support to people entering wood products processing in the forms of lowered electricity costs and low interest loans. Furthermore, taxes imposed on these production activities have remained low.

In addition, the success of agroforestry can be attributed to technical assistance by local governments. A technical extension service has been created for farmers, whose agents hold demonstrations that are geared toward proper planting techniques and intermediate treatments such as application of fertilizer. The governments have also emphasized the role of research and development of the agroforestry systems and the individual trees that are used in these systems, with a focus on the silvicultural characteristics and biological performance of the fast growing and hardy hybrid poplars. Indeed, these characteristics have much to do with why poplar has been widely adopted in this area, which make it easier to realize the economic returns from the timber in less amount of time (Zhu 1995).

Fig. 2: Hybrid poplar-wheat intercropping by a local farmer in Heze, Shandong.

According to Daversa (2006), farmers' income obtained from their land has increased by 30-70 percent as a result of interplanting hybrid poplar into their fields. Because poplar management is less intensive, farmers now have more time away from their farms, during which they can partake in other jobs. The expansion of agroforestry systems in has also promoted the development of small-scale wood products mills of are wood panels, fiberboard, veneers, and plywood. Indeed, many households have moved off of their farms to partake in this prosperous business. Currently 28,000 mills have been established within Heze, with a total employment of 500,000 villagers. The total wood utilization amounts to approximately six million cubic meters per year, with an annual processing value of $ 850 million. Wood products manufacturing has allowed for the accumulation of capital, which in turn can be used to further invest in the sector, and thus the business can continue to grow. Individual households are engaged in producing unfinished veneer or wood panels, whereas the mills often take the processing a step further to manufacture more refined products like plywood and fiberboard.

Yin and Hyde (2000) and Laura (2006) present evidence that agroforestry has positive impacts on agriculture. However, the data sets used by both of them are small, which cause their results fairly sensitive to the sample. In contract, this paper uses panel data sets covering a larger range and longer time periods to gain robust results. Also, this paper tents to assess determines of the development of agroforestry. The paper is organized as follows: we begin our investigation with a brief discuss of the conceptual method. We then provide the relevant data in the third section. In forth section, the empirical results are reported and major finding are discussed. Lastly, we provide the summery and conclusions.

Fig. 3: A local woman lays out wood veneer that has just been processed at a small scale wood-products manufacturing enterprise in Heze, Shandong. In the far right corner, another woman runs a ladle to continue veneer production. Local poplar logs were used in this process.

ECONOMETRIC ESTIMATION

By estimating an cereal production function with terms describing the environmental services provided by agroforestry, we can formally test the hypothesis that agroforestry has affected agricultural productivity positively. That is, recognizing that the overall productivity gains from integrating crops and trees under the constraint of limited land, farmers internalize the positive efforts contributed by trees to land productivity (Yin and Hyde 2000).

The basic production function for this paper takes the form as follows:

$$\ln Y_{it} = \alpha_0 + \beta_1 \ln A_{it} + \beta_2 \ln L_{it} + \beta_3 M_{it} + \beta_4 F_{it} + \beta_5 E_{it}^{\ 1} + \beta_6 E_{it}^{\ 2} + \nu_i + \varepsilon_t \quad (1)$$

where Y is the aggregate farming production, A is sown area, L is labor, M is machinery, F is net chemical fertilizer, and these input and output variables are log transforms. Es are terms for agroforestry – E^1 is the ratio of shelterbelt area, and E^2 is forest coverage. These proxies for the environmental services of agroforestry work as production shifters. α is the constant term, while βs are parameters for estimation. ν_i is the cross-section error term which reflect factors like soil quality and whether, and ε_t is time series error term. Unlike Yin and Hyde (2000) and Laura (2006), which use the pool data method in their estimation, we use the panel data method here. The former imposes a strong assumption –the differences between regions are fixed. The latter is more flexible because it allows us to test this assumption.

To assess the driving forces of agroforestry development, we also set agroforestry as a function of per capita land holding, farming production, prices of timber, and prices of agricultural products. We assume that this function takes a linear form:

$$E_t = \gamma_0 + \gamma_1 L_t + \gamma_2 Y_{t-1} + \gamma_3 P_{1,t} + \gamma_4 P_{2,t} + \varepsilon_t \quad (2)$$

where E_t is an agroforestry proxy as defined above, L_t is land holding per capita, Y_{t-1} is a lag term of farming production, $P_{1,t}$ is the price index of timber, $P_{2,t}$ is the price index of agricultural products, and ε_t is the error term. We expect that land holding per capita has a negative impact of agroforestry, meaning that declining land holding likely induces stronger agroforestry development. The inclusion of lagged production indicates past production feedbacks (positively) to current decision of agroforestry in local farmers' quest for improved livelihood. The expected sign of the coefficient of timber price is positive, suggesting that higher value of trees stimulates the development of agroforestry. Conversely,the prices of agricultural products may have negative impacts on agroforestry.

Data set used in this paper were collected from three counties – Liangshan and Rencheng in Shandong, and Tongxu of Henan for the period of 1978 – 2002. Table 2 includes the definition of all variables and their descriptive statistics. Our measure of farming production is the sum of the annual value products of grain, cotton, and oilseed, deflated by the agricultural producer price index. As suggested by Yin and Hyde (2000), the total sown area is a better measure of land use than cultivated area because the sown area accounts for the effect of multiple cropping. The measure of agricultural machinery (in total horse power) may potentially overestimate its contribution to farming because many farm machines are used for transportation as well. The price index of timber is only for timber with 24 cm diameter. The price index of agricultural products includes prices of wheat, rice, and maize. These indexes are calculated using 1978 as the base year.

Table 2: Definition of all variables and their descriptive statistics for the data collected from Liangshan and Rencheng in Shandong, and Tongxu of Henan for the period of 1978 - 2002.

Variable	Definition	Mean	St.Dev.	MIX	Max
Production	Total farming output (wan yuan)	57197.77	51214.7	6228	180657
Shelterbelt	Ratio of shelter belted area	64.03	21.6	21.2	93
Forest cover	Forest coverage	13.34	3.09	6.4	19.1
Labor	Total rural labor force (wan ren)	24.35	5.65	14.87	33.68
Land	Total cultivated land area (wan mu)	79.99	3.73	71.64	96.91
Machinery	Rural machinery power (wan kw)	2.23	1.18	0.2	4.37
Fertilizer	Net chemical fertilizer (wan ton)	29.4	16.79	5.06	70.4
P1	Price index for timber	1.55	0.18	1	1.93
P2	Price index for agricultural products	2.65	1.121	1	4.92

Table 3 reports our regression results. Results in column 1 and 3 are estimated with the fixed effects model, while those in column 2 and 4 are estimated with the random effects model. The Hausman test led us to rejection of the fixed effects model, implying that the differences between regions are not fixed statistically. The collinearity between labor and machinery is high, which may cause coefficient insignificance. To mitigate the problem, we excluded the machinery variable, and the results are in column 3 and 4. Still, the difference between these two specifications is small. From the Hausman test again, we found the results the random-effects model are more robust. So, our explanation will be based on results in column 2. Note that these results are still preliminary.

Table 3: Coefficient estimates for aggregate production.

	[1]	[2]	[3]	[4]
Variable	Fixed effects	Random effects	Fixed effects	Random effects
Shelterbelt	0.021	0.017	0.03	0.02
	[0.007]**	[0.006]**	[0.007]**	[0.006]**
Forest cover	-0.051	0.00	-0.019	0.031
	[0.035]	[0.037]	[0.036]	[0.034]
Land	-2.917	0.983	-2.009	1.183
	[1.037]**	[0.938]	[1.084]	[0.951]
Labor	0.513	-0.527	0.94	-0.095
	[0.541]	[0.612]	[0.569]	[0.581]
Machinery	0.904	0.531		
	[0.260]**	[0.275]		
Fertilizer	0.34	0.456	0.563	0.606
	[0.139]*	[0.165]**	[0.133]**	[0.149]**
Constant	12.621	-2.697	8.547	-4.016
	[4.898]*	[4.931]	[5.136]	[4.979]
Observations	75	75	75	75
R-squared	0.89		0.88	

Expression in brackets is standard errors.

* significant at 5%; ** significant at 1%

In general, the coefficients on most of explanatory variables satisfy expectation. The coefficient of land is insignificant statistically. But this is not surprising if we look at the data closely. The combination of a cultivated land decline and a multiple cropping index gain leads to a relatively stable sown area. Meanwhile, cereal production has increased rapidly. As such, land has little predictive value for farming output. Our results are consistent with previous studies by Yin and Hyde (2000) and Laura (2006). The coefficients of labor and machinery are also insignificant, which may not be surprising given their high correlation with fertilizer and their employment beyond farming. More accurate data about labor and machinery will improve the estimated contribution of labor and machinery to farming output. The coefficient on fertilizer is positive and significant, independent to the specification of model. It implies that fertilizer has made more contribution to agricultural production comparing to other inputs.

The coefficient of shelterbelt is positive and significant, suggesting that the capability of shelterbelts to control wind velocity and wind erosion is much important to farming. We did not find evidence that forest cover has positive effort on agricultural productivity. A possible reason is that majority of the forest cover is not necessarily associated with farming and trees are used for other purposes.

Table 4 reports the estimated determinants of agroforestry development. The coefficient of farmland per capita is negative and significant. This result suggests that land scarcity is an important factor in driving agroforestry. Farmers have more incentive to introduce the agroforestry to maximize their gains when land holding is more limited. The coefficient on price index of timber is positive and significant. In Shandong, the expansion of forest product industry has resulted in a stronger demand for timber. The increased timber price has made tree planting more attractive than agricultural production. The coefficient on the lag term of farming output is insignificant.

Table 4: Estimated determinants of agroforestry development (coefficient estimates).

Variable	Shelter belt	Forest cover
Land per capita	-35.755	-2.878
	[9.779]**	[2.311]
Farming production	0.075	0.001
	[0.048]	[0.011]
Price of timber	0.136	0.001
	[0.051]*	[0.012]
Price of agricultural products	-18.46	0.688
	[6.666]*	[1.576]
Constant	166.212	22.719
	[59.864]*	[14.151]
Observations	22	22
R-squared	0.95	0.88

Standard errors in brackets

* significant at 5%; ** significant at 1%

THE FINANCIAL PERFORMANCE OF INTERCROPPING

In this paper, we have used the Cobb-Douglas agricultural production function under a panel data setting to evaluate the economic impacts of agroforestry on agricultural productivity. In our sample, the economic impact of agroforstry is positive and significant. The finding provides an insight that improvement of agricultural environment by agroforstry may be an important factor to sustain the long-run agricultural growth. The analysis on the determiners of development of agroforestry finds that land scanty is an important factor which stimulates the development of agroforestry. In addition, as the local forest industry has developed, the agroforestry is also driven by the forest product markets through the increasing timber prices. These two factors lead to the agroforestry expending so rapidly.

Since the data limitation, the coefficients on some variables are not robust. We should broad our sample size and examine our data further, before we place confidence in these findings. This weakness about data should be taken into account in future research on economic impacts of agroforestry. By the same reason we are not able to account more factors which may affect the development of agroforestry, such as government's policy. This may be a new research direction in the future.

To understand the comparative advantage of poplar intercropping, it's worthwhile to look into the performance of intercropping, which is designed in two ways – growing small- or large- diameter logs.

Option 1 – Producing small-diameter logs

In this case, the common planting density is 222 trees/mu, with a spacing of 2m×1.5m; a survival rate of 95% leads to the harvest of 211 trees/mu in four years. The average diameter is about 12cm, with a tip diameter of 8cm.

There are two methods to estimate its economic benefit:

I) Estimation by weight: The average fresh weight per tree (trunk and branches) amounts to 60 kg, and the total yield is 12660 kg/mu (211 trees×60 kg/tree). With a factory price of 0.22 yuan/kg (in 2003), the gross return is 2785.2 yuan (12660 kg×0.22 yuan/kg). With a discounting rate of 5%, the present-value revenue is 2377.76 yuan, so average is: 594.4 yuan. Deducting management cost of 200 yuan/mu/yr, the net present value is 396.4 yuan.

II) Estimation by combined volume and weight: Stumpage volume 10.8 m^3/mu with a conversion rate of 75%, log volume 8.1 m^3/mu, log revenue 8.1×250=2025 yuan.

Branch per tree is 15 kg, factory price by 0.22 yuan/kg (price in August 2003).
Branch yield per mu 211×15 = 3165 kg; income per mu is 3165×0.22 = 696.3 yuan.
Total income = log + branch = 2025 + 696.3 = 2721.3 yuan.
Present value is 2345.95, Annual NPV per mu is 386.5 yuan.

In summary, producing small-diameter logs can result in a NPV of 386~396 yuan/mu.

Option 2 – Producing large-diameter veneer logs (diameter ~ 32 cm)

Planting density is 33 trees/mu, spacing is 5m×4m; survival rate is 95%, 31 trees/mu are harvested in eight years.

A) Timber: stumpage volume per mu 0.5799×31=18 m^3/mu, log volume 18×70% = 12.6 m^3/mu, market price is 650 yuan/m^3 (in 2003), timber income 12.6×650 = 8190 yuan.

B) Branch: 100 kg per tree and factory price 0.22 yuan/kg (in 2003), income is 682 yuan.

C) Total: revenue 8190 + 682 = 8872 yuan/mu, with a discounting rate of 5%, present value is 6292.2 yuan, or 786.5 yuan/mu; deducting management cost of 200 yuan/yr, net present value is 586.5 yuan/mu/yr.

Benefit of integrated farming and forestry

Take the example of 33 trees/mu, spacing 5m×4m, and producing large diameter timber in 8 years.

A) The yield and income of crops interplanted in high-yield forest: in the first 3 years, annual crops can be grown at least partially, so the trees do not need additional inputs of fertilizer and water (Table 5).

In the first 3 years, net revenue from annual crops is from 979 to 1061 yuan (Table 5). Total net present value from farming and forestry 5671.1 ~ 5753.0 yuan per mu, so annual NPV is 708.9 ~ 719.1 yuan/mu.

Table 5: Yield and income of crops interplanted in high-yield forest.

1st year	Wheat 300kg/mu (300yuan)	Wheat 300kg/mu (300yuan)
	Cotton 150kg/mu (600yuan)	peanut 300kg/mu (720yuan)
2nd year	Wheat 250kg/mu (250yuan)	Wheat 250kg/mu (250yuan)
	Cotton 100kg/mu (400yuan)	peanut 150kg/mu (360yuan)
3rd year	Wheat 250kg/mu (250yuan)	Wheat 250kg/mu (250yuan)
Total (5% discounting)	1745.76 yuan	1827.7 yuan
Cropping inputs	300+300+200	300+300+200 yuan = 766.7
Net income per mu	979.1 yuan	1061 yuan

Yin and Hyde (2000) reported that China's northern plains region, which includes Hebei, Henan, Shandong, Liaoning, and the northern parts of Jiangsu and Anhui, experienced a substantial upsurge in agroforestry, primarily shelterbelts and intercropping, during the late 1970s and 1980s (see Table 6). Forest cover there increased from five percent in 1977 to eleven percent in 1988, thereby greatly easing the local construction timber and fuelwood situations, and significantly improving the environment for agriculture. They estimated that at least five percent of the agricultural production increase was attributable to agroforestry development.

Table 6: Panel production in selected provinces and the whole country.

	Hebei	Jiangsu	Shandong	Country
1995	<41		<465	
2000	3423	1601	3512	29547
2005	11484	29414	12735	109402

Note: Figures, in current value of million yuan, are from China Forestry Statistics

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UN OUTIL DE MODÉLISATION ÉCONOMIQUE POUR L'ÉVALUATION DES SYSTÈMES AGROFORESTIERS VISANT LA PRODUCTION DE BOIS DE QUALITÉ AU QUÉBEC

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Résumé : L'année 2006 a vu en Gaspésie (Québec) la mise en place de plusieurs systèmes agroforestiers dans lesquels la composante sylvicole a pour principal objectif la production de bois de qualité. En complémentarité avec les essais sur le terrain qui visent à étudier la faisabilité technique et l'acceptabilité du développement de ces systèmes, la validation de leur viabilité économique est essentielle.

Un modèle original a donc été développé pour simuler l'ensemble des coûts et des revenus associés à ces systèmes. Les particularités du modèle tiennent à sa conception basée sur la croissance des arbres. Quatorze paramètres permettent de décrire cette croissance en fonction des caractéristiques des essences plantées, du milieu naturel et des modalités de plantation. Plusieurs extrapolations ont été nécessaires pour pallier à l'absence de données sur la croissance individuelle des arbres au Québec.

Les premiers résultats font état d'une valeur actualisée nette (VAN) pratiquement nulle à la récolte des arbres. Toutefois, la prise en compte des avantages autres que sylvicoles du système, tels que l'amélioration de la production agricole et la préservation du caractère ouvert et dynamique des paysages, font revoir cette évaluation à la hausse. Ce modèle joue donc en faveur de la prise en compte de la multifonctionnalité de l'agriculture dans l'évaluation économique des pratiques agroforestières.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

Mots-clés : Agrosylvopastoralisme, modélisation économique, bois de qualité, modélisation de croissance, multifonctionnalité.

FARM AND FIELD SHELTERBELT PLANNING DECISION SUPPORT SYSTEM

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Abstract: The planning and design of farm and field shelterbelts in the Canadian Prairies is a well defined and documented process. Based on specific criteria such as the soils, landscapes, climate, building locations, waterways, and prevailing winds plans for the planting of tree species in various configurations can be designed that provide functional environmental protection and add resilience to the agricultural landscape. Historically, this planning has occurred through farm visits and through consultations with agroforestry specialists, while the remainder of the planting plans have been designed by the client with limited or no assistance, and later reviewed and approved by an agroforestry specialist. However, with financial pressures limiting on farm visits and the loss of shelterbelt planning knowledge through staff retirements, the ability to provide effective farm and field shelterbelt planning is quickly being lost. A farm and field shelterbelt planner DSS is currently being designed to utilize the historical rule bases, expert knowledge and growth characteristics of tree species in Western Canada. Spatial referencing will allow the integration of soil and landscape properties, and climatic properties. Delivered in a web based environment, the system will allow the client to interactively select management options, tree species, and environmental criteria to determine a best fit tree planting design for a specific farm and field scenario.

Key Words: Shelterbelts, planning, decision support systems.

SOIL INTERPRETATION MODEL FOR CROP AND FOREST TREE PRODUCTION IN NEW BRUNSWICK: CANSOIL-INTERPNB

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Abstract: The unique map polygons of the Pedo-Climate (soil-climate) map of New Brunswick are interpreted for the production of agricultural crops and forest trees using the soil interpretation model CanSOIL-INTERPNB. The suitability identification model helps in establishing management practices by qualitatively assigning the best site prediction for specific species or use. This proved to be a valuable decision making tool for agriculture and forest managers as well as engineers.

The prediction model can be applied at the local, regional, national and international levels providing that the soil and climate databases are available for the area under investigation. It will also help in the decision-making process concerning the establishment of research strategies for locating best sites that support sound ecosystem management. As a real time interpretation tool, the CanSOIL-INTERPNB has the ability to interpret soils for the production of six agricultural crops and twelve tree species. The model was successfully tested and applied in New Brunswick, Prince Edward Island and Nova Scotia, Canada.

Key words: Soil interpretations, soils suitability, soils in crop and tree production, modeling soil suitability, GIS and modeling, Canadian Soil Information System (CanSIS), ecosystem management tools.

INTRODUCTION

Soil survey interpretations are predictions of soil behaviour for specified land uses and management practices. They are based on soil and site properties that directly influence the specified use of the land and are considered a best approximation. The simplest form of soil survey interpretation is a map or table that shows a single-factor soil condition (Olson 1981). Pettapiece (1995) pointed out that the Land Suitability Rating System (LSRS) for spring-seeded small grains included most of the attributes of an optimum approach to soil productivity rating as outlined by Huddleston (1984).

Soil survey maps depict or present core properties of soils and landscapes that are mapped in the soil survey; such as drainage, depth, texture, rockiness, etc. And because only one factor is considered, these maps are readily understood and can be very effective at showing the limitations to or conversely the opportunities for a given land use.

The CanSOIL-INTERPNB model was developed as a real-time soil suitability interpretation tool which addresses soil and land use interactions and implications. The model is used to interpret

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soil map units (soil polygons), located on soil survey maps, for the production of:

1) Six agricultural crops which include Alfalfa, Apples, Spring Cereals, Winter Cereals, Forages and Potatoes (additional crops can be easily added). The ratings for spring cereals are valid for barley, oats and spring wheat; while the rating for potatoes can also be applied to other similar vegetable crops.

2) Twelve tree species which include Balsam Fir, White Spruce, Black Spruce, Eastern White Cedar, Jack Pine, Red Pine, White Pine, Sugar Maple, White Ash, Yellow Birch and Trembling Aspen.

3) Nine engineering applications which include Access roads, Forest roads, Sub-surface drainage, Sewage lagoons, Septic tanks, Deep ripping, Athletic fields, Housing with basements and Housing without basements.

The CanSOIL-INTERPNB model is designed to be a universal, user friendly public domain package that may be accessed by professional and non-professional users for the evaluation of different parcels of ground located in the landscape.

CanSOIL-INTERPNB MODEL PLATFORM AND COMPONENTS

The model platform

The CanSOIL-INTERPNB model version 1.1 was originally built on a Microsoft Access 2000 platform using Visual Basic 6.0 programming and is presently being re-packaged in VB.Net to establish universality.

The components of the model

The model is comprised of two components:

1) The Soil Database: This contains the formatted polygon file (PAT), soil map unit /component file (SMUF/COMP), soil name file (SNF) and the soil layer file (SLF) According to Fahmy and Rees (2002) and Rees et al. (2005) the core properties of these attribute files consist of the following features: soil code; province; drainage; water table; rooting depth; texture; organic matter; pH; base saturation; water holding capacity; bulk density; sn-group; modifier; taxonomy to subgroup level; state of decomposition (organic soil); wood content (organic soil); slope; stoniness; climate; cation exchange capacity; saturated hydraulic conductivity; and electrical conductivity.

2) The Interpretation of Unique Soil Map Unit Polygons: The soil map unit interpretation is dependent on the information found in the soil database (component 1) and the species specific suitability look-up tables; such as the soil drainage look-up table represented in Table 1. At present these tables are built on existing soil criteria, and as science advances these criteria may need to be adjusted in order to accommodate these advances. The CanSOIL-INTERPNB model allows the user to access and modify these look-up tables to accommodate any changes or adjustments that need to be made. The user can upgrade or

downgrade (real time modification) the suitability class of the concerned soil property therefore adjusting the interpretation.

Table 1: Drainage look-up table.

Soil Drainage Class		Suitability Rating					
Code	Description	Alfalfa	Apples	Spring Cereal	Winter Cereal	Forages	Potatoes
NA	Not-Applicable	0	0	0	0	0	0
I	Imperfect	3	3	2	2	2	2
MW	Moderately Well	2	2	1	1	1	1
P	Poor	4	4	3	3	3	3
R	Rapid	2	2	2	1	2	2
VP	Very Poor	4	4	4	4	4	4
VR	Very Rapid	1	1	1	1	1	1
W	Well	1	1	1	1	1	1

Drainage: 1= Good, 2= Fair, 3= Poor, 4= Unsuitable

All look-up tables are based on different soil suitability tables similar in structure to the suitability table for Black spruce (Table 2) derived from Fahmy and Rees (2002), other tables for agriculture crops are found in Compendium of Soil Survey Interpretive Guides Used in the Atlantic Canada Provinces (Anonymous, 1988).

Table 2: Soil suitability table for black spruce.

Major Soil Properties Influencing Use	Suitability Class[1]			
	Good	Fair	Poor	Unsuitable
Drainage (w)	W, MW	I, P	R, VP	-
Inherent fertility (f)	high, medium	low	Very low	-
Average texture of friable soil (x)	l, sil, scl	sl, cl, sicl	ls	s, sic, c
Thickness (cm) of friable soil with BD<1.6 g/cm^3 (d)	>40	20-40	<20	-
Slope Class (t)	a, b, c, d	e	f, g, h	-
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Downgrade one class for coarse fragments >50%.

This interpretation component of the CanSOIL-INTERPNB model includes look-up tables for Aspect, Climate (ranges of growing degree days GDD, used only for forest tree species), Soil Depth, Soil Drainage, Soil Fertility, Fertility Class, Flooding, Rockiness, Slope, Stoniness and Soil Texture. Each of these tables depict a suitability class from 1 to 4 (1 = Good, 2 = Fair, 3 = Poor, 4 = Unsuitable) for each species of agricultural and forestry crops as well as engineering and environmental uses. Any of these look-up tables can be activated/deactivated pending the needs of the user.

New species or uses and their suitability can also be added by the user to the look-up tables as they become available for different geographic locations (e.g. Eastern Canada, western Canada, Europe, southern USA, etc.).

Soil database file format and structure

The following are format examples of the database files that are used in the CanSOIL-INTERPNB model:

1) The Polygon Attribute file, PAT database (Fig. 1) records the polygon number, map unit symbol, area and perimeter.

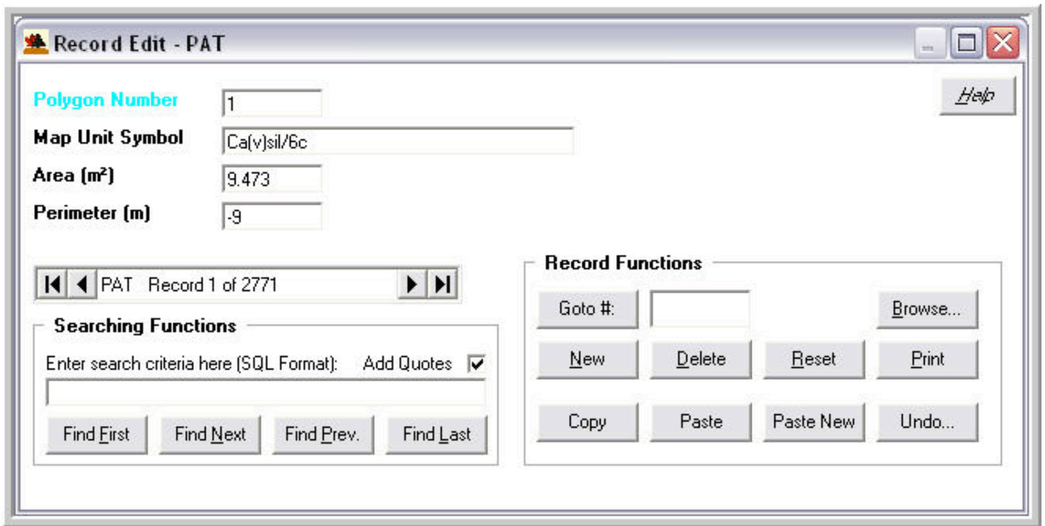

Fig. 1: Polygon Attribute File (PAT)

2) The Soil Map Unit/Component File, SMUF/COMP database (Fig. 2) separates the map unit symbol, found in the PAT, into soil codes and their corresponding extents.

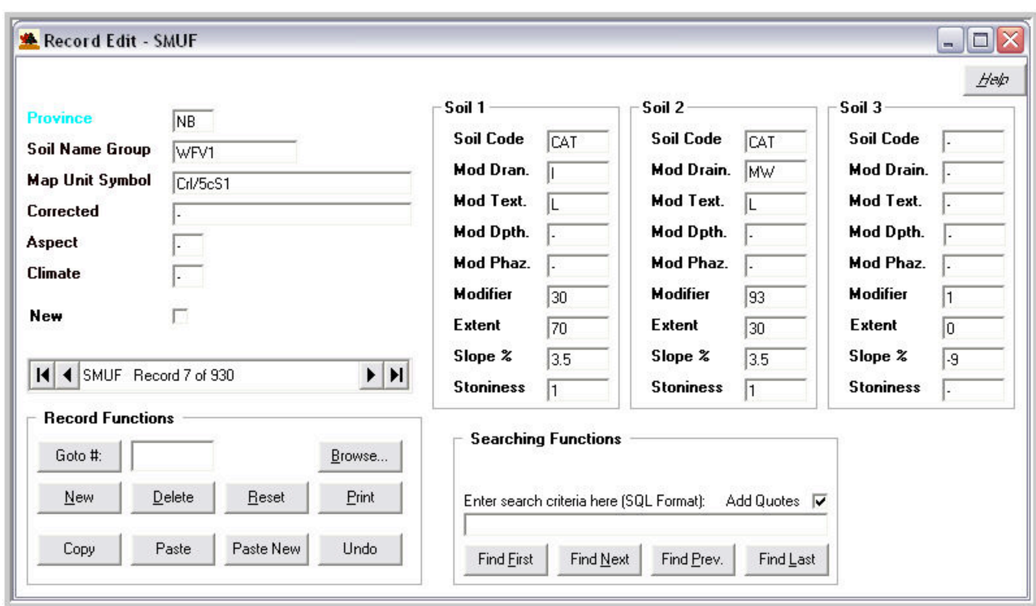

Fig. 2: Soil Map Unit/Component File (SMUF/COMP)

3) The Soil Name File, SNF database (Fig. 3) selects each of the soil codes from the SMUF/COMP and describes the properties of each of the soil codes.

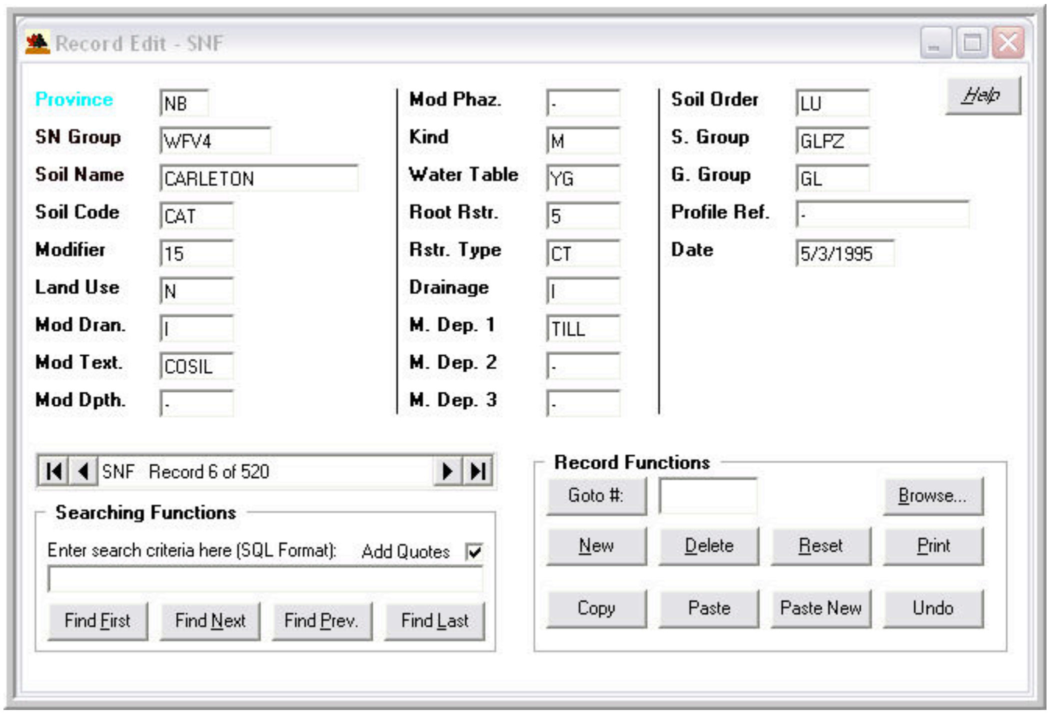

Fig. 3: Soil Name File (SNF).

4) The Soil Layer File, SLF database (Fig. 4) describes the morphology of each of the soil codes at the layer or soil horizon level.

Interpretation algorithm and creation of the Soil Map Unit Interpretation File (SMUI)

With the initial file database completed (PAT, SMUF/COMP, SNF, SLF) the CanSOIL-INTERPNB interpretation model performs the following algorithm:

- The model identifies the polygon symbol (map unit) from the unique listing, the soil code and a modifier, all found in the SMUF/COMP file. Then links these items to the SLF file and sets all ratings for that specific map unit to 0 (not rated).

- Then through a sequence of loops, starting with texture, depth, etc., it determines the suitability class of that specific polygon for the required species.

- From the SLF, it finds and assigns a Texture class based on the percent of sand, silt and clay for the friable solum layers that have a bulk density less than 1.65 g/cm^3, taking coarse fragment content into account.

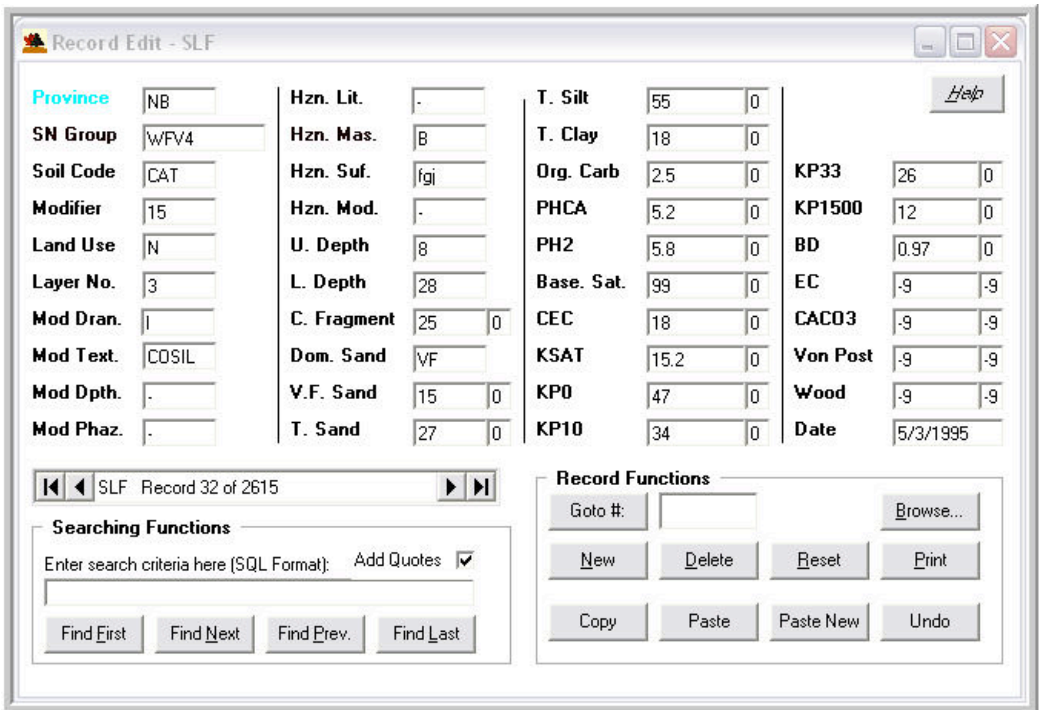

Fig. 4: Soil Layer File (SLF).

- It adjusts the rating and assigns a suitability class to the map unit through the look up process, using the texture class/suitability rating look up table for each of the species.
- It finds and assigns a Depth class of friable soil based on the criteria of soil bulk density (less than 1.65g/cm^3).
- It adjusts the rating and assigns a suitability class to the map unit using the depth class/suitability rating look up table for each species.
- If the rating class is greater than the existing rating (signifying a lower suitability, i.e. 1 = Good, 2 = Fair, 3 = Poor, and 4 = Unsuitable), then the rating class is changed or upgraded. If the rating class is less than the existing rating, it is ignored.
- It then finds and assigns the Rockiness from the SMUF and adjusts the rating accordingly. This sequence continues for the remaining properties such as Slope, Drainage, etc.
- Finally, it looks up the Fertility class for this specific soil code, adjusts ratings for this class and adds ratings to the soil map unit interpretation file (SMUI database).
- The soil map unit interpretation file (Fig. 5) includes all the soil map units transferred from the PAT file as well as the soil interpretations that have been calculated from the model. The interpretations consist of a suitability rating (G = Good, F = Fair, P = Poor, U = Unsuitable) and an extension symbol that justifies or explains the rating (f = fertility, w = drainage, d =

depth, x = texture, r = rockiness, etc.).

AGRSMUI - Browse

AGRSMUI Record 1 of 1 | Copy | Copy All | Paste New | Print | Help

AGRSMUI

Soil Map Unit Name	Alfalfa	Apples	S_Cereal	W_Cereal	Forages	Potatoes
(Ca+Cr)(s)l/4(b-d)R1	Pd	Pd	Fdrt	Pd	Fr	Fdrt
(Ca+Cr)(v)gl/3c	Fw	Fdw	G	G	G	G
(Ca+Cr)(v)l/2dS2R1	Fr	Fdr	Frt	Frt	Fr	Frt
(Ca+Cr)(v)l/2eS1R1	Frt	Fdrt	Pt	Pt	Frt	Ut
(Ca+Cr)(v)l/3(c-d)R1	Fwr	Fdwr	Frt	Frt	Fr	Frt
(Ca+Cr)(v)l/3(d-c)S2	Fw	Fdw	Ft	Ft	G	Ft
(Ca+Cr)(v)l/3cR1	Fwr	Fdwr	Fr	Fr	Fr	Fr
(Ca+Cr)(v)l/4(c-d)R1	Fwr	Fdwr	Frt	Frt	Fr	Frt
(Ca+Cr)(v)l/4(c-d)R2	Pr	Pr	Ur	Ur	Ur	Ur
(Ca+Cr)(v)l/4(d-c)	Fw	Fdw	Ft	Ft	G	Ft
(Ca+Cr)(v)l/4(d-c)R1	Fwr	Fdwr	Frt	Frt	Fr	Frt
(Ca+Cr)(v)l/5(d-c)R1	Pw	Pw	Fwrt	Fwrt	Fwr	Fwrt
(Ca+Cr)(v)sil/3(d-c)	Fw	Fdw	Ft	Ft	G	Ft
(Ca+Cr)(v)sil/3c	Fw	Fdw	G	G	G	G
(Ca+Cr)(v)sil/3cR1	Fwr	Fdwr	Fr	Fr	Fr	Fr
(Ca+Cr)(v)sil/6(d-c)	Pw	Pw	Fwt	Fwt	Fw	Fwt

Fig. 5: Soil Map Unit Interpretation File (SMUI).

Incorporation of CanSOIL-INTERPNB Model results into GIS-Based Mapping

The interpretation results (SMUI) from the model have the ability to be imported and incorporated into the original soil map. By using GIS-based software the results of the interpretation can be overlaid on the original soil map, therefore depicting the suitability of a given species for a given area. Figure 6 and Fig. 7 illustrate the soil interpretation results for Hartland New Brunswick. Figure 6 illustrates the soil interpretation for an agriculture crop (potato) and Fig. 7 illustrates the soil interpretation for a forestry crop (black spruce).

CanSOIL-INTERPNB MODIFICATIONS AND EXTENSIONS

Improvements are constantly being developed and can be incorporated into the CanSOIL-INTERPNB model. The model has the ability to incorporate major modifications; such as adding new criteria for quantitative interpretations. An example of a quantitative interpretation would produce a crop yield interpretation whereby the yield of potatoes (tons/ha) or yield for trees (m^3/ha) would be displayed. The model can also incorporate other land uses besides agriculture and forestry. The suitability of a land base can also be determined for engineering and environmental uses. This requires a modification to the software by an experienced computer programmer. Engineering suitability could be determined for uses such as access roads, housing, deep ripping and subsurface drainage. Environmental suitability could be determined for uses such as manure and food waste as well as sanitary landfills. In order to implement these new uses, suitability criteria must first be established and incorporated into the interpretation model.

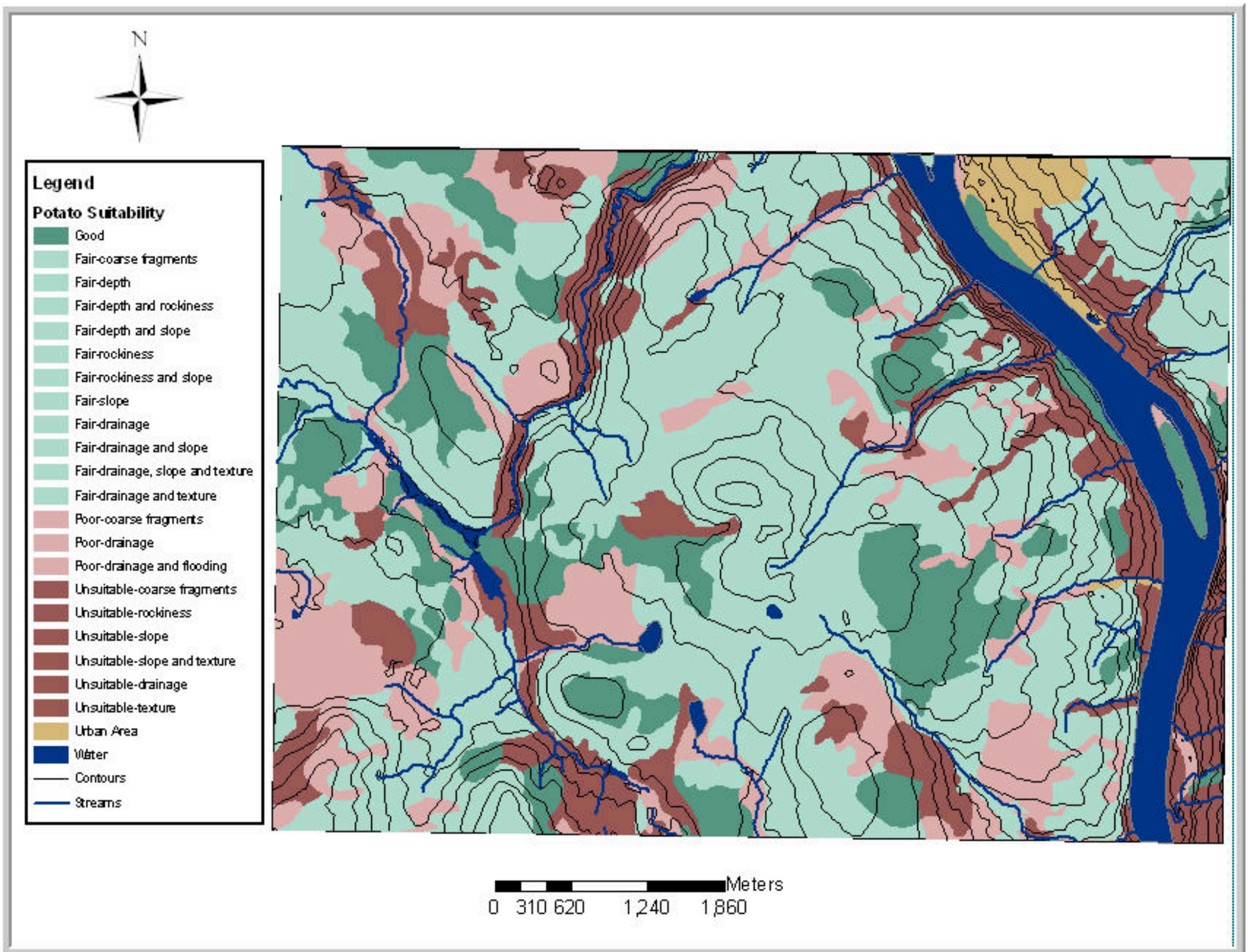

Fig. 6: Potato Suitability Map of Hartland, New Brunswick. Based on the Can-SOILINTERPNB Model.[1]

CONCLUSIONS

As a real-time interpretation tool the CanSOIL-INTERPNB model has the potential to be a valuable asset in the decision making process; not only for agriculture and forest managers but also in the establishment of research strategies that support sound ecosystem management at the local, regional, national and international scale.

[1] This figure is in colour in the electronic version of the Proceedings (CD)

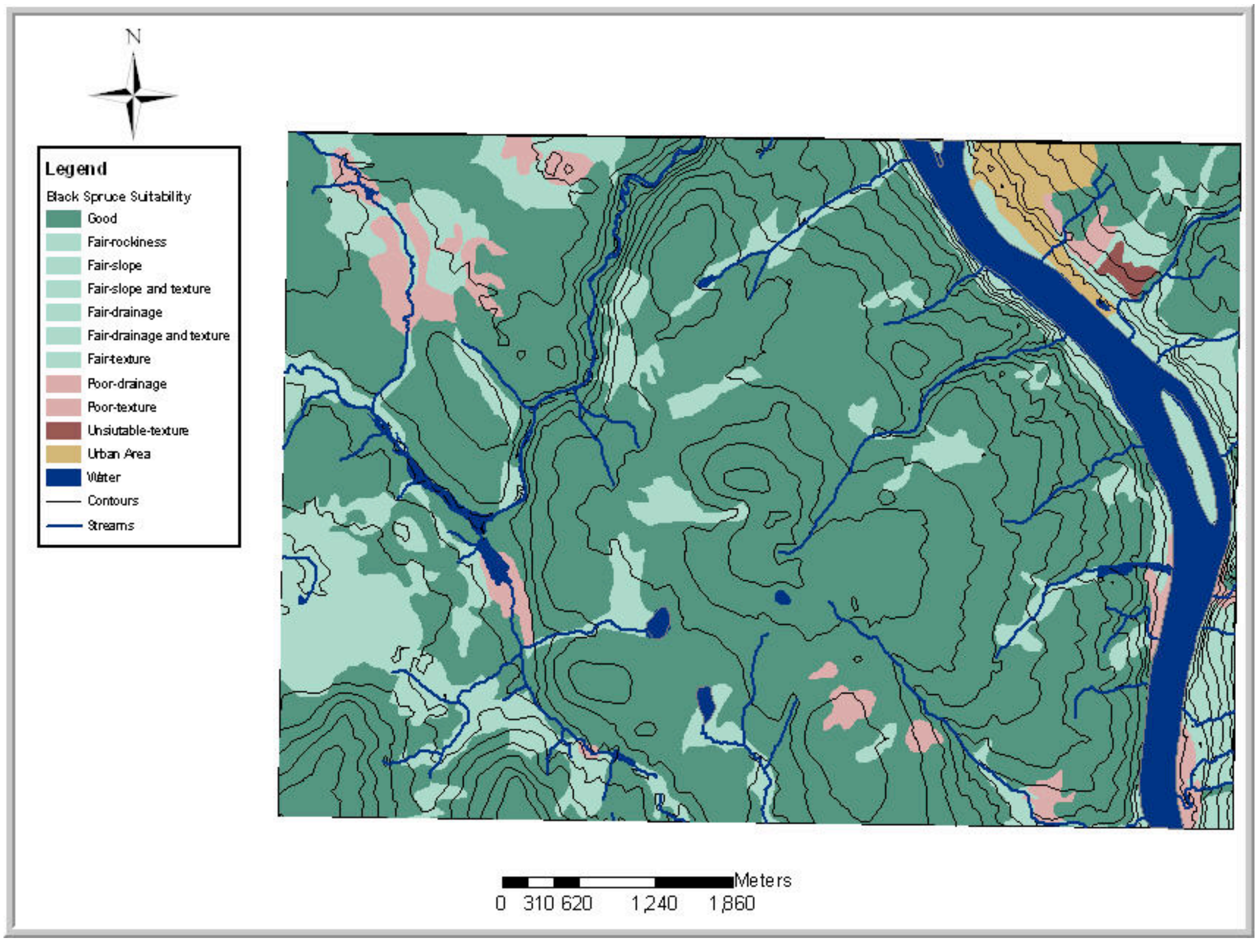

Fig. 7: Black Spruce Suitability Map of Hartland, New Brunswick. Based on the Can-SOILINTERPNB Model.[1]

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ONLINE MARKETING FOR ALTERNATIVE PRODUCTS

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Abstract: Agroforestry offers the promise of potential income from a diverse number of specialty or non-traditional timber products. However, the number of landowners who venture into niche or specialty markets is very small. The Missouri Virtual Exchange website was created to eliminate two critical barriers for landowners to enter alternative product markets. Barriers include a high risk/return ratio and a lack of knowledge about specialty products and markets. The purpose of the website is to provide a place where buyers and sellers can interact and goods and services can be transferred. Along with the virtual market aspects, the website will also be a source of valuable educational information regarding products and markets. The website is scheduled to launch in January of 2007. This paper will provide a preliminary analysis of the impact the website has in enhancing the development of alternative product markets, identify newly established quality guidelines and standards, and determine the effectiveness of online marketing as a strategy to build alternative markets.

Key Words: Online marketing, alternative products, markets.

L'AGROFORESTERIE : UNE PROPOSITION DE REVITALISATION POUR LA HAUTE-GASPÉSIE (QUÉBEC)

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Résumé : En 2003, 4000 ha de terres en friche ont été recensés en Haute-Gaspésie et en Estran, un des territoires les plus pauvres du Québec. Dès lors, le potentiel offert par ces terres a été mis de l'avant comme une opportunité majeure d'enrichissement de la collectivité. L'agroforesterie est un des moyens ciblés afin d'atteindre des objectifs de revitalisation du milieu tout en respectant les notions de développement durable.

En fait, le projet mobilise les gens du milieu autour d'intérêts communs. La tendance est le regroupement autour de cellules de travail particulières comme la culture sous érablière, la culture d'amélanchiers avec culture maraîchère intercalaire, etc.

L'exemple d'un groupe de promoteurs envisageant la culture d'amélanchiers permet d'observer tout le potentiel que possède un territoire en termes de ressources humaines, de patrimoine biologique, de disponibilités climatique et pédologique. Nous nous apercevons que plus nous approfondissons nos connaissances sur notre milieu écosystémique, plus le potentiel se dévoile. L'amélanchier, espèce végétale fruitière indigène, nous offrira son potentiel d'enrichissement de la collectivité si nous avons la capacité de le domestiquer en vue d'occuper un territoire; vitrine de notre culture et de notre savoir-faire. Sa mise en culture sera alors le reflet de notre compréhension du milieu.

L'agroforesterie permettra aux gens de la Haute-Gaspésie et de l'Estran de se donner des moyens d'occuper un territoire sans le dégrader ou l'épuiser de ses ressources, de vivre heureux et fiers de leurs réalisations, de léguer à leurs enfants une possibilité de perpétuer une nouvelle culture; celle de vivre de leur milieu et de prendre soin de leur paysage.

Mots-clés : Haute-Gaspésie, revitalisation, paysage, durable, Gaspésie.

VALUE CHAIN DEVELOPMENT OPTIONS FOR AGROFORESTRY

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Abstract: Western Canadian agriculture has witnessed many innovations that demonstrate the ability of growers to adapt to the unique growing requirements of different crops (i.e., wheat varieties, canola, lentils, etc.). This capability is an important core competence in the vision of agroforestry in the Prairie Provinces but, as the history of innovation has taught us, success is dependent on more than just growing new crops. It is necessary to develop the downstream industry capacity to process and deliver the crops to their end-use markets.

The wood products value chain can be segmented according to primary processing activities (pulping, stranding, sawmilling, and veneering). Each of these segments represents a potential buyer as well as a gateway to further value-added production. As such, this segmentation allows the downstream industry development targets to be identified. Each development pathway can be assessed according to:

- cost to develop – capital requirements, specialized infrastructure, etc.;
- economic impact on the local community – trees consumed, employment, taxes, etc.; and
- long term viability – product / market outlook, growth potential, etc.

This framework allows the agroforestry community of early adopters and industry builders to understand the challenges that lay ahead, and to set priorities for industry-wide growth. It allows industry builders to determine where outside investment is needed and where local capacity already exists. The segmentation exercise facilitates transition from the 'should we or shouldn't we' discussions toward the 'how will we' discussions related to agroforestry industry development.

Key Words: Industry development, segmentation.

INTRODUCTION / BACKGROUND

Western Canadian agriculture has witnessed many innovations that demonstrate the ability of growers to adapt to the unique growing requirements of different crops (i.e., wheat varieties, canola, lentils, etc.). This capability is an important core competence in the vision of agroforestry in the Prairie Provinces but, as the history of innovation has taught us, success is dependent on more than just growing new crops. It is necessary to develop the downstream industry capacity to process and deliver the crops to their end-use markets.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007.

INDUSTRY SEGMENTATION

In the classic movie 'field of dreams', the lead character was driven by a deep inward belief that if he built a ball diamond the players and spectators would show up. In the world of Hollywood, this made for a compelling story of conviction and perseverance that has been summed up by the saying 'if you build it, they will come'. Despite a similar need for conviction and perseverance, building an agroforestry industry requires more than a steadfast belief in the long term value of trees. In other words, believing that there will be a market for trees in the long term is a necessary but insufficient condition to ensure success.

So then, just what is needed to supplement the conviction and perseverance of agroforestry pioneers? Given the uncertainty of future, unknown markets, the agroforestry industry needs a strategy to manage this uncertainty and mitigate risk. The basis of that strategy is to manage the production of trees in such a way as to maximize the number of revenue opportunities as well as the value of the products / services. This approach stems from the diverse set of products that can be derived from each tree. Figure 1 illustrates the four types of timber products (commodity pulp or oriented strand board, or OSB logs, saw logs, veneer logs and biomass) that can be extracted from every tree.

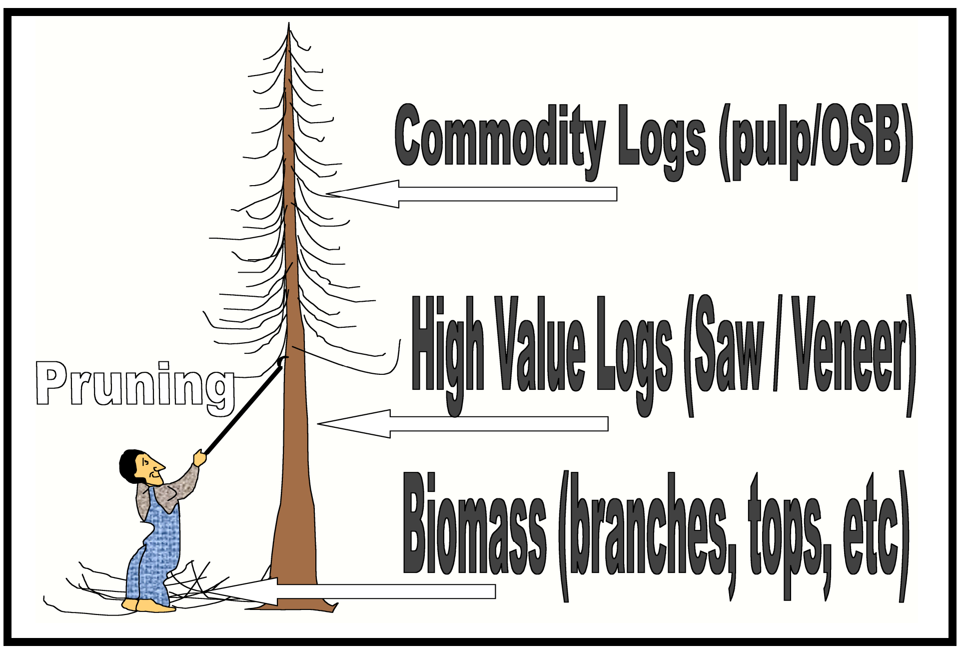

Fig. 1: Multiple timber product categories.

While these timber products reflect the largest and most established potential consumers of an agroforestry industry, they are not the only options. A vision of a highly diverse agroforestry industry must also recognize the potential to generate revenue from annual by-products (fruits, nuts and intercropped agricultural products like corn, watermelon, etc.) as well as the provision of ecological services (tourism, recreation, carbon sequestration, etc.). Figure 2 illustrates this first order of potential agroforestry revenues. It is important to note that annual by-products and ecological services represent revenue streams linked to the standing value of the trees. As such they are complementary to the production of the core agroforestry product: timber.

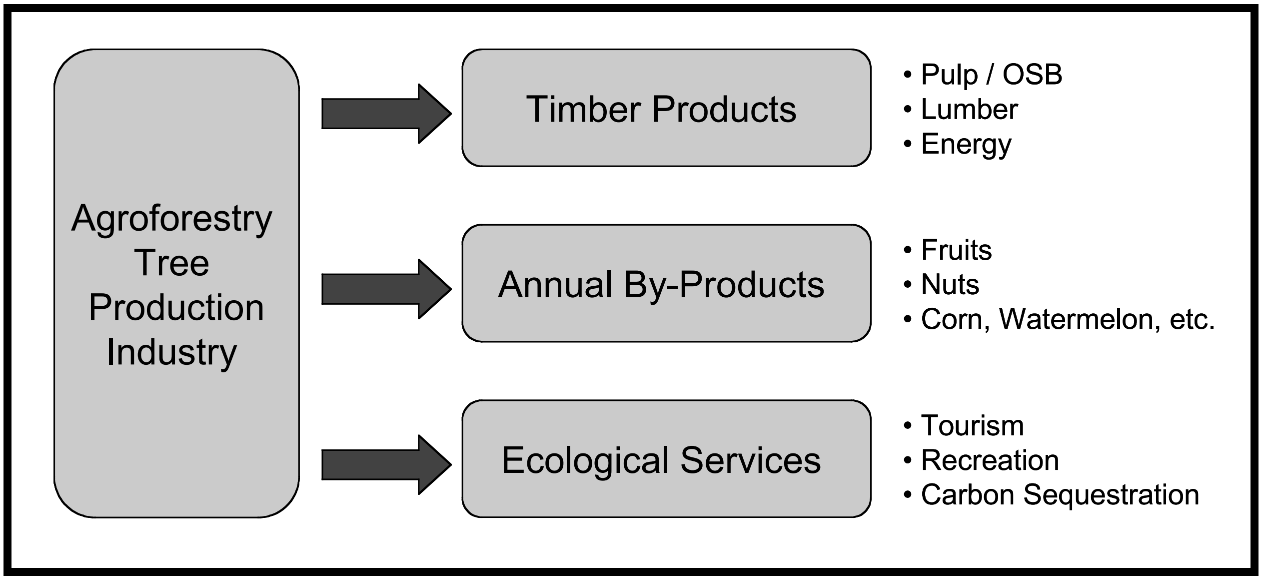

Fig. 2: Agroforestry revenue options.

The multi-use strategy is a slight departure from the way agroforestry or afforestation operations have been managed to date. Most operations have been tied to a pulp processing facility. As such these operations link the value of the trees, in a very narrow way, to the pulp market. This approach means that when each tree is put in the ground its owner is betting on the future, unknown demand for pulp timber. In an effort to hedge their bets, existing operations are increasingly looking to alternate products for additional revenue streams. For example, Potlach Corporation responded to a decline in pulp chip prices in the late 1990s by beginning to manage their plantations to produce saw logs (Eaton 2007).

From a production stand point, the implications of a multi-use strategy are relatively straightforward. Producers must adjust management practices (tree spacing, pruning, etc.) to maximize the yield of high value timber (saw logs and veneer logs) while minimizing the volume of commodity timber (pulp logs and OSB logs) and salvaging the biomass (branches, tree tops, etc.). However, from a broader industry development perspective, the multi-use strategy draws attention to the need for local processing capacity. Without multiple processing facilities within an acceptable transportation range (one to two hours), an agroforestry producer will not find consumers for its timber products, regardless of the demand for products derived from that timber.

This means that agroforestry industry development is about more than producing a man-made forest that is viewed as a valuable renewable asset. It must also include building the infrastructure, relationships and overall capacity to capture the value of the trees. While this represents a much larger challenge than just planting trees, it also represents an enormous opportunity to spur local economic development.

Table 1 presents a segmented view of the economic development opportunities consistent with the multi-use strategy. Processing capacity will be needed for commodity logs, higher value logs, biomass as well as semi-finished and finished goods. This processing capacity represents potential agroforestry consumers as well as gateways to further value-added production. The exact configuration of local agroforestry processing industries will vary from region to region. However, all value chains will reflect the dynamics of local supply and global demand. In order to guide economic development decisions, the various development opportunities have been assessed according to their cost to develop (capital investment), economic impact (mill employment) and long term viability (product life cycle assessment).

Commodity market opportunities include pulp mills, OSB mills and oriented strand lumber mills. Commodity logs will represent the vast majority of agroforestry yields making these facilities a necessity for the industries viability. However, each of these opportunities requires large investments that usually require non-local investment from multinational corporations. This is the reason existing afforestation operations are tied directly to pulp facilities. The size of the investment means agroforestry producers will likely need to cooperate with forestry timber owners to promote their assets in an effort to attract industry investment. Investments in commodity processing capacity have some of the largest employment impacts on the local economy and have proven to be an adequate basis for afforestation industries across North America. As for long term viability, the pulp industry is in a mature or declining state in North America making it the least desirable alternative. The oriented strand board industry has enjoyed significant growth for years but at over 60% market share in North America it is nearing maturity.[5] That leaves oriented strand lumber as the investment opportunity with the greatest long term potential for growth in demand.

Higher value market opportunities include softwood lumber mills, hardwood lumber mills and laminated veneer lumber mills. While this is not a comprehensive list it does reflect the diversity of investment options. The development of higher value processing capacity should be viewed as a complement to commodity processing capacity. This is because the facilities that target higher value timber are not able to feasibly process the lower value timber. As such, their successful existence is dependent on the existence of complementary commodity processing capacity.

The cost of the investments corresponds to the size of the facility and thus its employment impact. The large investment required for a laminated veneer lumber facility would support 110 employees in an industry expected to see global growth in demand. In contrast, the more traditional hardwood and softwood sawmill facilities represent investments that may not require non-local investors and can be supported by a smaller resource base. However, these are mature industries which are highly competitive.

[5] Schuler and Adair (2003) note that many products 'max out' at 70% or 80% market share, which OSB has attained in its primary market – single family housing construction.

Table 1: Processing capacity development options.

Processing Facility		Cost to Develop[1]	Economic Impact[1]	Long Term Viability[2]
Type of Facility	**Annual Capacity**			
Commodity Log Markets				
Large Hardwood Pulp mill	1 million ADMT / yr	+$1 billion	300 employees	Mature / Decline
Oriented Strand Board mill	600 million ft^2 / yr	+$200 million	130 employees	Mature
Oriented Strand Lumber mill	450 million ft^2 / yr	$260 million	190 employees	Intro / Growth
Higher Value Log Markets				
Small Softwood Lumber mill	100 million fbm / yr	$15 million	50 employees	Mature
Hardwood Lumber mill	10 million fbm / yr	$3.5 million	30 employees	Mature
Laminated Veneer Lumber mill	2.5 million ft^3 / yr	$75-$90 million	110 employees	Growth
Semi-finished & Finished Good Markets				
I-joist facility	11 million feet / yr	$1.1 million	11 employees	Growth
Panelized Wall (SIP) facility	92 000 units / yr	$1.5 million	6 employees	Intro
Finger Jointed lumber mill	55 million fbm / yr	$7 million	110 employees	Growth
Biomass Markets				
Small Cogeneration of Heat & Power	0.1MW to 2 MW	$2 - $9 million	n. a.	Growth
Wood Pellet Facility	60,000 tonne / yr	$6 million	+10 employees	Growth
Ethanol production from Syngas	75 million litres / yr	$70 million	70 employees	Intro / Growth

[1] Estimates taken from Mak (2006)

[2] Categories are based on the product life cycle model which includes: introductory, growth, mature and declining products.

ADMT = air dried metric tonne; fbm = board foot measures; MW = mega watts

Investments in traditional processing industries like sawmilling may form the basis for the production of semi-finished or finished goods. As an extension of the agroforestry industry, this sort of downstream processing capacity represents a way for the local economy to capture additional value from the resource base. The downstream processing capacity also represents an integration opportunity for the mature lumber industry. Value chain integration is increasingly important to the viability of wood products companies. The downstream investment opportunities include I-joist facilities, panelized wall facilities and finger-jointed lumber mills. All of these industries have positive long term growth expectations with a relatively low capital cost.

Finally, establishing markets for biomass can significantly improve the profitability of an agroforestry operation. Since biomass has traditionally been a valueless waste product, any revenue that it generates is theoretically a bonus to the bottom line. Biomass development opportunities include the cogeneration of heat and power, wood pellet production and ethanol production. The wood pellet opportunity has thus far shown the most consistent growth capabilities. However, ethanol demand is also forecast to grow significantly. The cogeneration of heat and power remains a niche within the energy sector. However, there is significant opportunity to grow that niche by providing a greater volume of local energy from locally available biomass.

Collectively the opportunities identified in Table 1 are only a sample of the types of investments that might be made in processing capacity. What is of particular importance is the segmentation of investment opportunities according to the type of timber product.

SUMMARY

To summarize, the future of the agroforestry industry depends on more than the innovative nature of producers and their steadfast faith in the long term demand for products derived from wood. A successful agroforestry industry will be intimately tied to a local timber processing industry that delivers products in demand around the world. This agroforestry industry will need to develop in concert with the processing capacity. To this end, a framework was developed to facilitate the segmentation and assessment of development options.

This framework allows the agroforestry community of early adopters and industry builders to understand the challenges that lay ahead, and to set priorities for industry-wide growth. It allows industry builders to determine where outside investment is needed and where local capacity already exists. The segmentation exercise essentially facilitates a transition from 'should we or shouldn't we' discussions toward the 'how will we' discussions needed spur large-scale agroforestry industry development.

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INTÉGRATION DE L'AGROFORESTERIE : L'EXEMPLE D'UNE DÉMARCHE RÉGIONALE

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Résumé : Les possibilités de diversification des revenus associés à l'exploitation d'une érablière par la culture de plantes de sous-bois telles que le ginseng à cinq folioles (*Panax quinquefolius*) sont bien connues depuis une quinzaine d'années. Ce n'est pourtant que récemment qu'un intérêt pour ces pratiques s'est développé en Gaspésie. La mise en place de parcelles expérimentales en 2003 en collaboration avec des propriétaires de lots boisés est à la base de cet engouement. Le regroupement de l'information technique et l'application terrain ont été rendus possibles grâce au Programme de mise en valeur du milieu forestier (Volet II) du Ministère des ressources naturelles et de la faune et à un réseautage régional et extrarégional. Cette phase initiale visait principalement à valider le potentiel de mise en culture de diverses plantes tout en analysant l'aspect technico-économique.

En plus de contribuer à l'acquisition de connaissances pour le bien de l'ensemble, il est intéressant de constater que cette approche assure le développement d'une expertise locale. Grâce au maintien d'une volonté de diversification des activités de la part des acteurs gaspésiens, on assiste actuellement à une phase d'expansion de ces approches alternatives. L'intégration dans les communautés régionales se réalise par l'organisation d'activités de transfert d'information et par la mise en place d'outils techniques. Ces éléments favorisent l'augmentation du nombre de personnes-ressource ainsi que le réseautage : deux éléments clés pour la mise en place de la filière. Couplé à la mise en place d'outil de suivi, ceci motive et appuie les communautés et intervenants dans une démarche de diversification durable de l'économie par l'intégration d'éléments compatibles aux activités actuelles.

Mots-clés : Culture, érablières, *Panax quinquefolius*, Gaspésie, sous couvert.

AGROFORESTRY EDUCATION IN ACTION

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Abstract: The Forest TEAM (Tropical Forest Ecosystem and Agroforestry Management) Program at the Hawaii Community College started in 2002 and offers students an opportunity to earn an Associates Degree (A.S.) in two years or a Certificate of Achievement (C.A.) in a year. Our program is unique in that it is succeeding in introducing traditionally under-represented students to the field of agroforestry and ecosystem management and preparing them for further study or work in the field. Students learn in a hands-on interactive environment where lectures are combined with field work and visits to local projects. We combine the teaching of basic field methods with that of high-demand skills such as GPS and GIS mapping. The skills and knowledge that students gain from this program have broad geographic application and prepare them for work in either the tropics or temperate zone. We are in the process of articulating the program with forestry programs in both tropical (the University of Hawaii) and temperate (Oregon State University) areas so that those who wish can continue their education in this field. Twenty students have graduated from the program since its inception and all are either employed in the natural resources field or are continuing their education at a 4-year institution. We believe that the model on which we have developed this program is a successful example of making agroforestry and ecosystem management accessible to a wide range of students and that our teaching methods could be used across a broad range of zones and climate.

Key Words: Education, agroforestry, ecosystem management.

ONLINE TOOL FOR ESTIMATING CARBON STORAGE IN AGROFORESTRY PRACTICES

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Abstract: The CarbOn Management Evaluation Tool for Voluntary Reporting (COMET-VR) is an online tool developed by the USDA Natural Resources Conservation Service and Colorado State University to estimate carbon sequestration in farm and rangeland soils under user-specified management scenarios. Development is underway to expand the capabilities of COMET-VR so users will be able to estimate changes over time in carbon storage (CS) in above- and below-ground components of agroforestry practices. Individual tree biomass is calculated using diameter-based allometric equations generalized for species groups. The Century soil carbon model, linked to COMET-VR, is used to estimate CS in soil for agroforestry plantings established within the last 20 years. Estimates of biomass growth and therefore reportable CS flux over the next 10 years are based on inventory data from both windbreak and forest plots in different regions of the US. The tool output will be an estimate of the annual change in CS suitable for use in the US Dept. of Energy voluntary greenhouse gas reporting program. It will also allow users to compare potential CS in agroforestry and other agricultural practices.

Key Words: Carbon sequestration, biomass, allometric equations, soil carbon, greenhouse gas reporting.

Mots-clés : Agroforesterie, flux de carbone, biomasse, modèle allométrique, carbone du sol, comptabilité de carbone.

INTRODUCTION

Agroforestry practices contribute to the storage of carbon in temperate-zone agricultural landscapes while maintaining food and forage production (Brandle et al. 1992; Montagnini and Nair 2004; Oelbermann et al. 2004). Planting woody vegetation on farm and rangelands not previously forested, i.e. afforestation, can significantly increase carbon storage (CS) in soils, vegetation and other components therein.

Practical methods have recently been developed to estimate CS on cropland, pasture and forests. Examples of carbon accounting methods for forest stands include the use of look-up tables generalized by forest type and region (Smith et al. 2006), computerized models of tree biomass growth that reflect stand conditions and silvicultural practices (e.g., the carbon submodel of Forest Vegetation Simulator, http://www.fs.fed.us/fmsc/fvs/index.shtml), and periodic direct measurement of the structural components of forests in which carbon is stored (Brown et al. 2004).

For farm and range lands, the online Carbon Management Evaluation Tool for Voluntary Reporting (COMET-VR) enables landowners to rapidly estimate potential CS in agricultural soils under various land management practices in the conterminous U.S. It uses the Century Soil Organic Matter model, a generalized biogeochemical ecosystem model that simulates changes in soil carbon, nitrogen and other elements (Parton et al. 1993). COMET-VR is designed to comply with the requirements for voluntary reporting of carbon emissions under the US Dept. of Energy's 1605(b) program (http://www.eia.doe.gov/oiaf/1605/frntvrgg.html). It is publicly available at www.cometvr.colostate.edu.

Since agroforestry by definition includes elements of both agricultural and forest landscapes, an appropriate carbon accounting system will include methods from both land uses. This paper describes the development of methods for estimating changes in CS in agroforestry practices that will be incorporated into COMET-VR, along with an example of its use to compare carbon values under different agricultural practices.

MATERIALS AND METHODS

Work to incorporate agroforestry practices into COMET-VR began at the USDA Natural Resources Conservation Service's (NRCS) West National Technology Support Center (WNTSC) in 2006. The agroforestry extension will enable users to estimate CS in the five most common temperate-zone practices, i.e., Windbreaks, Alley Cropping, Silvopasture, Riparian Forest Buffers, Multi-Story Cropping (also known as Forest Farming), as well as an additional category, Farm Forests and Woodlands. In keeping with the design criteria for COMET-VR, the agroforestry extension is designed for relative ease of use, national-scale (conterminous US) applicability, and reasonable estimation across a wide range of site factors.

Carbon can exist within various pools in agroforestry systems depending on their structure and management, including live trees, standing and down dead trees, understory shrubs, annual crops, leaf litter, and soil. However, most of the change in CS occurs as result of growth, and thus biomass accumulation, of live trees. Other pools such as down deadwood, understory and litter change relatively slowly (Smith et al. 2006). Technical guidelines for forestry reporting of greenhouse gases recommend measuring and monitoring of carbon in the live trees (above and below-ground) and soil pools of agroforestry projects (US DOE 2006a).

Although soil is an important reservoir of organic carbon, short-term change is significant only following afforestation of previously cultivated land (Post and Kwon 2000; Guo and Gifford 2002). Due to the 10-year reporting period for the US DOE 1605(b) program, changes in soil carbon are only estimated by COMET-VR for agroforestry plantings less than 20 years old. Otherwise, live trees are the only carbon pool in agroforestry systems for which fluxes are estimated by COMET-VR.

To calculate biomass and thus carbon content at the baseline (current) age, COMET-VR will use a series of diameter-based allometric equations developed by the US Forest Service (Jenkins et al. 2003). They predict total (above- and below-ground) dry weight biomass of individual trees from diameter at breast height (dbh) for all US tree species divided into ten different groups by genera (Table 1). The meta-analysis performed by the authors produced a set of equations designed to be used at the national scale over all sites, slopes, aspects, elevations, etc.

Table 1: Tree genera groups for biomass equations (adapted from Jenkins et al. 2003)

	Genera Group	**Representative Genera**
Hardwood	Aspen/alder/cottonwood/willow	*Alnus*, *Populus*, *Salix*
	Soft maple/birch	*Acer*, *Betula*
	Mixed hardwood	various
	Hard maple/oak/hickory/beech	*Acer*, *Carya*, *Fagus*, *Quercus*
Softwood	Cedar/larch	*Calocedrus*, *Larix*, *Sequoia*
	Douglar-fir	*Pseudotsuga*
	True fir/hemlock	*Abies*, *Tsuga*
	Pine	*Pinus*
	Spruce	*Picea*
Woodland	Juniper/oak/mesquite	various

Before one can begin using the COMET-VR tool, they must first perform an inventory of the standing live trees within the parcel of land for which they wish to estimate CS. Basic inventory information required will include the tree genera present, average dbh of the sampled trees in each genera group, and the estimated number or percentage of trees of that group on the parcel. For landowners who do not already have inventory data available, two different sampling methods are suggested. For linear plantings such as windbreaks and alley cropping, strip sampling within row segments is recommended, and for other agroforestry types, the zig-zag transect method is suggested (NRCS 2004). Guidelines and documentation for sampling methods will be provided in the COMET-VR online help file.

Once the COMET-VR tool is accessed online, the user will first be asked to enter some general information about the parcel they're reporting, including state, county, parcel size, and the average age of the agroforestry planting. From inputs of state and county, the parcel's location at two regional scales will be identified: Major Land Resource Area (MLRA) and the larger-scale Land Resource Region (LRR) (NRCS 2006a).

If the agroforestry planting is either new or less than 20 years old, the user will then be asked a series of questions leading to a description of conditions and a history of land management:

1. The predominant soil texture of the parcel, and whether or not the soil is hydric.
2. The land management applied during four time periods (pre-1970's, 1970 to mid-1990's, mid-1990's to current year, and next 10 years) from choices of irrigated and dryland crop rotations that are common in the MLRA of the parcel being assessed.
3. For the time periods from 1970 and later, the intensity of tillage utilized, e.g. intensive, reduced or no-till.

All these inputs are then transmitted by COMET-VR to the Century model which estimates the annual change in soil carbon over the next 10 years. This soil carbon calculation will be skipped for plantings established more than 20 years before present.

The next step will be to calculate the biomass of live trees on the parcel at the present (baseline) year. The user is asked to supply the information collected from their inventory sample (see above), along with the average age of trees in each genera group. Landowners in the Northwest growing Douglas-fir and those in the Southeast growing pine species may also specify the site productivity of their parcel, if known. Based on user input, COMET-VR then calculates total individual tree biomass for each genera group using the appropriate allometric equation coefficients.

Once the baseline biomass of an average tree in each genera group is estimated, the next step will be to predict how much that tree will likely grow over the next 10 years in the geographic region where the parcel is located. Recent data collected from permanent inventory plots both in forest stands (US Forest Service, Forest Inventory and Analysis, http://fia.fs.fed.us) and windbreaks (NRCS Ecological Site Inventory, http://esis.sc.egov.usda.gov/Welcome/ pgFSWelcome.aspx) in each state for which data are available were accessed online. Because FIA inventory data are collected over a range of stand conditions from dense, closed-canopy forest to sparsely-stocked stands, it was necessary to filter the data to select only those from relatively young, open stands which would more closely match the conditions found in agroforestry practices. Data were selected for the following criteria: All-live stocking class less than 59%; tree crown class co-dominant, dominant or open-grown; and age (corrected to "breast height" age) less than 126 years. For NRCS windbreak plots, it was not necessary to filter the ESI data.

Using the filtered FIA and unfiltered ESI datasets, coefficients were calculated for nonlinear regressions of age versus dbh for each genera group in each state, LRR and productivity class. Where data for genera groups were insufficient at the state level, data were combined by LRR and those regional values were used instead. In the few cases where both FIA and ESI data were available for the same genera group and location, the source that produced the higher r^2 was used. The difference between baseline and future (10 year) individual tree biomass, predicted by the appropriate growth equation, will then be used as the growth increment for trees in that genera group.

The final calculation step will be to expand the estimated 10-year biomass growth of an individual tree by the number or percentage of trees in that genera group over the whole parcel. Predicted growth values for all genera groups present are summed to give a total biomass flux for the parcel. This value is converted to carbon assuming a factor of 50% of dry-weight biomass. For new plantings (< 20 years) only, the annual soil carbon flux predicted by Century is added to the total. The final result reported to the user is the annual change in carbon mass (and CO_2 equivalent) for the parcel. If soil CS was estimated by Century, an uncertainty value will also be reported for that pool. However, due to the scarcity of long-term, well-documented agroforestry experiments, uncertainty values will not be estimated for carbon flux in live tree biomass.

RESULTS AND DISCUSSION

The alpha-version of the COMET-VR agroforestry extension and version 1.1 of the COMET-VR tool for agriculture were used to compare predicted CS values for a hypothetical parcel of cropland versus the same parcel with a field windbreak.

The example is a 50 ha parcel of non-irrigated cropland (non-hydric silty clay loam soil) in Lancaster County, Nebraska cropped with a corn (maize)-soybean rotation using conservation tillage. Based on past and current use of conservation tillage practices on the example parcel, COMET-VR estimated the annual CS increment for the next 10 year period under reduced tillage at 3.9 t C yr^{-1} and under no-till at 5.2 t C yr^{-1} (Fig. 1).

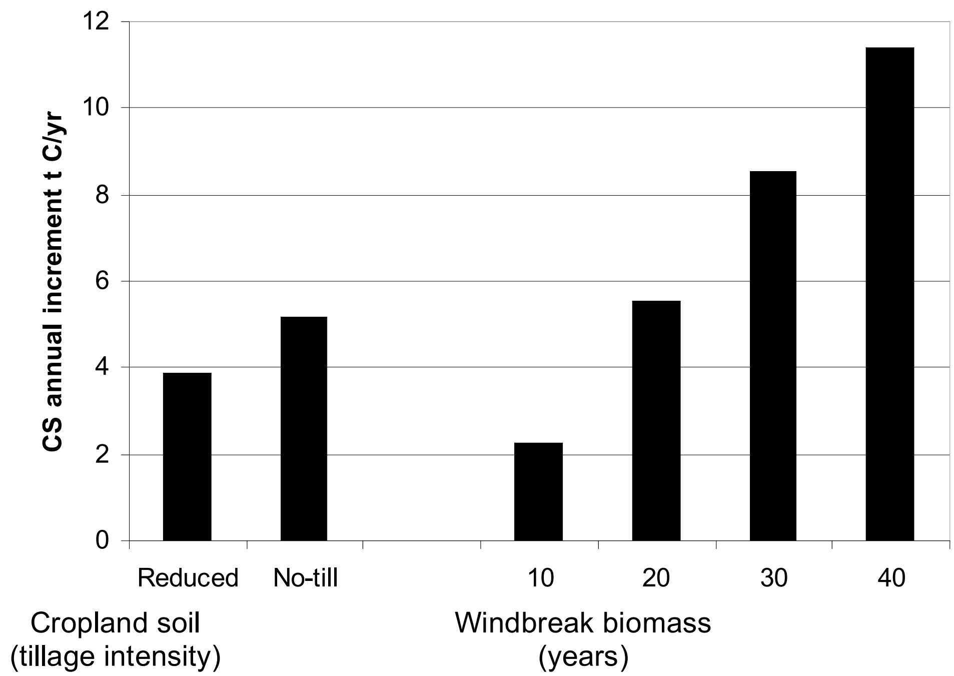

Fig.1. Annual increment in CS for the example 50 ha parcel for windbreak biomass over time and for cropland soil for ten years under a corn-soybean rotation with conservation tillage.

To compare estimated CS with an agroforestry practice, a four-row field windbreak planted along two sides of the same cropland parcel was modeled. The windbreak consisted of two rows each of pine and mixed hardwood trees. Trees occupied 1.7 ha, approximately three percent of the total land area.

Using the agroforestry extension of COMET-VR, CS of the windbreak trees was estimated over time (Fig. 1). From 10 to 40 years, the periodic annual increment in CS for the windbreak increased from 2.3 to 11.4 t C yr^{-1}. The steady increase in CS from the windbreak mirrors the growth of the trees predicted using the methods described above and assumes that site factors are not limiting. At some older age, the annual increment would reach a plateau according to the biological growth potential of the trees. In contrast, annual CS from cropland soil under conservation tillage will remain at a steady, but lower rate for the next 10 year period and will likely decline thereafer. For the whole parcel, annual CS accrual rate for the cropland soil with conservation tillage exceeds that for the windbreak biomass until about 15 years after the trees were planted. However, it appears that more C will be stored in the parcel over the long term by adding a windbreak compared to only using conservation tillage on the cropland.

COMET-VR's estimate of biomass growth, and thus carbon flux, is based on the use of allometric equations, i.e. from Jenkins et al. 2003, that were originally derived from data collected in forest stands where stocking levels are likely higher than would be found in agroforestry practices. Therefore, it is possible that the use of forest-derived biomass equations may underestimate biomass in more open-grown agroforests. Recent studies involving destructive sampling of trees growing in windbreaks in the U.S. Great Plains suggest that forest-derived equations may underestimate biomass of individual trees by at least 22% (Zhou, X., Brandle, J.R., Schoeneberger, M.M., Awada, T. and Mize, C.W. unpublished data). Since similar studies have not been performed on other genera in other locations, it is not possible at present to correct the values calculated by COMET-VR using the forest-derived biomass equations. However, filtering the forest inventory data to mimic the more open-grown conditions found in agroforestry, as described above, will help reduce this potential over-estimation.

CONCLUSIONS

COMET-VR is a first attempt to develop a user-friendly carbon accounting system for agroforestry practices in the contiguous US. The intended audience includes private landowners, farmers, ranchers, non-industrial private forest owners, NRCS field staff, and technical service providers. Public release of agroforestry extension of COMET-VR is expected in the later half of 2007. It will be available at same URL (see above).

Because it is based on allometric equations and growth estimates derived from regional datasets, the estimates produced by COMET-VR are generalized estimates for a site-specific location. More accurate accounting of biomass growth, and thus carbon flux, would require more site-based information, e.g. site index or localized growth curve formulae. This would be possible only for those genera groups and locations where large inventory plot datasets are available.

Woody shrubs or multi-stemmed trees are often used in agroforestry practices, e.g. windbreaks, and they contribute some amount of CS, although less than larger trees. Two relatively simple methods have been developed to estimate biomass of shrubs in windbreaks, based either on "shelterbelt volume" of the shrub row (Kort and Turnock 1999) or on diameter measurements of the three largest stems in the shrub crown (Zhou et al. 2007). Although insufficient data are available at present to derive equation coefficients for either method for all shrub genera in all potential locations, it is possible that a future release of COMET-VR could include a procedure for estimating biomass, and thus CS, of shrubs in agroforestry plantings.

Another potential future improvement for COMET-VR would involve further parameterization of the Century model to better predict soil carbon dynamics under agroforestry systems. Some field studies have been conducted to quantify changes in soil carbon in temperate-zone agroforestry practices, including alley cropping (Peichl et al. 2006; Oelbermann and Voroney 2007), riparian buffers (Tufekcioglu et al. 2003), silvopasture (Sharrow and Ismail 2004) and windbreaks (Kort and Turnock 1999; Sauer et al. 2005). Results of these and future studies in other locations would help parameterize the Century model for agroforestry.

We expect the agroforestry extension of COMET-VR to be used for a variety of purposes. It will be used under the DOE 1605(b) program for voluntary reporting. Landowners can already receive a subsidy for testing COMET-VR under the Conservation Security Program (NRCS

2006b). It is possible that other conservation provisions of the forthcoming Farm Bill in the US will encourage farmers to adopt practices such as agroforestry that increase CS and to monitor carbon fluxes with COMET-VR.

If it is accredited for such use, COMET-VR could also be used to monitor and report CS in agroforestry practices which are established as carbon offset projects under contracts with state programs (e.g., Regional Greenhouse Gas Initiative, http://www.rggi.org) or private companies (e.g., Chicago Climate Exchange [CCX], http://www.chicagoclimatex.com). For example, some private organizations, acting as aggregators of forestry carbon offset projects for CCX, are currently offering contracts for new riparian buffers and other widely-spaced (<625 stems ha) tree plantings (e.g. Iowa Farm Bureau, http://www.iowafarmbureau.com/carbon). The availability of an accredited, user-friendly tool for CS estimation will help landowners wishing to enroll their agroforestry plantings as carbon offset projects.

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L'AGROFORESTERIE : UNE AVENUE POUR CONCILIER PRESERVATION DU PAYSAGE ET PRODUCTION AGRICOLE

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Résumé : Depuis les années 1970, l'intensification et la spécialisation de l'agriculture québécoise ont entraîné une simplification de l'écosystème agricole, de grandes superficies de monocultures ayant succédées aux systèmes diversifiés qui prévalaient jusqu'alors. La disparition de ces paysages, composés de boisés, de pâturages, de prairies et de cultures annuelles, mais aussi d'éléments bâtis variés, a transformé profondément le territoire, entraîné des impacts sur l'environnement et, plus encore, altéré la relation entre la société en général et l'agriculture.

Face à cette situation, on peut se poser la question, à savoir si l'espace façonné par l'agriculture intensive n'est pas en décalage avec la perception et les besoins de la population en matière de paysages ruraux et quant aux usages non agricoles qu'ils peuvent supporter. La présente affiche pose l'hypothèse qu'une part de la solution à ce problème repose sur une réappropriation du paysage par l'agriculture par l'entremise d'aménagements agroforestiers multifonctionnels. En effet, parmi les éléments du paysage sur lequel il est possible de jouer, l'arbre et l'arbuste demeurent les plus accessibles et les plus polyvalents quant à leur rôle. Sur cette base, le repositionnement de l'agriculture comme activité aux multiples facettes, au-delà de la seule fonction productive, pourrait ainsi contribuer à résoudre les enjeux reliés à la dégradation du paysage. Dans cette perspective, l'agroforesterie s'avère un outil avantageux pour améliorer l'aspect esthétique du paysage, mais également pour générer des biens et services environnementaux tels que la purification de l'eau, la conservation des sols, le maintien de la biodiversité ou la séquestration du carbone.

Mots-clés : Paysages ruraux, valorisations paysagères, agriculture, agroforesterie.

Abstract: Since the 1970s, intensification and specialization in Quebec agriculture have led to a simplification of the agricultural ecosystem, major areas with continuous cropping having followed the diversified systems that had prevailed up to that time. These disappearing landscapes, composed of wooded areas, pastureland, grasslands and annual crops, as well as various built elements, have drastically transformed the territory, impacting the environment and altering the relationship between society at large and agriculture.

This issue leads one to wonder whether or not the space used in intensive farming is in step with public perception and needs with respect to rural landscapes and to supportable non-agricultural uses. This poster assumes that part of the solution to this problem lies in the farming community reappropriating the landscape through multi-purpose agro-forestal developments. Trees and bushes are still the most accessible landscape components that may be used, and they serve a multi-purpose role. The repositioning of agriculture as a multi-faceted activity beyond the sole productive role may therefore be instrumental in resolving the deteriorating landscape issues. In this perspective, agroforestry proves to be a beneficial tool not only to improve landscape aesthetics, but also to generate environmental goods and services such as water treatment, soil conservation, biodiversity conservation or carbon sequestration.

Key Words: Rural landscape, landscape preferences, agriculture, agroforestry.

LES RÉCENTES MUTATIONS AGRICOLES

Par ses pratiques, par le défrichement et par l'utilisation du sol, l'agriculture a largement contribué à modeler les formes des territoires ruraux et à modifier ses contours. Elle a par ailleurs permis de créer des percées visuelles et de conférer aux régions une couleur, des rythmes, des odeurs, un caractère et une identité. L'agriculture aura ainsi participé à générer de multiples paysages ruraux.

Les trente dernières années ont toutefois été marquées par une transformation profonde des milieux ruraux et de leur signature paysagère. Sans être le seul facteur, l'avènement de l'industrialisation accrue, y a joué un rôle majeur. Si l'intensification des pratiques a permis l'augmentation de la production agricole, elle a aussi entraîné des conséquences multiples sur l'environnement (ex. détérioration des sols, contamination des eaux, dégradation des écosystèmes, appauvrissement de la biodiversité, etc.) ainsi que sur la signature paysagère (MENV 2003; OCDE 2003). Ces récentes mutations agricoles peuvent se traduire en trois phénomènes largement reconnus: concentration, spécialisation et intensification (Debailleul 1998; Bowley et IIbery 1999; Fig. 1).

D'abord, on parle du phénomène de concentration pour évoquer le fait qu'au cours des cinquante dernières années, il y a une régression de l'écoumène agricole québécois se traduisant par la chute considérable des superficies totales des fermes. En 1951, la superficie des fermes couvrait 6,8 millions d'hectares alors qu'en 2001, celle-ci était de 3,4 millions (Statistique Canada). Cette disparition quasi-totale des fermes sur de larges pans de territoire s'est accompagnée d'une diminution significative du nombre de fermes durant cette période passant de 134 000 en 1951 à 32 000 en 2001. En 50 ans, la densité des fermes a ainsi considérablement diminué et les exploitations qui ont maintenu leurs activités ont vu leur taille moyenne doubler passant de 51 ha en 1951 à 106 ha.

Ensuite, on emploie le terme «spécialisation» pour décrire le fait que les exploitations agricoles se sont orientées vers un nombre restreint de production dont les formes extrêmes sont les élevages hors-sol et la monoculture (Ruiz et Domon 2005). Ce phénomène a participé à la disparition d'une agriculture traditionnelle caractérisée par des activités agricoles diversifiées, associant cultures et élevage, par des composantes paysagères spécifiques au modèle de production agricole traditionnel comme les pâturages, les boisées de ferme, le bâti agricole traditionnel, etc.

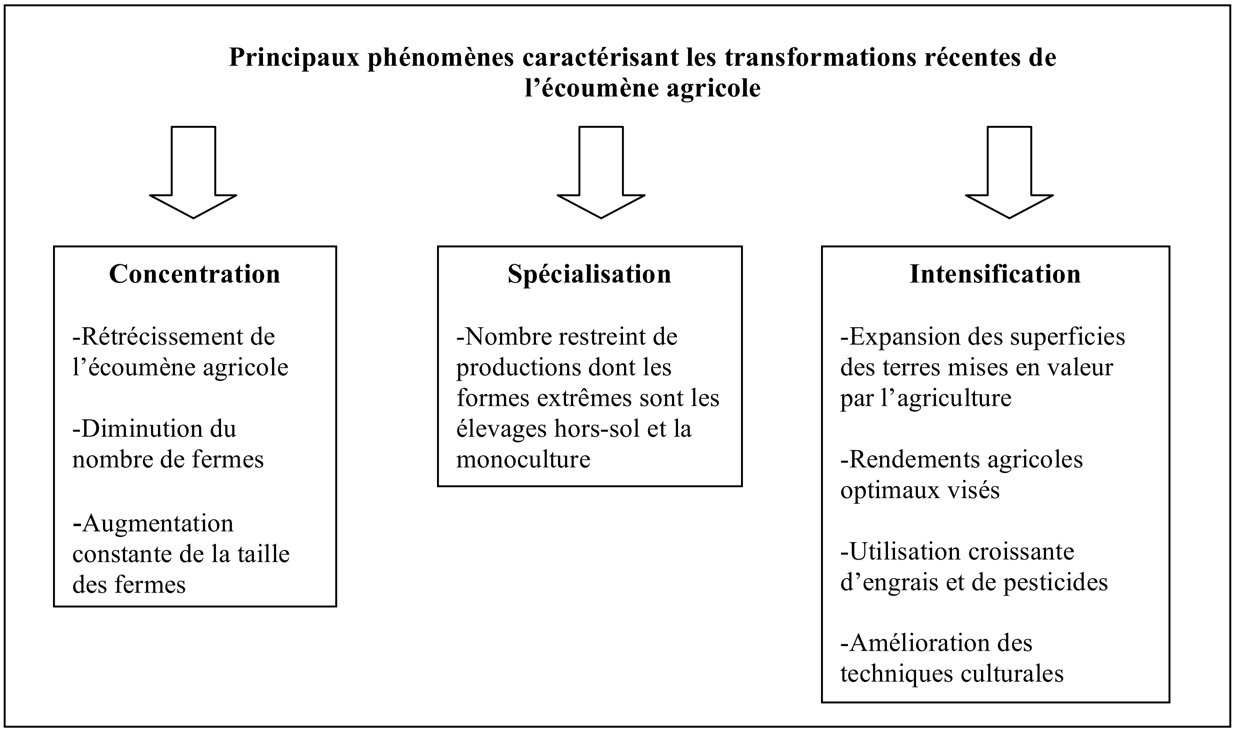

Fig. 1 : Phénomènes caractérisant les mutations récentes de l'écoumène agricole

Finalement, l'expansion des terres mises en valeur dans les régions localisées dans les basses terres de la Montérégie où se concentre l'agriculture au sein de fermes de moins en moins nombreuses, l'utilisation croissante d'engrais de synthèse et de pesticides, l'amélioration des techniques culturales et la mécanisation renvoient au phénomène d'intensification. (Ruiz et Domon 2005). Au même titre que le phénomène de spécialisation, l'expansion des superficies des terres mises en valeur a eu des répercussions importantes sur les pâturages et les boisés (Belvisi 2005).

Mais ces trois phénomènes n'ont pas touché l'écoumène agricole de façon égale sur les plans de la répartition spatiale de l'agriculture et des dynamiques paysagères. Alors que certains territoires connaissent une concentration au sein d'un nombre restreint de fermes et une expansion des terres mises en valeur par l'agriculture, d'autres territoires, en revanche, sont marqués par un abandon massif des terres agricoles et une diminution nette du nombre de ferme. Ces dynamiques agricoles révèlent ainsi une évolution contrastée des territoires ruraux : une zone d'intensification agricole et une zone de déprise agricole. Il s'agit de deux zones dont les évolutions agricoles peuvent se traduire à une échelle plus fine par des changements majeurs observables dans la structure des paysages.

LES DYNAMIQUES PAYSAGERES EN ZONES D'INTENSIFICATION ET DE DEPRISE AGRICOLE

En zone d'intensification agricole

La zone d'intensification est principalement située dans les basses terres de la Montérégie et de Lanaudière (Ruiz et Domon 2005). Dans cette zone, l'agriculture y est en expansion ou se maintient et l'ensemble du système d'exploitation agricole tend à s'orienter vers un nombre de production retreint et à utiliser de manière maximale les terres en fonction du type de spécialisation. Cela a donc pour effet de conduire à une uniformisation et à une homogénéisation sur le plan de la structure paysagère des milieux ruraux. Ces changements structurels se manifestent notamment par la disparition de nombreux éléments naturels (arbres isolés, boisés, écosystèmes, etc.), la modification de l'aspect d'éléments naturels (cours d'eau redressés, etc.) et l'introduction d'éléments d'origine anthropique standardisés (fossé, clôtures, les haies, cultures, standardisation des bâtiments agricoles, plastification[6], etc.). Ces dynamiques paysagères ont des conséquences non négligeables. Citons par exemple le déclin de certaines fonctions du paysage dont les fonctions écologiques (production de biens et services environnementaux en milieu agricole) et l'attribution d'une valeur souvent négative de la part de la société à l'égard de ces paysages ruraux façonnés par des systèmes de productions visant les rendements optimaux et guidé par une vision monofonctionnelle du territoire (Fig. 2).

En zone de déprise agricole

La zone de déprise agricole se caractérise, quant à elle, par des espaces marqués par l'abandon progressif de certaines portions du territoire où les conditions de terrain et la nature des sols représentaient des contraintes majeures pour permettre la viabilité économique des exploitations agricoles (Ruiz et Domon 2005). On retrouve ce type d'espace dans les centres urbains mais surtout dans les régions périphériques : Gaspésie, Côte-Nord, Saguenay-Lac-Saint-Jean, Charlevoix, arrière-pays du Bas-Saint-Laurent et de Chaudière-Appalaches, Laurentides, Outaouais et Abitibi-Témiscamingue.

Il s'agit d'espaces dont les tendances sont opposées aux précédentes. En effet, contrairement aux espaces d'intensification agricole, ceux-ci sont frappés par un déclin de l'agriculture se traduisant par deux tendances lourdes : l'abandon massif des terres agricoles et la disparition d'un nombre important de fermes. Ces dynamiques agricoles modifient la structure des paysages ruraux : abandon des bâtiments agricoles, enfrichement, enrésinement, suppression des marques distinctives du patrimoine bâti et paysager. Progressivement, ces dynamiques paysagères conduisent à l'appauvrissement des traits distinctifs régionaux pouvant engendrer une perte d'identité, à la sous-valorisation des territoires et à la disparition de certains paysages du quotidien, d'intérêt ou remarquable (Prud'homme 2002; Fig. 2).

[6] La plastification est un nouveau phénomène se caractérisant par l'aménagement de paillis ou de tunnels de plastique afin d'abriter les cultures. Il s'agit d'une pratique de plus en plus répandue qui s'effectue sans souci d'intégration dans les paysages ruraux (Commission des biens culturels du Québec, 2006).

En zone d'intensification agricole
(Tendances actuelles)

- Utilisation maximale des terres agricoles
- Concentration et spécialisation des fermes

Conséquences sur la structure des paysages ruraux

Uniformisation, homogénéisation et banalisation

- Disparition de nombreux éléments naturels (arbres isolés, boisés, écosystèmes, etc.)
- Modification de l'aspect d'éléments naturels (cours d'eau redressés, etc.)
- Introduction d'éléments d'origine anthropique standardisés (fossés, clôtures, les haies, bâtiments, cultures, standardisation des bâtiments agricoles, plastification, etc.)

Exemples de conséquences découlant des changements structurels des paysages ruraux

- Déclin de certaines fonctions du paysage dont la production de biens et services environnementaux
- Nouvelles structures de paysage qui peuvent projeter une image négative du système de production actuel

En zone de déprise agricole
(Tendances actuelles)

- Abandon massif des terres agricoles
- Disparition d'un nombre important de fermes

Conséquences sur la structure des paysages ruraux

Suppression des marques distinctives du patrimoine bâti et paysager

- Changement sur le plan de l'utilisation de l'espace : de l'exploitation agricole à l'enfrichement (fermeture des paysages)
- Introduction d'éléments d'origine anthropique : enrésinement

Exemples de conséquences découlant des changements structurels des paysages ruraux

- Appauvrissement progressif des traits distinctifs régionaux pouvant engendrer une perte d'identité (perte des éléments paysagers témoins de l'agriculture)
- Territoires sous-valorisés
- Disparition de certains paysages du quotidien, d'intérêt ou remarquable

Fig. 2 : Dynamiques paysagères en zones d'intensification et de déprise agricole et conséquences associées

Si les transformations des paysages ruraux soulèvent des préoccupations qui ne sont pas nouvelles en soi, celles-ci trouvent toutefois un écho particulier dans le contexte rural actuel.

LE PAYSAGE : UN ENJEU SOCIAL QUI TROUVE UNE RÉSONNANCE PARTICULIÈRE DANS LE CONTEXTE RURAL ACTUEL

Qualifié de «monde en changement» par Dugas (1984), l'espace rural a connu, depuis les dernières décennies, des restructurations majeures sur le plan sociodémographiques (Dugas 2000) et sur le plan des valorisations des territoires ruraux (Roy et al. 2005). Concrètement, ces changements se traduisent par une population agricole qui ne cesse de perdre ses effectifs au profit de l'arrivée de nouveaux acteurs d'origine urbaine qui confèrent aux milieux ruraux de nouvelles valeurs. Il s'agit de nouvelles valeurs qui prennent appui sur des valeurs patrimoniales et environnementales (Poullaoeuc-Gonidec 2001) et qui mettent à l'écart les formes modernes et les récentes dynamiques agricoles (Ruiz et Domon 2005). C'est ainsi que l'espace rural, après avoir été longtemps synonyme de lieu de production agricole, est perçu aujourd'hui comme un objet de contemplation, un symbole de nature, un refuge apaisé, un espace à vivre, procurant aménités et agréments esthétiques (Perrier-Cornet 2002; Roy 2005; Halfacree et Boyle 1998 tiré de Ruiz et Domon 2005).

Mais les transformations actuelles des territoires ruraux et de leur trame paysagère ne concordent pas toujours avec les nouvelles attentes de la société. Ce décalage est particulièrement marqué en zone d'intensification agricole caractérisée par des paysages banalisés, peu valorisés sur le plan patrimonial et souvent associés à un environnement dégradé (Ruiz et Domon 2005).

Face à cet enjeu paysager auquel sont actuellement confrontés les milieux ruraux, une des pistes de solution possible est de repositionner l'agriculture comme activité aux multiples facettes, au-delà de la seule fonction productive, en introduisant des aménagements agroforestiers multifonctionnels aux systèmes de production agricoles actuels. En effet, parmi les éléments du paysage sur lequel il est possible de jouer, l'arbre et l'arbuste demeurent les plus accessibles et les plus polyvalents quant à leur rôle. Dans cette perspective, l'agroforesterie s'avère un outil avantageux pour contribuer à résoudre les enjeux reliés à la dégradation des paysages ruraux tout en générant des biens et services multiples tels que la diversification des revenus agricoles par la production de bois et de produits non ligneux, la protection des cultures et la production de biens et services environnementaux (purification de l'eau, conservation des sols, maintien de la biodiversité ou la séquestration du carbone, etc.; De Baets et al. 2007a).

L'AGROFORESTERIE : UNE SOLUTION POUR REPONDRE AUX NOUVELLES ATTENTES DE LA SOCIETE

Par leurs multiples retombées sociales, économiques et environnementales auxquelles les pratiques agroforestières sont associées, celles-ci sont donc considérées comme des outils intéressants pour renforcer la multifonctionnalité de l'agriculture (Pointereau 2004; Gouin et Royer 2003 tiré de De Baets et al. 2007b). Ce qui est le plus intéressant dans le cas présent, c'est que l'introduction de systèmes agroforestiers aux modèles de production agricoles actuels peut infléchir les dynamiques paysagères en cours dans les zones d'intensification et de déprise agricole contribuant à répondre en partie aux besoins et attentes de la société.

En zone d'intensification agricole, l'aménagement de systèmes riverains agroforestiers, de haies brise-vent et de systèmes de cultures intercalaires par exemple, contribuerait à créer de nouvelles structures dans le paysage, estompant ainsi le caractère uniforme et homogène des paysages ruraux actuels. En plus de participer à la diversification et l'embellissement des paysages ruraux, ces systèmes agroforestiers multifonctionnels peuvent générer des biens et services environnementaux tels que la purification de l'eau, la conservation des sols, le maintien de la biodiversité ou la séquestration du carbone. Dans un contexte où les valeurs environnementales participent largement à modifier les façons d'apprécier et de se représenter le paysage (Berleant 1998; Paquette et al. 2003 tiré de Domon et al. 2004; Poullaouec-Gonidec et al. 2005), on peut penser que les paysages façonnés par les pratiques agroforestières contribueront nécessairement à améliorer l'image de l'agriculture. En France, certains travaux, dont ceux réalisés par Deffontaines (2001) et Ambroise et al. (2000), ont d'ailleurs mis en évidence le fait que le paysage constituait un outil pour améliorer l'image de l'agriculture et pour redonner confiance aux producteurs agricoles.

Si les bandes riveraines arborées ou arbustives et les haies brise-vent sont de plus en plus intégrées aux paysages ruraux en zones d'intensification agricole, ce n'est pas le cas pour les systèmes de cultures intercalaires. Toutefois, on commence à s'y intéresser sur le plan de la recherche universitaire. Cet intérêt est particulièrement palpable à l'Université Laval où un projet de recherche vise à mettre au point des systèmes de cultures intercalaires (SCI) intégrant des feuillus nobles (comme le noyer et le chêne) et des peupliers hybrides aux productions agricoles (GIRAF 2001).

En zone de déprise agricole, l'aménagement de systèmes agroforestiers s'avère également une avenue prometteuse pour créer des paysages originaux, créatifs et attractifs qui puissent redynamiser les territoires marqués notamment par l'abandon des terres agricoles, l'enfrichement, la perte du patrimoine bâti et naturel. Déjà, les premières tendances dégagées par le projet de mise en valeur de l'espace rural de la municipalité régionale de comté (MRC) du Rocher-Percé (Baumgartner 2006), laissent présager que l'implantation de systèmes agroforestiers dans des régions périphériques contribuera, notamment : à renforcer l'identité locale; à une reprise des terres en friche; à une diversification des revenus; à une restructuration des parcelles agricoles; à un regain de motivation chez les agriculteurs, à une valorisation de leur travail auprès de la société; à une amélioration de l'aspect esthétique des milieux ruraux caractérisés par un déclin de l'agriculture (Baumgartner 2006). La Fig. 3 présente un exemple de paysage façonné par un système de cultures intercalaires implanté dans le contexte de ce projet.

Cette recherche a révélé que l'agroforesterie présente un grand potentiel pour, non seulement assurer une production agricole diversifiée, mais également pour proposer des solutions originales à des défis contemporains comme la préservation de la biodiversité, la protection des sols et des eaux, la séquestration du carbone et bien sûr, la préservation et la création de paysages ruraux de qualité. Cette capacité de l'agroforesterie à modeler le paysage laisse entrevoir des possibilités de développements qu'il y aura lieu d'explorer plus en profondeur pour le bénéfice des propriétaires terriens comme de la société en général.

Fig. 3 : Système de cultures intercalaires (association de sureau-blanc et de légumineuses) en vue aérienne avec le village de Val-d'Espoir (Percé) en contrebas (photo : B. Anel, 2006)

En terminant, l'offre de paysage de qualité en milieu rural peut être influencée par les interventions gouvernementales existantes en matière agro-environnementale, puisque celles-ci portent sur l'implantation d'éléments qui sont partie prenante de la structure paysagère (bande riveraines, haies brise-vent etc.). Dans un souci d'arriver à une gestion intégrée du territoire, il importe donc de réfléchir aux possibilités d'intégrer un paramètre « paysager » dans la planification et la réalisation des certaines mesures agro-environnementales visées par les interventions gouvernementales.

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SECTION 9

Programmes, politiques et adoption de l'agroforesterie

Programmes, Policies and Adoption of Agroforestry

KEYNOTE SPEAKER

EXPÉRIENCES À LA FERME EN AGROFORESTERIE AU CANADA ATLANTIQUE – ON FARM AGROFORESTRY DEMONSTRATION IN ATLANTIC CANADA

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Résumé : L'agroforesterie commence à prendre de l'importance au Canada atlantique depuis les quatre dernières années. Par contre, l'intérêt se fait sentir différemment selon les différents enjeux des provinces et les initiatives locales émergentes. La planification environnementale, la prise en charge des associations de producteurs agricoles, les colloques et sessions d'information, la formation appliquée ainsi que les projets de démonstration ont tous contribué à sensibiliser la communauté agricole à l'agroforesterie.

La volonté d'innover est présente, mais l'agriculture en Atlantique fait face à de nombreux défis qui limitent le développement de l'agroforesterie. Parmi ceux-ci, notons le manque d'information, l'absence de services techniques, de transfert technologique, d'analyse socio-économique, de recherche et développement à la ferme, la faible disponibilité d'espèces d'arbres et d'arbustes adaptées aux besoins ainsi que le manque de programmes adaptés aux besoins et aux réalités de la région.

Le CCSEEC a initié un projet pilote sur l'agroforesterie, financé par le Programme de couverture végétale du Canada, sous le volet aide technique régional d'Agriculture et Agroalimentaire Canada. Celui-ci vise à favoriser l'adoption de pratiques agroforestières par la mise en place de sites de démonstration et d'activités de sensibilisation au Nouveau-Brunswick et à l'Île-du-Prince-Édouard. Dans le cadre de cette initiative, le CCSEEC travaille étroitement avec ses partenaires lui permettant de rejoindre la clientèle cible et d'adapter ses activités en conséquence. Ainsi, l'Association pour l'amélioration des sols et des cultures de l'Île-du-Prince-Édouard de même que celle du Nouveau-Brunswick, la Faculté de Foresterie de l'Université de Moncton, campus Edmundston, et les ministères provinciaux de l'Agriculture sont assis autour d'une même table afin d'identifier les activités propices pour permettre le développement de l'agroforesterie en Atlantique.

Abstract: Agroforestry has been getting more and more attention in Atlantic Canada over the last four years. However, the interest is different in each province depending upon the issues and emerging local initiatives. Environmental Farm Planning, Taking Charge initiatives by agricultural producers associations, workshops and information sessions, applied training and

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demonstration projects all contributed to raising awareness of agroforestry in the agricultural community.

The desire to innovate is real but the agricultural sector in Atlantic faces numerous challenges that limit the development of agroforestry. Amongst these challenges are lack of information, an absence of technical support, technological transfer, socio-economic analysis, research and development, a low availability of trees and shrubs adapted to needs and a lack of programs adapted to needs of the region.

The ECSWCC initiated a pilot project in agroforestry, funded by Greencover Canada under the Regional Technical Assistance component program of Agriculture and Agri-Food Canada. This project aims to encourage adoption of agroforestry practices through on farm demonstration sites and awareness activities in New Brunswick and Prince Edward Island. In this initiative, the ECSWCC works closely with partners in order to search out appropriate target audience and adapted activities. The Prince Edward Island Soil and Crop Improvement Association (PEISCIA), the New Brunswick Soil and Crop Improvement Association (NBSCIA), the Faculty of Forestry of the Université de Moncton - Campus Edmundston and the provincial Departments of Agriculture are all sitting around the table to identify appropriate activities that will foster the development of agroforestry in the Atlantic region.

KEYNOTE SPEAKER

DEVELOPING THE INFRASTRUCTURE TO STIMULATE AGROFORESTRY PRODUCTION IN THE U.S. – DÉVELOPPEMENT D’UNE INFRASTRUCTURE STIMULANT LA PRODUCTION AGROFORESTIÈRE AUX ÉTATS-UNIS

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Abstract: Experience over two decades has taught us that multiple “doors” lie between the promise and the reality of widespread agroforestry adoption. The infrastructure required to stimulate widespread use of agroforestry practices will come from weaving together an integrated and deliberate tapestry of approaches including: top down, bottom up, high tech, high touch, targeted funding and active partnerships.

Many promising trends are helping to pull agroforestry from the little known and distrusted shadows of U.S land-use tradition into the light of future opportunity. Consumer driven demand for healthier food and a healthier environment is supporting rapid and sustained growth in the private sector including organic and local food markets, farmers markets, CSAs and national grocery chains (e.g., Whole Foods). This is, in turn, helping to revive the viability of a diversified, environmentally healthy family farm. Nationwide efforts to reduce nonpoint source pollution and increase wildlife habitat are being supported by national agriculture policy. Climate change is causing a shift in interest toward long-term carbon storage and agroecosystem resilience. Finally, fossil fuel costs are driving a renewed interest in ligno-cellulosic bioenergy as alternative energy sources. Much more can be done with better coordination of effort, minor shifts in U.S. Farm Bill priorities and resource allocations and, concurrently, political will to support these changes within the nations’ land grant university system.

Key Words: Policy, institutions, research, private sector, markets, technology transfer.

Résumé : Au cours des deux dernières décennies, on a pu observer qu’il reste du chemin à parcourir pour que le rêve d’assister à l’adoption à grande échelle des pratiques agroforestières devienne réalité. L’infrastructure requise pour stimuler l’utilisation en masse de méthodes agroforestières découlera de notre capacité à forger un alliage formé de diverses stratégies : descendante, ascendante, haute technologie, *high touch*, financement ciblé et partenariat actif.

Plusieurs avenues prometteuses aident à sortir l’agroforesterie de son carcan où l’ont enfermée les techniques traditionnelles d’utilisation des sols aux États-Unis, de sorte qu’elle peut maintenant s’imposer comme nouveau débouché. La demande des consommateurs pour des aliments et un environnement plus sains stimule la croissance du secteur privé, notamment ceux

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des aliments biologiques et locaux, des fermiers, des ASC et des chaînes d'épicerie nationales (par ex. Whole Foods). Par voie de conséquence, ce phénomène favorise la viabilité des fermes familiales, diversifiées et soucieuses de l'environnement. Les efforts déployés à la grandeur du pays permettant de réduire la pollution diffuse et de favoriser l'établissement d'un plus grand nombre d'habitats fauniques ont reçu l'appui d'une politique agricole nationale. Les changements climatiques suscitent l'intérêt quant au stockage à long terme du carbone et à la résilience de l'agroécosystème. Enfin, le coût de l'énergie fossile provoque un regain d'intérêt envers le recours à la biomasse ligneuse comme source d'énergie de rechange. Grâce à une meilleure coordination de nos efforts, à une légère redéfinition des priorités du Farm Bill américain et à une meilleure gestion des ressources, et avec l'appui d'une volonté politique, nous pourrons enregistrer encore plus de progrès et appuyer ces changements au sein du système universel d'octroi des terres de notre pays.

Mots-clés : Politique, établissements, recherche, secteur privé, secteurs d'activité, transfert technologique.

KEYNOTE SPEAKER

ASSURER LE PASSAGE DE LA RECHERCHE AU TERRAIN : LE PROGRAMME « AGROFORESTERIE 2006/08 » EN FRANCE

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FROM RESEARCH TO THE FIELD, THE FRENCH PROGRAM "AGROFORESTERIE 2006/08"

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Résumé : Le programme européen SAFE (Des Systèmes Agroforestiers pour les Fermes Européennes) de recherche en agroforesterie qui s'est achevé en 2005 a apporté des éléments nouveaux dans la connaissance des interactions arbre-culture et la justification du développement de pratiques agroforestières. En parallèle, les enquêtes réalisées auprès d'un large échantillon d'agriculteurs ont montré que les systèmes agroforestiers séduisent plus d'un tiers des personnes interrogées. Mais face à la méconnaissance de ces systèmes et aux tracas réglementaires, la mise en place sur le terrain et l'accompagnement des porteurs de projets relevait du parcours du combattant. Néanmoins, depuis ces dernières années, et grâce notamment aux retombées du programme SAFE, la réalité du développement de l'agroforesterie prend forme.

En 2006, plus d'une vingtaine de partenaires se réunissent pour lancer un programme de développement de l'agroforesterie en France. Coordonné par Agroof Développement, ce programme vise à structurer le développement de l'agroforesterie et à assurer le lien entre la recherche et le terrain

Les grands axes de ce programme sont :

- Création d'une association nationale afin de favoriser la communication entre les acteurs, favoriser la promotion de l'agroforesterie et assurer une meilleure prise en compte des ces systèmes dans les différentes politiques réglementaires.
- Réalisation d'un bilan des connaissances actuelles et mise à disposition d'outils d'aide à la décision et de documents de synthèse
- Création d'un réseau des parcelles de démonstration sur tout le territoire
- Création d'un programme de recherche développement impliquant recherche, développement et enseignement.

En 2008, près de 300 projets devraient voir le jour, dans toute la France, dans toute catégorie d'exploitation.

En parallèle, des contacts sont pris avec quelques partenaires européens pour mieux prendre en compte l'agroforesterie dans les réglementations européennes et étudier la possibilité de la création d'un réseau européen d'utilisateurs de l'agroforesterie. La Commission Européenne a

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d'ailleurs introduit une mesure de soutien à l'agroforesterie dans son Règlement de Développement Rural pour la période 2007-2013.

Pour plus d'information, voir le site du programme : www.agroforesterie.fr.

Abstract: The European Safe (Silvoarable Agroforestry for Europe) Programme which is achieved since 2005, brought some new elements for the knowledge of tree-crop interactions and the justification of agroforestry practices. In France, after 2001, a progressive agroforestry development of a modern agroforestry was observed. However, the creation of silvoarable projects was very hard to set up, due to some regulations constraints and a lack of knowledge.

In the continuity of the SAFE programme, in which a farmers' survey showed that one third of them were interested in adopting silvoarable practices, a new development programme aims to promote silvoarable systems. In 2006, coordinated by Agroof Développement, more than 20 partners joined themselves to initiate a national programme for agroforestry development.

The goals of this programme are:

- Creation of a national association which aims to promote agroforestry, support the communication effort between the members and represent the agroforestry partners in their relationship with French administration.
- Realisation of a synthesis of the Research Development knowledge for public use.
- Set up of silvoarable plots for training and research activities on the whole territory
- Creation of a programme of Research Development with the Research, Development and Education partners.

In 2008, almost 300 projects will be set up, in every part of France, in all kinds of farms.

At the same time, contacts with the European partners will be reinforced to make sure that silvoarable systems are better taken into account in the European regulations and to study the possibility of a European end-users network. Besides, the European Commission introduced a measure to support the agroforestry investment in its Rural Development Programme for the 2007-2013 period.

For more information on this programme, go to: www.agroforesterie.fr (in French only).

KEYNOTE SPEAKER

AGROFORESTRY INITIATIVES AND POLICY DEVELOPMENTS IN BRITISH COLUMBIA
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INITIATIVES ET ÉLABORATION DE POLITIQUES AGROFORESTIÈRES EN COLOMBIE-BRITANNIQUE

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Abstract: Agroforestry in British Columbia is in the early stages of acceptance particularly in the areas of producer awareness, provincial policy, and the integration of traditional agriculture and forestry management systems. To foster the potential of a viable agroforestry sector, a series of initiatives are currently underway to engage producers, agencies, First Nations and policy administrators.

Key Words: Strategic plan, industry development, silvopasture, forest farming, MPB.

Agroforestry in British Columbia is at the beginning of an escalating interest in alternate crops and cropping strategies. This, in part has been bolstered by a series of reports on non-timber forest resources (NTFRs), many of which can be grown and harvested from managed agroforestry systems. In addition, interest in the nutraceuticals market, emphasis on environmental farm planning, sustainable food and forestry systems have heightened the need for agroforestry systems that provide an opportunity for sustainable production through integrated and intentional management. To this end, a series have initiatives have been started to support this interest.

In 2003, an Agroforestry Industry Development Initiative (AIDI) was started by industry and government to increase agroforestry activities in BC. The focus of the AIDI is to assist the development of an emerging agroforestry industry thereby increasing cropping opportunities for producers, diversifying cash flow and labour allocation, resulting in increased net farm income and community stability. The Initiative has a five-year plan with federal/provincial funding delivered through a 50:50 cost-share arrangement for a total of one million dollars. The AIDI is housed under the Agri-Food Futures Fund (AFFF) which is a $22.8 million joint federal/ provincial program established in 2001 as part of the Canada – British Columbia Framework Agreement on Agricultural Risk Management. The Investment Agriculture Foundation of BC acts as the trustee for the fund and the BC Federation of Woodlot Associations is the industry partner.

To establish a comprehensive roadmap for the fund, a five year British Columbia Agroforestry Strategic Plan was developed and vetted to a host of agencies and industry associations. This was followed by a series of regional workshops that attempted to identify the major interest areas, opportunities and constraints to adopting agroforestry systems in BC. These reviews identified four broad issues as being central to the development of an agroforestry industry in British Columbia: economic viability and environmental sustainability; access to information and extension; disconnection between practitioners, buyers and consumers; and, development and diversification of markets. In an effort to target these issues, four goals were established as the cornerstones of the AIDI:

- Development of partnerships with producers and associated organizations.
- To increase awareness of the benefits and limitations of agroforestry systems.
- Establishment of links to agroforestry practitioners and products with buyers and consumers.
- Development of an agroforestry marketing strategy.

From 2004-2007, the emphasis has focused on the development of partnerships, initiation of tech transfer activities and formulating tools for practitioners. Proposed activities continue with establishing targeted demonstration sites but with an increased emphasis on non-site-related workshops for producers, and building of both market and production tools. Progress in implementing activities relating to building partnerships, and increasing awareness and understanding of agroforestry systems (Goals 1 and 2) is consistent with timelines in the strategic plan and with an industry in the building phase. In contrast, many of the activities of Goals 3 and 4 (industry connectivity and market strategy) depend on a degree of awareness and industry momentum which are characteristic of a more mature industry and have correspondingly been slower in their development. Currently, the fund has or is supporting 26 separate projects of which 10 are demonstration projects located across BC while the remaining projects represent a variety of tech-transfer workshops and documents.

In recent years, one of the single most influential factors in raising the profile of agroforestry in BC is the unprecedented Mountain Pine Beetle epidemic found in almost all pine stands in the Interior regions of British Columbia. The Mountain Pine Beetle (MPB) epidemic has been described as a '…catastrophic natural disaster, causing widespread mortality of lodgepole pine, the Interior's most abundant commercial tree species' (BC MPB Action Plan 2006-2011, 2006). It is recognized that the epidemic affects not only forest ecosystems and values but also severely impacts the stability and long-term economic well-being of many communities. A large proportion of communities in British Columbia depend to a large degree on the forest resource as a source of economic well being – from direct jobs created by the forest industry and their supply and service sectors, through to downstream community service sectors and the tourism industry, which is dependent in part on the visual and recreational landscapes created by BC's forests. As of December 2006, the area covered by red-stage trees was approximately 9.2 million hectares with approximately 5.1 million hectares in the Southern Interior Forest Region, 3.9 million hectares in the Northern Interior Forest Region and the balance in the Coast Forest Region. Projections indicate that the epidemic will cease only once it has infested most of the mature pine in the province. Modeling data from the Ministry of Forests and Range indicate that at the current rate of spread, 50% of the merchantable pine will be dead by 2008 and 80% by 2017 (2006 Summary of Forest Health Conditions in British Columbia 2006).

As a consequence of the magnitude of the issue, dealing with the effects of the MPB epidemic has been identified as a provincial priority exceeding the scope of any one ministry. The MPB Action Plan outlines an approach to mitigating the impacts of the epidemic on forests, communities, and the provincial economy involving several government ministries, each of which has responsibilities to incorporate appropriate parts of the plan into annual Service Plans. Within the plan the established sectors such as agriculture are encouraged to operate at maximum capacity to aid in addressing projected short-falls in community stability and sustainability. In general, there are three avenues of accomplishing this, complementary to one another and necessary to increasing the level of sector intensity:

- Fostering the continued competitive capacity of BC's established agricultural commodities and enhancing growth to maximize yields of the traditional agri-food sector.

- Facilitating continued industry development of BC's emerging industries and market development to yield both crop and product diversification augmenting the productive capacity of the agri-food sector.

- Encouraging investment opportunities through diversification of products, production systems and landscapes; and, through the experiential opportunities provided by this diversification.

Potential activities identified by the BC Ministry of Agriculture and Lands addressing community and resource sustainability challenges created by MPB, relate to: identification of opportunities to augment agricultural production through increased access to arable and suitable Crown lands; fostering of forest and agricultural management practices compatible with one another on the same landbase; and, diversification of crops and products. In response to enhancing and diversifying BC agriculture, the BC Ministry of Agriculture and Lands has developed an Agroforestry MPB Strategic Framework which identifies silvopasture and forest farming as opportunities to increase agricultural sector capacity. Both systems, silvopasture through increased access to grazing resources and forest farming through enhanced managed production of non-timber forest products, provide opportunities to add stability to and diversify both local and provincial economies. The framework identifies specific actions and projects which address checks to implementation. To initiate some of the recommendations of the Agroforestry MPB Strategic Framework (2006), funding was secured through the Greencover Canada Program Technical Assistance Component to support research, technical transfer and capacity building projects for silvopasture and forest farming systems that were tailored to the unique economic, environmental and land management conditions presented by the MPB phenomena. In addition, agroforestry, in particular silvopasture and forest farming, has been identified in the BC Interior Cariboo-Chilcotin Beetle Action Coalition's Agriculture Sector strategy with linkages to a comprehensive forage strategy, specialty crop development and land use planning in the region.

Currently, non-timber forest resources have been estimated to contribute approximately $680 million to BC's economy with over 30,000 British Columbians earning all or part of their living from the sector (FPB Special Report, 2004). The BC government proposes to move ahead cautiously on the development of policy regarding NTFR's to avoid disrupting existing small businesses and to respect the new relationship with First Nations. One of the lead institutions in this area is the Center for Non Timber Resources (CNTR) at Royal Roads University, Victoria, BC. The CNTR has been a key delivery agency in BC and has led numerous research studies, published several tech-transfer documents, hosted international events, held training sessions and advised on policy. Provincial and federal agencies, First Nations and NGO's are cooperating with the CNTR through an inter-agency committee on numerous initiatives and research regarding policy and commercialization of NTFR's. In addition, there is increasing interest in linking some of the current (200 plus species) wild harvested and marketed non-timber forest resources to particular agroforestry management systems. To this end, the CNTR has been engaged to develop some of the forest farming initiatives identified in the above Agroforestry MPB Strategic Framework and to provide recommendations regarding the development of case studies focused on a management continuum of forest farming and integrated riparian management systems.

The acceptance of agroforestry by the forest resource and agricultural sectors is still very much in its infancy. Yet with the substantial economic and environmental pressures represented by the MPB epidemic, coupled with the need to diversify the agricultural sector from a commodity – based to valued added industry, agroforestry systems offer a long term sustainable land management approach. Yet in order to increase the awareness and adoption of agroforestry, a knowledge base of each of the agroforestry production systems on a regional basis is needed paired with an accepting policy environment. The initiatives mentioned above represent the avenues we hope will start to address some of these economic, information, policy and market gaps.

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KEYNOTE SPEAKER

DEVELOPMENT OF AGROFORESTRY PRACTICES AND POLICIES IN THE PRAIRIES: LESSONS FOR THE ADVANCEMENT OF AGROFORESTRY IN CANADA

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ÉLABORATION DE PRATIQUES ET DE POLITIQUES AGROFORESTIÈRES DANS LES PRAIRIES : LEÇONS POUR L'AVANCEMENT DE L'AGROFORESTERIE AU CANADA

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Abstract: Agroforestry in the prairie region of western Canada is identified primarily with the establishment of windbreaks and field shelterbelts. If a broader suite of agroforestry systems and practices are to become common and accepted in modern agricultural production, proponents must continue to educate farmers, industry and policy makers of the economic and environmental benefits that agroforestry can provide. The development of agroforestry programming and policy by Agriculture and Agri-Food Canada, PFRA has provided lessons that may be of value for the advancement of agroforestry in Canada.

The positive role that trees can play in the agricultural landscape is well understood. Agroforestry systems, tree plantations and managed woodlots can all provide income to farmers and landowners. What sets agroforestry apart is that much of the value of these systems is the result of interactions between the agricultural and forestry components. While most people understand the concept of planting trees for lumber or fiber, the idea of planting trees to increase agricultural productivity and diversify farm income is not. To advance agroforestry policy and adoption in Canada, clear language and agreed upon definitions are required.

Agroforestry has the potential to contribute toward meeting many of the challenges and opportunities facing agriculture today. The impacts of climate change, increased environmental awareness, environmental goods and services and bio-fuels are just some of the issues that industry is confronting. If agroforestry is to contribute to the future sustainability of agriculture, proponents must be able to clearly and concisely define the functions and benefits of agroforestry.

Résumé : L'agroforesterie dans la région des Prairies de l'Ouest canadien est associée principalement dans l'esprit des gens à l'aménagement de coupe-vent et de brise-vent dans les champs. Si un ensemble élargi de pratiques et de systèmes agroforestiers devait devenir chose courante et acceptée dans le milieu de la production agricole contemporain, les tenants doivent poursuivre leur sensibilisation des producteurs, de l'industrie et des décideurs aux avantages d'ordre économique et environnemental potentiels de l'agroforesterie. L'élaboration de politiques

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et de programmes agroforestiers par l'ARAP d'Agriculture et Agroalimentaire Canada a permis de tirer des leçons susceptibles d'être utiles pour l'avancement de l'agroforesterie au Canada.

On comprend très bien l'effet bénéfique des arbres en milieu agricole. Les systèmes agroforestiers, les plantations d'arbres et les terrains boisés aménagés peuvent fournir des revenus aux producteurs agricoles et propriétaires fonciers. Ce qui démarque l'agroforesterie, c'est qu'une grande partie de la valeur de ces systèmes est directement attribuable aux interactions entre les éléments agricoles et les éléments forestiers. Bien que la plupart des gens comprennent le principe de la plantation d'arbres pour obtenir du bois de construction ou des fibres, le principe de la plantation d'arbres dans le but d'accroître la productivité agricole et de diversifier les revenus agricoles est moins bien connu. Pour faire avancer les politiques agroforestières et favoriser l'adoption de ces politiques au Canada, il faut à tout prix établir un vocabulaire clair et convenir des définitions.

L'agroforesterie peut potentiellement contribuer à surmonter un grand nombre de défis et à profiter des occasions en agriculture aujourd'hui. Les effets du changement climatique, une meilleure sensibilisation à l'environnement, l'augmentation des biens et des services environnementaux et des biocarburants sont quelques-unes des questions de l'heure dans ce domaine. Si l'agroforesterie doit contribuer à la durabilité de demain des pratiques agricoles, ses tenants doivent arriver à définir clairement et de manière concise les fonctions et les avantages de l'agroforesterie.

THE AFFORESTATION GAP
THE PROGRAM AND POLICY CHALLENGE

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Abstract: The Saskatchewan Forest Centre (SFC) provides direct support to grow the forest and agroforest sector. As part of the SFC mandate, several agroforestry demonstration sites have been established across the province. Through technology transfer activities of the SFC Agroforestry Unit, a great increase in interest has been seen in growing trees as part of crop rotations, mostly throughout the forest fringe/northern grainbelt. Many questions arise that the SFC has worked to answer in order to respond to this interest. Of main concern is the economics of growing trees.

The development of a reasonable predictive model creates several challenges, including predicting yield, prices and cost of production twenty years out. A future value model (FV) was developed that shows costs and returns for different yield, management and end use scenarios. The results show that a plantation managed for a high value end use is certainly profitable with the resources available today.

Challenges to programs and policies that would reduce costs, improve yield potential and remove risk remain in research and development. Issues such as applicability of crop insurance, role of farm income programs and other risk sharing programs and finance require development. From the analysis, a substantial opportunity exists to lower cost across three specific areas: yield improvement through genetic research, mechanization and access to registered herbicides for vegetation management. A commitment to replicating the rapeseed to canola success story and creating scarcity and competition through efficacy in use of the Crown forests would contribute greatly to the realization of this industry for Saskatchewan farmers.

INTRODUCTION

Since 2001, the Saskatchewan Forest Centre has provided direct support to grow the forest and agriculture sector. Through a series of partnership agreements with nationally renowned corporations, it provides technology transfer services to forest, farm, and value added clients and, through a development fund it fills gaps in province specific knowledge in support of the sector.

The agroforestry component of the Centre is mandated to:

- broaden economic choices for farmers and landowners; and
- increase the long term wood supply.

In 1999 Saskatchewan launched a major expansion of its forest industry, seeking to more than double primary sector output. Over the past several years Saskatchewan has seen nearly $1B of investment in the primary forest sector. As a result, the Province is moving towards full

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utilization of its "Crown" forest resource. Through a combination of government policy, expected supply pressures and a potential response to the Kyoto Protocol, major opportunities now lie in developing a fibre supply on private lands that would diversify Saskatchewan's rural economy, and in building the associated products and businesses that would add value to this resource.

Provincially and nationally much attention is focused on trees as a viable farm crop and carbon sink, most particularly poplar. Saskatchewan has a significant potential to establish trees as a new crop system given its large agricultural land base, relatively low land prices, soil suitability and declining returns from traditional crops. It contains almost 50% of Canada's farmland. Saskatchewan contains millions of acres of land that was cleared for agricultural use since the turn of the 20th century; these acres hold great potential for the successful development of a new industry based on planting trees as a crop.

Agroforestry, and the plantation component described generically as afforestation, are key delivery methods. Demonstrating that trees are a viable crop is undertaken by the SFC Agroforestry Unit through technical information, workshops and advice. In the course of its work, a number of issues have been identified by the farm community including questions about the economics, future markets risk sharing, and agronomics. As a part of its mandate, the Centre has established a number of demonstration sites across the Province utilizing several different species. For the purpose of this paper and presentation, it is not the intent to consider every possible tree variety that might be grown. The focus is on the species which can produce the greatest biomass in the shortest possible time which has a demonstrated use in the lumber industry, hybrid poplar.

MODELING METHODOLOGY AND FUTURE VALUE RESULTS

The adoption of hybrid poplar as a viable alternative will only occur if the economics of the crop, which has high front end costs for establishment and twenty years to realize a return, can be proven up. The development of an economic model for this variety demonstrates further the most immediate gaps in program and policy.

The development of a reasonable predictive model creates several challenges associated with predicting yield and prices twenty years out.

Yield

Saskatchewan does not have an abundance of hybrid poplar plantations from which to gather yield data. In addition, those the sites which are available for study generally lack sufficient management information which will be a key determinant of yield. Vegetative management for the first three to four years is critical to establishment. Other data sources include shelterbelts of which there are many across the province; however, given expected differences between plantation layout verses the shelterbelts, yield data is considered somewhat suspect. Other jurisdictions provide another source of information but they are equally difficult to translate to the Saskatchewan environment with great confidence. Notwithstanding the difficulties with the data, the combination of information sources suggest a yield range from dryland plantations of 100 to 180m^3 per acre, with 100m^3 being a poor yield and 180m^3 exceptional.

Price

A significant challenge is the estimation of current prices, let alone predicting what the value of the resource will be when it is ready for harvest in twenty years. Hybrid poplar's close substitute is native aspen which is harvested from both Crown forest and private lands. Generally, it is directed toward the commodity industries of pulp and oriented strand board (OSB) and private lands represents a very small percentage of the total tree fibre harvest. Standing privately held aspen has a purchase price in the range of \$2 to \$4/m$^{3.}$

The difficulty in accepting these values as indicative of future poplar values will tend to understate the price. There is no competitive, transparent market. There are effectively only two buyers, the Crown forest is not yet fully utilized and as such there is no scarcity. Saskatchewan is one of two Canadian jurisdictions which have not fully built out its forest industry and so a significant annual allowable cut is available. In addition, while the fibre in such application as OSB are substitutes, the differences between the consistency and quality of a hybrid poplar stand will favour the poplar plantation significantly over native aspen.

It quickly becomes evident that development of a shadow pricing model is required and there appears to be two approaches. One is to review the standing value of poplar in other jurisdictions where there are competitive forces and then to attempt to equalize the other variables that might determine price between Saskatchewan and these other jurisdictions. Some of the variables which will complicate pricing include wood quality and yield, distance to the mill, respective distance to market, etc.

A simpler methodology, which this paper utilizes, is an indifference model which relates to the cost of aspen fibre delivered to the mill. It is known from industry that total costs, including planning, stumpage and renewal fees, silviculture, roads and harvest/haul to get aspen from Saskatchewan's Crown forest is: \$30 to \$35/m^3; and value aspen logs delivered are \$60 to \$65/m^3

Utilizing these values and inflating them out 20 years gives a future value for the commodity (e.g., OSB) fibre and higher value logs which, in an environment of scarcity, will set the floor price. The key assumption is that the industry would be indifferent in regard to where they source their fibre if the cost to them is the same.

Costs of production

A number of the costs associated with poplar production have been taken from experiences in the establishment of the SFC's demonstration network. As with any crop production systems, costs are related to specific decisions.

The range of plant stock costs is related to choice of cuttings verses rooted stock. The planting costs represent hand plantings and are higher than those experienced in the crown forest. The difference in cost is a result of the distance to take a planting crew out of Prince Albert across Saskatchewan to relatively small planting areas associated with the demonstration site development. In addition, the efficiency of hand planters relative to mechanized is significantly higher given the level of mechanization currently available. As noted earlier, vegetative management is critical to success and the cost range reflects chemical verses mechanical control with mechanical being higher cost. Pruning is recommended to create clear lumber where some portion of the tree is targeted toward the higher valued industries. If a producer were targeting the OSB market, the pruning and its related costs would not be undertaken.

Carbon credits

The model does not include any value for carbon credits arising out of afforestation. Current Chicago climate exchange prices suggest that average annual returns from afforestation in Saskatchewan might realize $25 to $30 per acre. This would add significant incremental support to making afforestation financially viable.

A core set of gaps in policy and programming becomes evident as a net return model is built out. This model is a future value model utilizing the cost and price structure outlined above. The model is based on the most conservative data in the range. Hence, it uses the highest cost of the range. The cost of harvest/haul is inflated out 20 years as is the two mill delivery costs which represent the price to producers. Taxes have been assumed to be $5/ac/yr. The model also has built in a return to land and management of $25/ac/yr. In addition to the data above, the following model assumptions have been applied to develop a future value model.

FUTURE VALUE (FV) MODEL

A future value (FV) model was developed to show costs and returns for four scenarios of hybrid poplar production in Saskatchewan. The FV model makes several assumptions with regard to cost over the next 20 years as trees mature to harvest. Table 1 shows the costs and cost range for the low range of yield at $100m^3$ per acre and Table 2 shows costs and cost range for a higher yield of $150m^3$ per acre.

Future value model assumptions:

- 10X10 spacing – 440 plants/acre;
- Two yield models of $100m^3$ (Table 1) and $150m^3$ (Table 2);
- Discount rate of 6%;
- Inflation rate of 2% per year;
- Utilize high cost/low price of range;
- 1/3 of tree used for value added market model.

Table 1: Key costs for a yield of hybrid poplar of 100m^3/acre in 20 years

Activity	Costs*	Cost Range*
Land preparation		$40/ac
Plant stock	$0.25 to $0.60/cutting	$110 to $264/ac
Hand Planting	$0.20 to $0.25/cutting	$88 to $110/ac
Vegetative Management	3 to 4 years	$150 to $240/ac
Pruning	2 to 3 years	$120 to $180/ac
Taxes	$5/ac/yr for 20 yrs.	$100
Harvest/Haul	$15 to $18/m^3	$1,500 to $1,800/ac
Return to Land & Management	$25/ac/yr for 20 yrs.	$500
TOTAL		**$2,524 to $3,194/ac**

* 2004 dollars

Table 2: Key costs for a yield of hybrid poplar yield of 150m^3/acre in 20 years

Activity	Costs*	Cost Range*
Land preparation		$40/ac
Plant stock	$0.25 to $0.60/cutting	$110 to $264/ac
Hand Planting	$0.20 to $0.25/cutting	$88 to $110/ac
Vegetative Management	3 to 4 years	$150 to $240/ac
Pruning	2 to 3 years	$120 to $180/ac
Taxes	$5/ac/yr for 20 yrs.	$100
Harvest/Haul	$15 to $18/m^3	$2,250 to $2,700/ac
Return to Land & Management	$25/ac/yr for 20 yrs.	$500
TOTAL		**$3,358 to $4,134/ac**

* 2004 dollars

Four scenarios for returns that incorporate two yield models and two end use markets were developed (Table 3). Scenario 1 is the low end yield range of 100m^3 per acre with the end use target being the commodity market of OSB. Scenario 2 uses the low end yield range of 100m^3 but targets the higher end value added market. Scenario 3 uses the higher end yield of 150m^3 targeting the low end commodity market of OSB. Scenario 4 used the higher yield range of 150m^3 and the higher end value added market.

Table 3: Net future value model

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Yield	100m3 /ac OSB**	100m3 /ac VA***	150m3 /ac OSB**	150m3 /ac VA***
Revenue	$5,200	$6,672	$7,801	$10,030
Costs*	$6,503	$7,024	$6,800	$7,200
Net	**($1,303)**	**($352)**	**($39)**	**$1,668**

* includes $25/acre/yr to management and land
**OSB is the commodity market
***VA is 1/3 to value added market (rest to commodity market)

The production of wood fibre at a yield of 100m^3 per acre targeted toward the OSB market (scenario 1) will result in a significant net loss. The annual return to land and management of $25ac/yr. totals almost $1000 on a future value bases. Thus, scenarios 2 and 3 come close to breaking even with scenario 4 achieving substantial returns above the cost of production and return to land and management.

SUMMARY

The significant challenge to realizing a return to the production of hybrid poplar is the large front end costs and 20 year wait until a return is realized. The net return model with the four scenarios indicates the potential to almost break even in two out of the four scenarios with only one of them generating significant profits. It is evident that maintaining flexibility in production will be important. Thus, pruning to ensure a higher value product seems prudent given the future market and price uncertainties.

In addition, it is evident that utilization of the lower costs of the range would change the net results and the profitability substantially. As a result, actions that reduce front end costs and increase value will enhance the profitability. There are several policy issues that require additional work to place hybrid poplar plantations on an equal footing with other agricultural crops. Issues such as applicability of crop insurance, role of farm income programs, and other risk sharing programs and finance require development. But from the analysis above, a substantial opportunity exist to lower cost across three specific areas:

- Develop local planting crews and/or develop an automated multi-row planter. If planting costs were reduced to one half, it would save almost $50/ac in 2004 dollars.

- Vegetative management is critical but the significant drawback to cost reductions is the lack of registered herbicides. Several are registered for shelterbelt use but it is not clear that this registration can be applied to plantations. Expanding the registration for pre- and post-emergent herbicides will lower vegetative management costs from the high of $240/ac to $150/ac.

- Replicate the rapeseed to canola success for trees with a focused commercial poplar research and development program. It could in one instance reduce the need for pruning if tree development simply focused on tree form (self-pruning). This would eliminate a $180 per acre cost item.

- Define a carbon trading system which would support agroforestry and afforestation projects.

In total, these actions would save $320 per acre basis 2004 dollars and substantially change the economics in the model. The Poplar Council of Canada is working to expand the registration of herbicides. In the other two areas achieving the results required above should not be difficult, given Saskatchewan's capabilities in genetics and farm machinery development.

In addition, a focused research and development program might work towards enhancing yield and/or shortening the rotation time. Success in this area will further positively affect the economics of hybrid poplar plantation farming.

Lastly, it is important that the province continue to build out the Crown forest and reach the annual allowable cut to create demand for wood fibre based on scarcity and a competitive market.

LE PORTRAIT DE L'AGROFORESTERIE AU QUÉBEC

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Résumé : L'acceptation grandissante du concept de développement durable et la recherche d'une agriculture plus respectueuse de l'environnement constituent une opportunité pour le développement de l'agroforesterie au Québec. L'agroforesterie procure de nombreux avantages, tels que la protection des cultures, la diversification des revenus agricoles par la production de bois et de produits forestiers non ligneux. Les pratiques agroforestières stimulent aussi la biodiversité, contribuent au captage du carbone et embellissent les paysages. En somme, l'agroforesterie constitue un fournisseur remarquable de biens et de services écologiques s'inscrivant dans un contexte de gestion intégrée des terres agricoles.

Au Québec, l'agroforesterie suscite un intérêt grandissant de la part des intervenants agricoles et forestiers. L'agroforesterie s'y pratique déjà sous différentes formes, mais son grand potentiel de contribution à l'économie et à l'environnement demeure encore largement sous-exploité. Afin de libérer ce potentiel, une démarche systématique a été entreprise afin d'en évaluer le potentiel de développement sur le territoire, d'établir une stratégie de mise en œuvre et d'en assurer le déploiement à large échelle. À la base de ce développement se situent le rapprochement des forces vives présentement associées à l'agroforesterie au Québec et la structuration d'un partenariat québécois qui soutiendra la démarche.

La présente conférence a pour principaux objectifs : (1) décrire le domaine de l'agroforesterie au Québec, (2) de proposer une définition qui réponde au contexte québécois, (3) faire une analyse stratégique sommaire et (4) de proposer un certain nombre de recommandations pour le développement de l'agroforesterie au Québec.

Mots-clés : Pratiques agroforestières, définitions, ressources, forces et faiblesses, développement, adoption, gestion intégrée du territoire.

Abstract : The growing acceptance of sustainable development and the quest for an environmentally sane agriculture represent interesting opportunities for the development of agroforestry in Quebec. Agroforestry produces numerous advantages, such as the protection of crops and the diversification of rural incomes through the production of wood products and non timber forest products (NTFP). In short, agroforestry is a remarkable producer of environmental goods and services that fits very well into an integrated land use management context.

In Quebec, agroforestry reveals a growing interest from actors from both agricultural and forest sectors. Agroforestry is practiced under different forms in this province, but its great potential in contributing to the economy and the conservation of natural resources remains largely unexploited. In order to reveal this potential, a systematic process has been undertaken to evaluate its economic potential on Quebec's territory, to establish an operational strategy and to assure its development on a large scale. At the roots of this development lays an effort connecting all dynamic forces of Quebec's agroforestry and the founding of an official partnership which will sustain this process.

This conference's main objectives are: (1) To describe the field of agroforestry in Quebec, (2) to propose a definition faithful to Quebec's context, (3) to make a brief analysis and (4) to propose a number of recommendations concerning the development of agroforestry in Quebec.

Key Words: Agroforestry practices, definitions, resources, strengths and weaknesses, development, adoption, integrated land-use management.

INTRODUCTION

Les concepts généraux de l'agroforesterie ont depuis longtemps été développés et appliqués dans les pays tropicaux. En milieu tempéré, la recherche d'une agriculture plus respectueuse de l'environnement constitue une circonstance opportune pour le développement de l'agroforesterie. L'agroforesterie procure de nombreux avantages, tels que la protection des cultures, des animaux d'élevage, des sols et des cours d'eau. L'agroforesterie permet également de diversifier les revenus agricoles par la production de bois et de produits forestiers non ligneux. Les pratiques agroforestières stimulent aussi la biodiversité, contribuent au captage du carbone et embellissent les paysages. En somme, l'agroforesterie constitue un fournisseur remarquable de biens et de services environnementaux s'inscrivant dans un contexte de gestion intégrée des terres agricoles et de l'espace rural.

Au Québec, l'agroforesterie suscite, pour les raisons évoquées ci-haut, un intérêt grandissant de la part des intervenants agricoles et forestiers. L'agroforesterie s'y pratique déjà sous différentes formes dans la plupart des régions, mais son potentiel de contribution à l'économie et à l'environnement demeure encore largement sous-exploité. Pour libérer ce potentiel, une démarche systématique est requise afin d'en définir le domaine, d'en évaluer les possibilités de développement sur le territoire, d'établir une stratégie de mise en œuvre et d'en assurer le déploiement à large échelle. À la base de ce développement se situent le rapprochement des forces vives présentement associées à l'agroforesterie au Québec et la structuration d'un partenariat québécois qui soutiendra la démarche. C'est dans une telle perspective que se place le présent portrait de l'agroforesterie.

La présente étude a pour principaux objectifs de définir le domaine de l'agroforesterie au Québec, de proposer une définition qui réponde au contexte québécois, de faire une analyse stratégique sommaire et de proposer un certain nombre de recommandations. La réalisation du mandat a comporté trois grandes étapes, qui composent les grandes sections du rapport, soit : 1) la délimitation du domaine de l'agroforesterie et la proposition d'un cadre conceptuel ; 2) la cueillette, l'analyse et l'organisation de l'information sur l'état des pratiques agroforestières ; 3) l'étude des opportunités et des problématiques vis-à-vis du développement de l'agroforesterie. Cette dernière phase a été complétée par la proposition et l'organisation d'éléments stratégiques préliminaires ainsi que de recommandations en vue du développement de l'agroforesterie québécoise.

LE DOMAINE DE L'AGROFORESTERIE AU QUÉBEC

La première étape dans l'établissement de l'état de l'agroforesterie consiste à lui donner une définition opérationnelle et à en établir le domaine pour le Québec. Il existe dans la littérature diverses définitions générales de l'agroforesterie. Partant de ces définitions et considérant le contexte québécois, la définition suivante, à la fois simple et conceptuellement juste, est proposée :

> *L'agroforesterie est un système intégré de gestion des ressources du territoire rural qui repose sur l'association intentionnelle d'arbres ou d'arbustes à des cultures ou à des élevages, et dont l'interaction permet de générer des bénéfices économiques, environnementaux et sociaux.*

Il existe un éventail de systèmes agroforestiers à travers le monde, et un certain nombre de classifications sont possibles, selon les critères utilisés. Une classification repose, par exemple, sur le type de composants : on distingue alors les systèmes sylvopastoraux (association élevages – espèces ligneuses), agrosylviculturaux (association espèces ligneuses – plantes saisonnières) et agrosylvopastoraux (association élevages – espèces ligneuses – plantes saisonnières).

La classification des systèmes agroforestiers peut aussi se faire en s'appuyant sur la principale fonction des systèmes ; il s'agit de la classification retenue dans le présent portrait. Ainsi, bien que tous les systèmes agroforestiers possèdent la capacité de fournir simultanément plusieurs produits et services, une telle classification distingue, d'une part, les systèmes à vocation productive et, d'autre part, les systèmes multifonctionnels. Ces derniers combinent la production de produits ligneux et non ligneux aux services environnementaux, sociaux et territoriaux.

L'agroforesterie étant un concept relativement nouveau au Québec, il y a aussi lieu d'en préciser le domaine et de le situer par rapport aux activités des domaines de la forêt et de l'agriculture qui lui sont analogues ou connexes. La Fig. 1 propose une délimitation de ces domaines. Elle met en évidence la superposition de l'intérêt des secteurs forestier et agricole pour certaines productions considérées tantôt agricoles, tantôt forestières, ainsi que leur relation étroite avec le domaine de l'agroforesterie. Cette illustration communique l'idée que les secteurs de la foresterie et de l'agriculture ainsi que le domaine émergeant de l'agroforesterie partagent de multiples enjeux, et qu'il est dans leur intérêt mutuel de collaborer en vue d'un développement intégré sur le territoire.

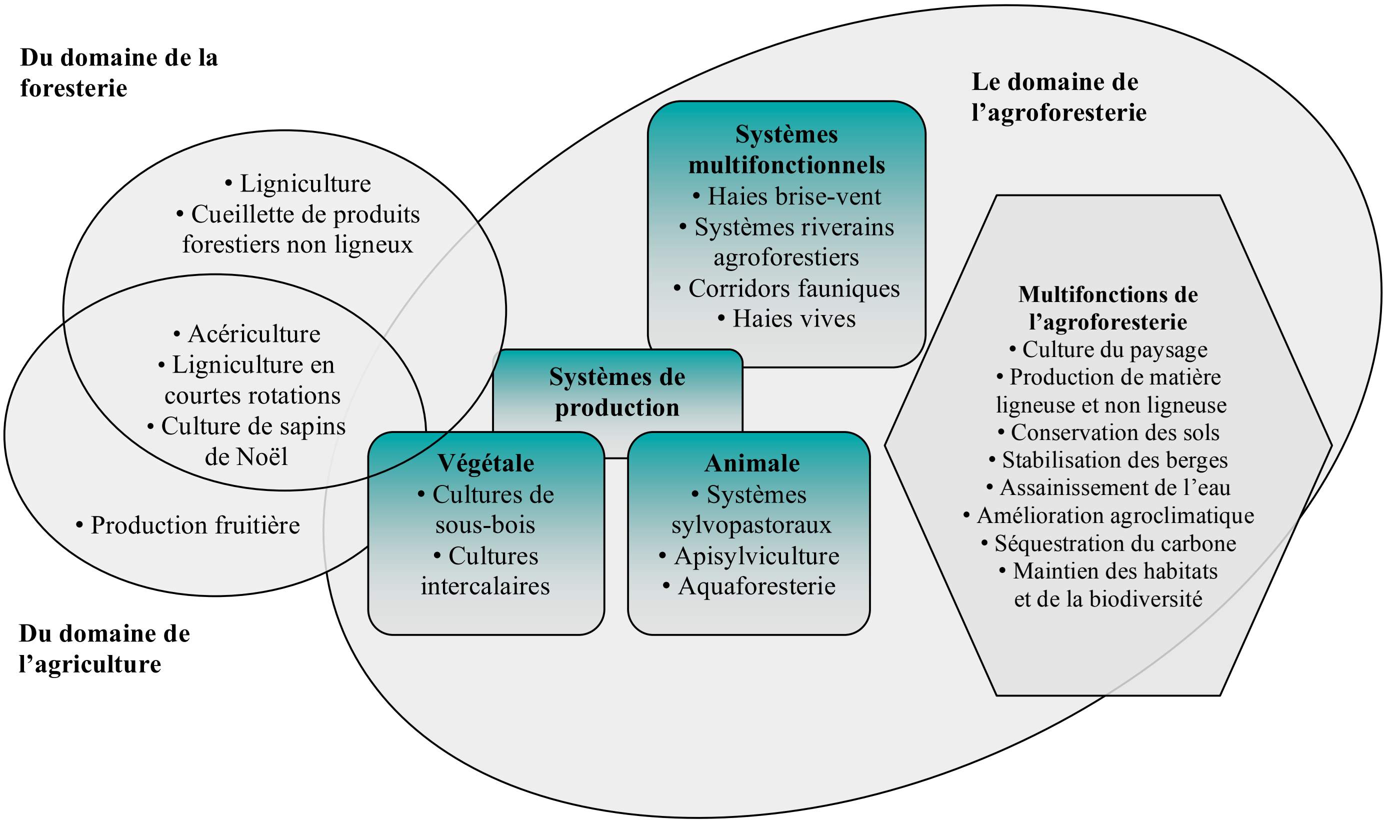

Fig. 15 : Le domaine de l'agroforesterie au Québec

LE PORTRAIT DES SYSTÈMES AGROFORESTIERS MULTIFONCTIONNELS

Les principaux systèmes agroforestiers multifonctionnels présents au Québec sont les haies brise-vent et les systèmes riverains agroforestiers. Alors que le concept de corridor faunique intéresse quelques acteurs locaux et régionaux, aucun cas de haie vive – un agencement d'espèces végétales qui forment une clôture naturelle – n'est répertorié.

Les haies brise-vent

Les haies brise-vent sont des alignements minces de végétaux, généralement ligneux, et le plus souvent de grande hauteur, normalement rectilignes, orientés perpendiculairement aux vents nuisibles dominants, qui protègent les terres cultivées, les pâturages, les voies de communication, les bâtiments agricoles et domestiques du vent ainsi que du sable et des poussières entraînés par le vent. La haie brise-vent est sans doute la pratique agroforestière la plus répandue du Québec. À partir du milieu des années 1980, approximativement 400 km de haies brise-vent ont été implantées annuellement sur le territoire rural québécois. Le succès de cette pratique peut s'expliquer par un effort de vulgarisation important, par la formation des conseillers techniques et par des programmes gouvernementaux d'aide technique et financière, notamment le programme Prime-Vert et le Programme de couverture végétale du Canada. Depuis quelques années, la Fédération des producteurs de porcs du Québec promeut l'utilisation des haies brise-vent pour réduire les odeurs émanant des complexes animaliers.

La vulgarisation et l'accompagnement technique auprès des producteurs agricoles sont généralement réalisés par les clubs-conseils agroenvironnementaux (CCAE) et les conseillers régionaux du ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), lequel est responsable du programme Prime-Vert. L'Institut de technologie agroalimentaire (ITA), campus de La Pocatière, joue un rôle primordial dans la recherche et le développement sur les haies brise-vent au Québec et dans l'Est du Canada. L'ITA de La Pocatière entretient des liens étroits de collaboration avec le Centre des brise-vent d'Agriculture et Agroalimentaire Canada (Administration du rétablissement agricole des Prairies), situé en Saskatchewan.

Les systèmes riverains agroforestiers

Les systèmes riverains agroforestiers sont établis le long des cours d'eau pour la stabilisation des berges, la protection de la qualité de l'eau et des habitats, la régularisation des débits des cours d'eau et le captage du carbone. Comme les haies brise-vent, ils peuvent aussi générer de la matière ligneuse et des produits forestiers non ligneux, et ils contribuent de plus à l'esthétique du paysage.

Au Québec, la Politique de protection des rives, du littoral et des plaines inondables incite les producteurs agricoles à conserver une bande riveraine naturelle ou aménagée (herbacée, arbustive ou arborée) d'une largeur de trois mètres entre les champs et les cours d'eau, de manière à assurer une protection contre l'érosion et le ruissellement. Malgré cette exigence et malgré le soutien technique et financier des programmes existants, présentement, les bandes riveraines arborées ne bénéficient pas de la même popularité que les haies brise-vent. Le manque d'intérêt actuel peut s'expliquer par le fait que les bénéfices économiques de l'installation d'une bande riveraine arborée sont moins perceptibles que ceux de la haie brise-vent, laquelle peut augmenter le rendement des cultures ou réduire les coûts de chauffage des bâtiments.

Depuis quelques années, le concept de systèmes riverains agroforestiers qui jouent de multiples rôles sur les plans écologique et économique reçoit une attention accrue de la part de plusieurs acteurs environnementaux et agricoles à cause des services écologiques qu'ils fournissent. Au Québec, par exemple, la Fondation de la faune du Québec et les comités de bassin versant en font la promotion, appuyés par des partenariats avec l'Union de producteurs agricoles (UPA) et les CCAE. Le réseau hydrographique du territoire agricole québécois est très dense, avec une moyenne de 1,7 km/km^2, et la productivité des cultures sur les zones adjacentes aux cours d'eau laisse souvent à désirer. Ces surfaces gagneraient donc à être valorisées par l'entremise de systèmes riverains agroforestiers. Le potentiel d'implantation de ces systèmes et leur capacité à produire des biens et services rémunérateurs pour l'agriculteur demanderaient à être quantifiés pour l'ensemble du territoire agricole.

LES SYSTÈMES AGROFORESTIERS À VOCATION PRODUCTIVE

Les systèmes agroforestiers productifs comprennent les systèmes sylvopastoraux, l'apisylviculture, les cultures sous couvert arboré, les cultures intercalaires et l'aquaforesterie. Aux fins de cette étude s'ajoute la ligniculture en courtes rotations.

Les systèmes sylvopastoraux

Les systèmes sylvopastoraux intègrent des arbres, des cultures fourragères et des animaux d'élevage selon une dynamique d'interactions planifiées. Bien que les élevages et la forêt cohabitent depuis longtemps sur le territoire agricole québécois, on rencontre peu de systèmes sylvopastoraux au Québec. Trois systèmes d'élevage repérés démontrent des similarités avec les systèmes sylvopastoraux :

- l'élevage de grands gibiers dans des boisés aménagés ou naturels afin d'imiter l'habitat naturel et d'augmenter le rendement de ce type d'élevage ;
- l'inclusion de boisés de ferme dans les pâturages afin de créer des aires d'abri pour les bovins ;
- la pratique de « l'installation minimale », c'est-à-dire des enclos d'hivernage en forêt ayant pour but d'augmenter la santé des bovins pendant l'hiver.

Au Québec, l'accès du bétail aux cours d'eau peut entraîner des problèmes de détérioration des rives et affecter la qualité de l'eau. Pour cette raison, le Règlement sur les exploitations agricoles (REA) interdit le libre accès des animaux aux cours d'eau ; conséquemment, de l'équipement d'abreuvement doit être installé.

L'apisylviculture

L'apisylviculture, ou l'apiculture à l'aide d'une espèce ligneuse, se pratique à grande échelle au Québec, notamment en associant des productions fruitières à l'apiculture. Un exemple de cette association est l'installation de ruches dans les bleuetières dans la région du Saguenay-Lac-Saint-Jean. La pollinisation de 90 % des bleuetières dans cette région est stimulée par l'introduction de ruches dans les champs de bleuets, basée sur des ententes formelles entre les apiculteurs et les producteurs de bleuets.

La culture sous couvert forestier

La culture sous couvert forestier est une autre pratique agroforestière importante au Québec, et ceci, pour deux raisons. D'une part, les cultures sous couvert forestier se profilent comme une stratégie intéressante de diversification des revenus dans les régions québécoises. D'autre part, ces cultures diminuent la pression humaine sur les populations naturelles de nombreuses plantes indigènes ombrophiles. Au Québec, il s'agit principalement de la culture du ginseng, de champignons, de la sanguinaire, de l'hydraste et de l'asaret. La culture de l'if du Canada présente aussi un intérêt.

À l'exception des champignons, les plantes sous couvert arboré se cultivent généralement dans les érablières matures pour des raisons d'ordres écologique et logistique. En effet, ces cultures ont une bonne complémentarité avec l'acériculture, car les activités liées à chacune s'effectuent à un moment différent dans la saison. Certaines organisations se révèlent particulièrement actives dans la recherche et le développement liés aux cultures sous couvert forestier au Québec : Ginseng Boréal, le Centre d'expertise sur les produits agroforestiers (CEPAF), Mycoflor (champignons), l'Université Laval, le ministère des Ressources naturelles et de la Faune du

Québec (MRNFQ). Bien que la production actuelle au Québec demeure modeste, un nombre grandissant de producteurs (majoritairement des acériculteurs) s'intéressent aux cultures sous couvert forestier.

Les cultures intercalaires

Les cultures intercalaires, soit l'établissement d'une culture annuelle entre des rangées d'arbres ou d'arbustes, est une pratique agroforestière peu connue au Québec. Toutefois, on commence à s'y intéresser sur le plan de la recherche universitaire, notamment à l'Université Laval, où le Groupe interdisciplinaire de recherche en agroforesterie (GIRAF) et d'autres acteurs de la recherche et du développement économique se sont associés dans l'intention d'étudier les interactions écologiques entre des végétaux ligneux et des cultures annuelles. Des sites de cultures intercalaires ont été implantés en Gaspésie par des agents de développement local, notamment à Val-d'Espoir (haricot – sureau blanc) et à Gaspé-Nord (courge d'hiver – amélanchier).

De par ses caractéristiques, le concept forêt-bleuets se rapproche de la culture intercalaire. Il s'agit de la culture de bleuets sur des éclaircissements de larges bandes de forêt (60 m), en alternance avec des bandes de forêt (42 m) qui sont exploitées de façon intensive. La mise au point du concept a été appuyée par le MRNFQ et par le Service canadien des forêts (Ressources naturelles Canada). Ce type d'aménagement a été réalisé dans quatre régions québécoises (en Gaspésie, au Saguenay-Lac-Saint-Jean, sur la Côte-Nord et en Mauricie), l'ensemble représentant environ 2 000 hectares.

L'aquaforesterie

Les plantations de saules et de peupliers possèdent la capacité de retenir le phosphore et autres matières contaminantes provenant d'eaux usées de diverses origines. Une seule expérience en aquaforesterie a été repérée au Québec. L'Institut de recherche en biologie végétale (IRBV) mène un projet de recherche visant l'utilisation de plantations de saules et de peupliers pour le traitement des effluents de pisciculture. Ce projet a pour objectif d'analyser la capacité de cette pratique à épurer les effluents avant qu'ils ne soient déversés dans un cours d'eau.

La ligniculture en courtes rotations

Dans la ligniculture en courtes rotations, des arbres et arbustes à croissance rapide, comme le saule et le peuplier, sont utilisés afin d'obtenir un maximum de rendement en matière ligneuse. Les plants de saules sont mis en terre une première année, puis récoltés par fauchage à tous les trois ans, pour une durée d'une vingtaine d'années. La coupe a pour effet de favoriser une repousse vigoureuse des tiges et d'accroître ainsi la production, d'où l'intérêt de la ligniculture de saules pour l'industrie du bois. La matière ligneuse de saules peut être intégrée, par exemple, à des panneaux de particules ou servir à la production d'énergie. Dans le cas du peuplier, la récolte du bois s'effectue de 10 à 20 ans après la plantation, après quoi les arbres doivent être replantés. Le peuplier trouve plusieurs usages dans les secteurs de la transformation du bois et des pâtes et papiers.

Sans être considérée comme une pratique agroforestière en soi, la ligniculture en courtes rotations offre un potentiel certain, entre autres pour la mise en valeur de terres en friche, et s'inscrit donc parmi les options technologiques à considérer sur le territoire agricole en harmonie avec les autres productions agroforestières. Plusieurs organisations, dont le ministère des Ressources naturelles du Canada, Agriculture et Agroalimentaires Canada, le MRNFQ, le Jardin botanique et le Centre d'expertise sur les produits agroforestiers (CEPAF), réalisent des travaux de recherche et de développement portant sur cette production.

LES PRODUITS AGROFORESTIERS ET LEUR MISE EN MARCHÉ

Les produits agroforestiers se divisent en deux grandes catégories, soit les produits ligneux et les produits non ligneux, ces derniers étant connus sous l'appellation PFNL, ou « produits forestiers non ligneux ».

Les produits forestiers ligneux

En agroforesterie, les haies brise-vent, les cultures intercalaires et les systèmes riverains agroforestiers offrent un potentiel intéressant de production ligneuse. Ce potentiel serait toutefois à être évalué de manière plus précise pour l'ensemble du territoire agricole québécois. Une production ligneuse prometteuse est anticipée dans les haies brise-vent et en ligniculture en courtes rotations de saule. La nature de ce dernier produit le destine principalement à la valorisation énergétique et à la production de fibres pour la production de bois d'ingénierie ou pour les pâtes et papiers.

Étant donné que la plus grande partie des haies brise-vent a été implantée récemment, peu d'expériences de mise en marché de produits agroforestiers ligneux ont été réalisées au Québec. La matière ligneuse issue de l'agroforesterie pourra bénéficier des réseaux de commercialisation régionaux existants en foresterie pour les résineux et les feuillus. Néanmoins, les modalités exactes de la mise en marché des produits agroforestiers ligneux restent à analyser.

Les produits forestiers non ligneux

Les produits forestiers non ligneux constituent une catégorie de production qui, au Québec, se situe, dans plusieurs cas, encore à un stade de démarrage et, souvent, à celui de la recherche et du développement. Pour certains produits, comme le bleuet, le miel ou le ginseng, les filières de mise en marché sont assez bien développées. Les principales catégories de PFNL sont présentées dans le Tableau 1.

Pour le développement des nouveaux produits, l'existence d'un marché constitue un facteur clé. À l'heure actuelle, le plus grand problème commercial concernant les PFNL est le manque de volume offert aux grossistes québécois et étrangers. Ceci n'est pas uniquement dû à la faible production de ces plantes au Québec, mais aussi à un manque d'organisation de l'offre. Il en résulte que la demande de certains marchés spécifiques aux PFNL – par exemple, le marché des produits naturels et de santé – n'est pas satisfaite. La popularité croissante des cultures sous couvert forestier laisse présager que cette carence de production pourrait à moyen terme s'estomper pour certaines productions.

Tableau 1 : Différentes catégories de produits forestiers non ligneux (Mompremier 2003)

Produits alimentaires	**Matériels et produits manufacturiers**	**Produits sanitaires et curatifs**	**Produits décoratifs et esthétiques**	**Produits environne-mentaux**	**Produits horticoles**
Baies	Adhésifs	Médicaments	Arbres de Noël	Biogaz	Arbres décoratifs
Miel	Alcool	Huiles essentielles	Cônes d'artisanat	Biopesticides	Arbustes
Sèves et sirops, sucres, caramel, beurres	Huiles essentielles	Cosmétiques	Artisanat avec l'écorce	Produits recyclés	Fleurs sauvages
Champignons	Résines	Parfums et fragrance	Artisanat de bois d'œuvre		Gazon
Noix	Produits ligneux spécialisés	Produits pour le traitement des animaux	Sculptures		Paillis
Semences	Bougies, chandelles	Shampooing	Arrangements floraux		Amendements du sol
Thé	Tissus	Savons	Couronnes		
Légumes	Térébenthine		Teintures naturelles		
	Encens				

Le développement de marchés alors que la production est en train de se mettre en place présente des risques que les agriculteurs et la petite industrie ne peuvent assumer seuls. Ainsi, par exemple, les filières de certains PFNL prometteurs, telles la sanguinaire et l'actée à grappes, mériteraient d'être soutenues à court et à moyen termes par des programmes et par l'apport d'expertise dans la mise en marché. Par ailleurs, les PFNL tout comme les produits ligneux pourraient bénéficier d'une stratégie de mise en valeur appuyée sur un label du type « produit agroforestier québécois ».

LES SERVICES RENDUS PAR L'AGROFORESTERIE AU QUÉBEC

En plus de produire des produits ligneux et non ligneux, les systèmes agroforestiers constituent également de remarquables fournisseurs de services, lesquels répondent à des besoins concrets de la société. Le Tableau 2 illustre l'éventail des services agroforestiers et, du même coup, l'intérêt socio-économique global de l'agroforesterie.

L'agroforesterie, qui s'inscrit de façon pratique dans le concept du développement durable, se révèle un outil concret pour mettre en valeur la multifonctionnalité de l'agriculture. Les pratiques agroforestières peuvent contribuer à la mise en place de « paysages humanisés » dans les régions rurales, et elles représentent aussi un volet important de l'approche multi-ressource de la gestion de la forêt privée. Cette polyvalence contribue à l'intérêt grandissant que démontrent des acteurs du développement économique régional pour les pratiques agroforestières, lesquelles sont intégrées dans divers projets d'aménagement et de développement. L'agroforesterie, génératrice de biens et de services environnementaux, peut ainsi être à l'origine de la création de tout un réseau de petites et moyennes entreprises dérivées qui offrent des services aux agriculteurs pour assurer le soutien aux opérations, à la récolte des produits, à leur transformation, à leur mise en marché.

Tableau 2 : Les différents services agroforestiers (adapté de Gold et al. 2000; Bellefontaine et al. 2001; Gordon et al. 1997)

Services économiques	• Diversification des activités économiques • Diversification des revenus agricoles • Augmentation du rendement de systèmes agricoles conventionnels • Mise en production de terres fragiles ou marginales
Services environnementaux	• Augmentation de la biodiversité floristique et faunique • Diminution de l'érosion éolienne et hydrique • Amélioration de la fertilité des sols • Amélioration du régime hydrologique des sols • Atténuation de la pollution atmosphérique, sonore et olfactive • Épuration d'eaux • Séquestration et stockage de carbone • Réduction de la déforestation • Amélioration de microclimats • Atténuation des effets des changements climatiques sur l'agriculture
Services sociaux	• Création d'emplois • Sécurité alimentaire • Embellissement du paysage • Amélioration de la perception de l'opinion publique quant à l'activité agricole et forestière
Services territoriaux	• Occupation diversifiée du territoire • Occupation de terres marginales (friches agricoles, parcelles en pente, etc.)
Services culturels	• Mise en valeur des connaissances locales et indigènes

Les fonctions économiques et environnementales sont souvent approchées de manière sectorielle dans le contexte des politiques et des programmes agricoles gouvernementaux, ce qui se traduit par de multiples volets qui évoluent en parallèle : assurances agricoles, réduction des risques pour l'environnement, conservation des sols, protection de la biodiversité, séquestration du carbone, etc. Pour sa part, l'agroforesterie représente un puissant outil d'intégration : la mise en place planifiée de ces systèmes atteint les divers objectifs simultanément.

LES RESSOURCES NÉCESSAIRES AU DÉVELOPPEMENT DE L'AGROFORESTERIE

Afin de déployer le potentiel agroforestier au Québec, un certain nombre de ressources doivent être accessibles aux producteurs agricoles : matérielles et foncières, humaines, informationnelles et financières.

Ressources matérielles et foncières

En premier lieu, selon le système à implanter, l'agroforesterie demande que des terres agricoles ou forestières soient disponibles. Le Québec possède une abondance de surfaces disponibles pour l'implantation de pratiques agroforestières, sous la forme de terres agricoles et forestières, privées et publiques. Les boisés de ferme et les terres agricoles en friche semblent très prometteurs pour une mise en valeur agroforestière. Aussi sollicitées pour des activités de reboisement forestier (ou afforestation), les friches doivent faire l'objet d'une attention particulière afin que leur aménagement ne crée pas de conflits avec d'autres usages du territoire. Un inventaire du territoire disponible devra être réalisé afin d'évaluer le potentiel de l'agroforesterie québécoise.

En plus des ressources matérielles habituelles – équipement, bâtiments –, l'agroforesterie requiert un matériel génétique (semences, plants) adapté aux besoins du domaine. Au Québec, un réseau de pépinières privées et publiques (appartenant au MRNFQ) assure la production de plants et de semences d'arbres et arbustes. Pour certaines productions (ginseng, champignons), de petites entreprises indépendantes distribuent le matériel (par exemple : Ginseng Boréal, Mycoflor inc.). L'accroissement du secteur de l'agroforesterie créera éventuellement une demande pour certaines espèces et pour de nouveaux produits.

Ressources humaines

Il existe déjà une bonne base de ressources humaines au Québec pour soutenir l'agroforesterie, autant dans les milieux éducatif et scientifique que dans les organismes de conseil agricole et forestier. À l'Université Laval, une maîtrise en agroforesterie tropicale et tempérée est offerte, alors que l'ITA, campus de La Pocatière, organise des cours techniques sur les bandes riveraines et les haies brise-vent. Cette dernière institution offre également une passerelle « agroforestière » entre le DEC en agroenvironnement et le baccalauréat en Agroforesterie à l'Université de Moncton, au Nouveau-Brunswick. Toutefois, on constate l'absence d'un programme technique complet en agroforesterie, couvrant tous les systèmes agroforestiers en climat tempéré et les aspects socioéconomiques et de gestion reliés à son application en milieu rural au Québec.

Dans le secteur agricole, les CCAE prêtent de l'assistance technique aux producteurs intéressés dans l'implantation de bandes riveraines et de haies brise-vent. De plus, le MAPAQ a formé des conseillers pour les aspects techniques de ces systèmes agroforestiers dans le cadre du programme Prime-Vert. Les contreparties forestières des CCAE, les groupements forestiers, accordent de plus en plus d'attention au potentiel non ligneux des forêts privées et disposent de techniciens spécialisés pour soutenir un processus vers l'exploitation forestière multi-ressource. Parmi les organismes les plus actifs dans le transfert de technologie envers les producteurs agroforestiers, on retrouve le CEPAF (haies brise-vent, bandes riveraines, cultures sous couvert forestier, ligniculture), Ginseng Boréal (cultures sous couvert forestier), Mycoflor inc. (champignons, cultures sous couvert forestier). Une riche expertise est aussi présente au sein de cellules spécialisées du MRNFQ et du MAPAQ ainsi que dans les centres de recherche œuvrant en agroforesterie. Enfin, le Centre des brise-vent d'Agriculture et Agroalimentaire Canada entretient de multiples partenariats avec des équipes de chercheurs du Québec, dont au Service canadien des forêts, à l'ITA et à l'Université Laval.

Ressources informationnelles

Au Québec, l'acquisition de connaissances en agroforesterie se fait par le biais de quelques groupes de recherche qui, en se basant sur la multidisciplinarité de l'agroforesterie, construisent souvent des partenariats avec des acteurs environnementaux, agricoles, forestiers et territoriaux. Néanmoins, les possibilités d'obtention de fonds de recherche en agroforesterie semblent plutôt dispersées et modestes. Un exemple remarquable d'un groupe de recherche en agroforesterie est le GIRAF, de l'Université Laval, qui encadre entre autres les projets de recherche des étudiants à la maîtrise et au doctorat. La diffusion des expériences scientifiques se réalise par des colloques, comme « L'agroforesterie au Québec », en 2002, et « Des arbres sur ma ferme », en 2004, ainsi que par des revues et ouvrages spécialisés. Pour le grand public, l'agroforesterie demeure encore méconnue, quoique certains médias, comme la revue agricole La Terre de chez nous et l'émission La Semaine verte, aient déjà abordé le sujet à quelques reprises.

Les ressources financières

Le financement de la mise en place de systèmes agroforestiers varie selon le contexte – agricole ou forestier – et selon la finalité poursuivie – par exemple, la production de fruits, la réduction des nuisances olfactives, la protection des cours d'eau ou la mise en valeur du paysage. Au Québec, ce sont les programmes incitatifs agroenvironnementaux qui soutiennent le plus les systèmes agroforestiers, soit le programme Prime-Vert et le programme de Couverture végétale du Canada (PCVC). Ces programmes encouragent l'adoption de haies brise-vent et la protection des bandes riveraines par des producteurs agricoles. La portée des projets reste restreinte, et l'approche est essentiellement ferme par ferme, mais ces programmes offrent aussi la possibilité d'inscrire les pratiques de gestion bénéfiques à l'intérieur d'une démarche collective, ce qui est grandement souhaitable en matière d'aménagement de systèmes agroforestiers.

Dans le secteur forestier, le Programme de mise en valeur de la forêt privée du MRNFQ pourrait, dans des cas précis, favoriser l'implantation de pratiques agroforestières comme les cultures intercalaires sur des terrains forestiers. À part ces programmes, il existe plusieurs fonds disponibles pour financer des projets individuels qui répondent aux critères spécifiques de chacun des bailleurs de fonds, dont le MRNFQ, la Fondation de la faune du Québec et le Fonds d'action québécois pour le développement durable (FAQDD). Enfin, au Québec, on peut également compter sur des structures de financement comme la Financière agricole et le Programme de financement forestier, qui offrent des outils financiers adaptés à de tels investissements. Les fonds de recherche, les programmes incitatifs et le financement sont ainsi dispersés à travers plusieurs secteurs, ministères et institutions. De surcroît, les programmes incitatifs ne touchent essentiellement qu'à deux systèmes, soit les haies brise-vent et les systèmes riverains. Les cultures intercalaires, les cultures sous couvert forestier et les systèmes sylvopastoraux ne sont présentement pas soutenus par les programmes existants au Québec.

LES ENJEUX DE L'AGROFORESTERIE AU QUÉBEC

L'identification des forces et faiblesses de l'agroforesterie permet de préciser les enjeux qui devront être solutionnés pour pouvoir développer ce domaine d'activité. Ces forces et faiblesses ont été identifiées lors d'une consultation effectuée en avril 2006 auprès de 21 intervenants en agroforesterie au Québec. Le Tableau 3 les présente de façon sommaire.

Grâce aux efforts d'acteurs gouvernementaux, privés et universitaires, le Québec peut aujourd'hui compter sur un certain nombre d'éléments clés : un nombre grandissant de haies brise-vent et une croissance des bandes riveraines arborées ; un programme de maîtrise francophone en agroforesterie ; plusieurs centres de recherche et développement qui acquièrent des connaissances en agroforesterie. De plus, les agriculteurs peuvent recevoir une aide de l'État pour certaines pratiques agroforestières, notamment pour des haies brise-vent et pour l'aménagement de bandes riveraines arborées. Cependant, un certain nombre d'enjeux doivent être surmontés afin d'assurer le déploiement du potentiel agroforestier québécois.

Tableau 3 : Les forces et faiblesses de l'agroforesterie au Québec

Forces	• La multifonctionnalité de l'agroforesterie (environnementale, économique et sociale) s'inscrit bien dans le courant du développement durable. • L'agroforesterie permet de diversifier les revenus à la ferme et présente un intérêt pour le développement économique régional. • L'agroforesterie contribue au maintien et à l'amélioration de la biodiversité ainsi qu'à la protection de l'environnement. • L'agroforesterie est un outil prometteur pour la mise en valeur des friches.
Faiblesses	• Il y a une carence de financement et d'incitations pour les pratiques agroforestières. • Il existe un manque de maillage et de coordination entre les différents intervenants. • Le manque de connaissances technico-économiques concerne la plupart des systèmes. • La formation en agroforesterie reste peu développée.

Ainsi, l'éventail des systèmes admissibles aux aides demeure restreint, et le financement opérationnel et structurel fait globalement défaut, ce qui est dû en bonne partie à un manque de reconnaissance de l'agroforesterie par les instances politiques et institutionnelles. Depuis plusieurs années, la société exige une gestion plus durable des ressources naturelles. L'agroforesterie possède le potentiel de diminuer la double pression qui s'exerce sur la forêt et sur les terres agricoles. Depuis 2005, l'Union européenne reconnaît l'agroforesterie au même titre que la foresterie et l'agriculture (Conseil de l'Union Européenne 2005) et, en France, depuis 2002, des programmes incitent les producteurs agricoles à mettre en place des productions agroforestières. Au Québec, le manque de reconnaissance institutionnelle de l'agroforesterie dans les politiques et programmes tant agricoles que forestiers constitue le premier enjeu à solutionner.

D'autres enjeux majeurs comprennent : le besoin d'inclure l'agroforesterie dans une perspective économique et commerciale plutôt qu'essentiellement agroenvironnementale ; l'acquisition, la gestion et le transfert de l'information et des connaissances ; finalement, la formation technique et scientifique.

CONCLUSION

L'agroforesterie offre de nombreux avantages, tant pour les producteurs agricoles que pour la société en général. Sans être une panacée, l'agroforesterie, par ses multiples fonctions environnementales et économiques, peut aider les secteurs agricole et forestier à trouver des solutions innovatrices aux problèmes actuels, dont le manque de rentabilité, l'impact sur l'environnement et la perception parfois négative du public à leur égard. Mieux encore, l'agroforesterie peut améliorer la qualité de vie des citoyens et des producteurs, aider à diversifier les revenus et contribuer à la revitalisation économique des régions dans le respect d'une gestion durable des ressources naturelles présentes sur le territoire.

Le présent rapport a mis en évidence que la popularité de toutes les pratiques agroforestières est en croissance. Un certain nombre d'éléments contraignants empêchent toutefois que le potentiel agroforestier québécois se déploie complètement. Parmi ceux-ci, la méconnaissance de l'agroforesterie par les instances politiques, mais aussi par le grand public, est un des plus importants. Il en résulte une promotion et un développement dispersés des pratiques agroforestières. D'autres contraintes, comme la carence des mécanismes incitatifs, la faible concertation entre les intervenants actuels et l'absence de certaines connaissances technico-économiques sur les systèmes agroforestiers, ont été identifiées lors de la réalisation de la présente étude.

À la suite des constats de cette étude, il ressort clairement que l'élaboration d'une stratégie et d'un plan d'action s'impose. À cette fin, cinq éléments stratégiques préliminaires sont proposés en vue du développement de l'agroforesterie au Québec, soit :

1. faire reconnaître le domaine de l'agroforesterie par les acteurs et décideurs politiques et institutionnels;
2. préconiser un partenariat intersectoriel;
3. adopter une approche de développement économique et de marchés;
4. appuyer le développement sur une base technique et économique solide;
5. assurer un financement structurant et opérationnel adéquat.

La mise en œuvre des recommandations du portrait de l'agroforesterie doit reposer sur la mobilisation des forces vives œuvrant actuellement pour l'agroforesterie au Québec ainsi que sur l'engagement de nouveaux partenaires. La réalisation du présent état de situation a permis de jeter les bases d'une collaboration intersectorielle, laquelle demande à être élargie. Le partenariat à établir rassemblerait les acteurs des domaines agricole, forestier, territorial et du développement économique, provenant tant du secteur gouvernemental et de l'industrie que de l'éducation et de la recherche. Ces partenaires pourront préciser la stratégie et établir un plan d'action vers la mise en œuvre de ce grand chantier que représente l'agroforesterie au Québec.

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POLICY AND PROGRAM INCENTIVES IN THE ADOPTION OF AGROFORESTRY IN MISSOURI

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Abstract: More landowners in the USA are concerned about management of their lands and natural resources in the light of negative effects of many agricultural practices on the environment. Land conservation program incentives, which include agroforestry, were designed by government agencies to ameliorate the problem. The study identifies and compares the characteristics of adopters and non adopters of agroforestry practices, and participation in state and federal government incentive programs that include trees and those who do not. The data from this study is drawn from a 2006 survey of 360 landowners conducted in four counties in two regions of Missouri, USA selected because of their proximity to agroforestry research centers, their rural or urban character, and a land holding greater than ten acres. Chi-square tests performed on selected variables find significant difference between adopters and non-adopters regarding their networks (contact with other farmers, their membership in organizations is higher in adopters), age between 30 and 50, and a greater proportion of adopters with positive perceptions of the economic importance of trees, as well as being informed, captured by more than one type of magazine subscription. Logistic regression is used to test on the level of significance of the independent variables on adoption, where age, contact with other farmers and number of magazines they subscribe to are significant determinants of adoption. Lessons are drawn on how sources of information can encourage stewardship practices that incorporate trees in the context of very diverse groups of landowners.

Key Words: Adoption, policy, incentive program, agroforestry, landowners.

INTRODUCTION

The effect of large scale agriculture on the environment has changed the policies of agriculture in the United States and in other parts of the world. The principal goal of agricultural policies worldwide previously was increasing agricultural output, but today protecting the environment and the resource base of agricultural production is becoming a concern of equal importance in much of the world (Lichtenberg 2000). Farming practices employed by America's two million farm operators have a major impact on the health of the ecosystem, sedimentation levels in streams and rivers, nutrient and pesticide runoff, groundwater contamination and air quality (Lambert et al. 2006).

The search for highly productive yet sustainable and environmentally responsible agricultural systems, has led to a renewed interest in agroforestry practices in the temperate regions of the world (Matson et al. 1997 cited in Jose 2004). Agroforestry enables landowners to generate income from the production of a wide range of conventional and specialty products and at the same time help in protecting and conserving the soil, water and other natural resources (Gold et al. 2004). Its adoption in temperate regions is not widespread compared to tropical countries.

Government intervention through various types of public programs is one way of motivating landowners to adopt agroforestry. At present, policy makers have limited knowledge of farmers' participation in agroforestry incentive programs. Despite incentives, adoption of agroforestry compared to agricultural-related programs is low. Concerns and issues exist about the costs, benefits and implementation of incentive programs. Batie (2001) listed the following constraints to participation by farmers in government programs; inadequate funding, the lack of problem targeting, the lack of programs tailored to specific circumstances, the complexity of the programs, and the reduced capacity of agencies to deliver such programs. These have been the criticism of farmers and ranchers on existing farm bill conservation programs.

Building strong partnerships and networks among landowners to help increase their knowledge can be an alternative approach to motivate landowners to invest in agroforestry. A review of available literature on adoption lists several limitations to adoption of agroforestry which include farm size, age, education, lack of information and technical assistance, lack of institutional support, lack of social networks, profitability and lack of established market information (Ervin and Ervin 1982; Korsching et al. 1983; Ayuk 1997; Long 2003; Workman et al. 2003; Gold et al. 2004; Strong 2004).

This study of landowners in Missouri seeks to identify what factors played a role in adopting agroforestry practices to enable policy makers, researchers and extension outreach professionals to understand differences in the motivating principles of the various types of landowners and how programs might incorporate these. In order to capture the diversity of motivating principles, and the role of proximity to and contact with research centers in Missouri several criteria were used for site selection. Criteria included proximity to university research station with agroforestry activities, regions with different agroecological and land use characteristics, a rural county per region, a county with an urban center per region, and land size holdings of ten or more acres.

LOCATION AND SAMPLE

Two distinct regions were selected. In Central Missouri where the horticulture and agroforestry research center of the University of Missouri is located (HARC), two counties were selected. These include Howard, a rural county where the center is located, and a county with a significant urban population, Boone where the city of Columbia is located. The second region is in the Ozarks, a region characterized by livestock production and forests, where two counties were selected. The first is Crawford with the Wurdack research center of the University of Missouri is located, and the second is Phelps, a county with the city of Rolla.

The random sample was chosen from county tax assessors' lists of property owners of the two counties per region. Random sampling with replacement was used. The sample frames included 4000 for HARC region (Howard and Boone counties) and 2100 for the Wurdack region (Crawford and Phelps counties). Respondents were contacted in the order drawn; 184 face to face interviews were completed for HARC and 176 for Wurdack, a total of 360 interviews. Questions asked included landowner characteristics, knowledge of the different agroforestry practices, benefits and obstacles of planting trees and sources of information about planting trees, along with questions about the landowners' activities and income sources.

ADOPTION OF AGROFORESTRY TECHNOLOGIES

The characteristics of adoption of agriculture and agroforestry technologies have been studied for decades. Studies addressing characteristics of adoption are discussed in this section to conceptualize a framework of adoption from previous studies.

Agroforestry as a new practice

The fundamental challenge in developing a new farming system is to have it adopted and maintained by farmers (Pannell 1999). By far the most difficult part of achieving widespread adoption is the complex system that agroforestry represents compared to current farming practices. Pannell (1999) identified four conditions under which farmers will consider adopting a new practice: awareness of the innovation, perception that it is feasible to implement the technology, perception that the innovation is worth trying and that the technology promotes the farmers objectives. Workman et al. (2003) also showed that lack of familiarity with the practice and lack of demonstration by professionals are seen as major obstacles to the use of agroforestry.

Lack of market and market information

Widespread adoption of agroforestry is lagging in North America because of the absence of readily available market information (Gold et al. 2004) when compared to commodities where market information is readily available. Workman et al. (2003) observed that lack of markets and market information ranked second in importance as a major obstacle to adopting agroforestry.

Access to information/Social network

Swanson et al. (1986 cited in Kurtz 2000) find sources of information as a barrier to adoption of soil conservation practices. Inability to access information regarding practices that provide solutions to problems inhibits adoption (Kurtz 2000). Long (2003) used the America Farmland Trust survey of 1,617 landowners in five states using logistic regression to identify how information about conservation practices can motivate landowners to adopt the practices. Out of the 1,617 landowners interviewed, 22 used practices based on information they received. Four landowners were interested in a practice, and then sought information about it. The interviewed landowners were informed of practices mainly through relatives, friends, government agencies, cooperatives and university extension. (Glendinning et al. 2001) said the most commonly used channels of communication were the extension agent, neighboring farmers and group meetings used to promote the new technology.

Perception of trees

There are many studies on the impact of farmers' social-psychological variables towards the adoption of new agricultural technologies and soil conservation technologies to enhance agricultural yields. But there is still a gap in the understanding of how these factors influence the motivation of farmers to grow trees in agroforestry systems (Stood and Mitchell 2004). A valuable approach in developing agroforestry is to utilize the perceptions of landowners with regard to trees and forest. It is likely that the successful adoption of conservation practices will be influenced more by a farmer's attitude and perceptions than any other factors (Adewale and Martin 1995). Stood and Mitchell (2004) find, with a survey of farmers in traditional agroforestry systems of western Himalaya that perceptional and attitudinal aspects, such as their perceptions of restrictions of trees on their own land, were the most important socio-psychological factors influencing tree growing. Mangaoang (2002) showed how tree farming depends largely on how people perceive the value and usefulness of the undertaking in their day-to-day living, finding that those who perceive that cultivation of trees is economically beneficial, are more likely to engage in tree farming. Beliefs about the potential benefit from trees, whether related to natural resources or economic issues, can have an impact on whether farm operators will adopt agroforesty in temperate regions (Valdivia et al. 2001).

Education

A positive association has been found between education and the use of conservation practices (Ervin and Ervin 1982). Korsching et al. (1983) also showed that education relates directly to innovation. The higher the level of education the more likely landowners are to be interested in adopting new practices like agroforestry.

Age

There is inconsistent evidence about the relationship of age and innovativeness (Rogers 2003). About half of the many diffusion studies on adoption show no relationship, a few found that early adopters are younger and some indicate they are older (Rogers 2003). Age is thought to be detrimental to the adoption of agroforestry as the older people are, the less likely they are to be interested in implementing new practices. Ayuk (1997) concluded that it can be due to the fact that, the profitability of adoption may be an increasing function of time.

Farm Size

Studies on farm size and the use of practices show either a significant effect (Nowak and Korsching 1981) or a strong positive relationship (Ervin and Ervin 1982). Most studies indicate the larger the farm size the greater the use of conservation practices. Lynch and Brown (2000) found that farm size affects by the choice of buffer. Feder et al. (1985) reviewed the extensive literature on adoption of agricultural innovations reaching a similar conclusion, farm size is one of the most important factors determining adoption decision.

THE MODEL AND ESTIMATION

Adoption of Agroforestry (AoA) is a function of market information (MI); perception of trees (PT); individual characteristics (D & E); and social networks (N). The relationship is expressed as: AoA = F (MI;PT;D&E;N). Two approaches are used to study the differences between groups and the effects of the variables on adoption. The first compares the characteristics of adopters and non adopters using Chi-Square tests. The second is a logistic regression model that measures the effect of each variable of the adoption of agroforestry.

Landowners perception of trees (PT), perceived benefits of planting trees, whether related to natural resources or economic issues will have a positive effect on adoption (+). Market Information (MI) measured as awareness of timber markets and confidence in getting a fair price for wood have a positive relationship with adoption of agroforestry (+). Social Networks (N) measured as membership in organizations, contact with extension agent, contact with other farmers, and number of magazines subscribe have a positive relationship with adoption (+). Individual characteristics – demographic and economic (D & E) such as the older the farmer is beyond 50 it is negatively (-) related to adoption of agroforestry due to the shorter planning horizons of older farmers. A higher educational level is assumed to be positively (+) related to the adoption of agroforestry. Educated landowners may have a better understanding of the environmental benefits and other merits of adopting agroforestry; Economics (E) measured as farm size will have a positive effect on adoption.

Defining the variables

The dependent variable, adoption and non-adoption of agroforestry, was constructed from a set of six questions asking how much land a respondent had under various agroforestry practices. The variables were recorded as '1' for adopters, those who have land in any of the practices; and '0' for non-adopters, who do not have land in any of the practices.

Independent variables included perception of trees –economic and non economic-, sources of information – markets and other-, networks, and demographic characteristics. The perception of trees was captured by the landowners' perception of the benefits and obstacles of planting trees. These were grouped into economic and non economic benefits and scored as follows: some what important = 1 and not important = 0. Perceived obstacles of planting trees were grouped as tree specific obstacles and economic and information obstacles in the following way: any influence = 1 and no influence = 0. The variables for market information were respondents' awareness of timber markets in their area: 1 = Yes and 0 = No, and level of confidence in getting a fair price for wood, depicted as some what confident = 1 and not confident = 0. The source of information was identification of where landowners obtain their information about the practice, their information networks. The variables are: a) whether the landowner attended field days with Extension Service (1 = Yes and 0 = No); b) landowner contact with other farmers with response as 1 = Yes and 0 = No; c) what forestry or farm related organizations the landowners belonged to, 1 = Yes and 0 = No if the landowners are in or not in any organization and if the landowner subscribes to magazines with 1=Yes or 0=No. The number of organization and number of magazines subscribed by each landowner is included. The variable age represents the age of the farmer by groups (30-50; 51-80; >80). Education is classified in four categories: less than high school, completed high school, some college, college and beyond. The question on how many acres of land a landowner owns, used to capture the farm size of each landowner, is classified in three categories, 10-500, 501-1001, and 1002-2500.

RESULTS AND FINDINGS

The purpose of this research is to determine which factors are characteristic of adopters of agroforestry practices. Adopters are those implementing any agroforestry practices. In the sample of 360 landowners 112 (31.2%) are adopters and 247 (68.8%) are non-adopters. Analysis of the differences between adopters and non-adopters as a function of participation in any incentive programs shows that of the 112 adopters, 78.6% have not participated in any incentive programs, while 21.4 percent have. In the case of non-adopters, 83.4% have not participated in any incentive program, and only 16.6 percent have. Participation in incentive programs is not the experience of the majority of landowners, but adopters do participate in programs more than non adopters in relative terms (Table 1).

Table 1: Comparison on participants and non-participants in incentive programs amongst adopters and non-adopters of agroforesty practices in two Missouri Regions, 2006.

	Non-participants in incentive programs	**Participants in incentive programs**	**Total**
Adopters	88 (78.6%)	24 (21.4%)	112
Non-adopters	206 (83.4%)	41 (16.6%)	247

Chi-square tests were performed on the selected variables to test for significant differences between adopters and non-adopters. Results are presented in Table 2. The following variables, awareness of timber market, confidence in having a fair price for selling wood products, contact with University Extension, education, farm size, non-economic benefits in planting trees, economic and information obstacles in planting trees were found to be not significantly different between adopters and non-adopters. On the other hand economic benefits of planting trees, contact with other farmers, number of organizations they belong to and age were highly significant different ($p<0.01$), while tree specific obstacles, and number of magazines subscribed to were found to be significant different ($p<0.05$), and education was different at $p<0.1$ between adopters and non- adopters (Table 2).

Logistic regression results

The logistic regression model tested the relationship between the explanatory variables listed in table 2 and adoption of agroforestry as the dependent variable. Only contact with other farmers and the number of magazine subscriptions had a positive and significant effect on the likelihood of adoption of agroforestry. Age on the other hand lowered the probability of adopting agroforestry.

Table 2: Frequency, percentage, and chi-square value of variables differentiating adopters and non-adopters of agroforesty in two regions of Missouri, 2006.

	Adopters Freq. percent	Non-adopters Freq. percent	Chi-square
Aware of timber market			0.646
Yes	51 45.9	119 48.6	
NO	60 54.1	126 51.8	
Confident of having a fair price for selling wood products			0.223
Some confidence	63 66.3	146 67.0	
No confidence	32 33.7	72 33.0	
Contact with other farmers			0.001
Yes	65 58.0	94 39.0	
NO	47 42.0	147 61.0	
Attended field days with Extension			0.189
Yes	22 19.6	35 14.2	
NO	90 80.4	212 85.8	
Member of a farm organization			0.008
Not a member	78 69.6	210 85.0	
Member of one	19 17.0	23 9.3	
Member of two	9 8.0	9 3.6	
Member of three	6 5.4	5 2.0	
Number of magazines subscribed to			0.052
Don't subscribe	32 28.6	77 31.2	
Subscribe 0ne	34 30.4	102 41.3	
Subscribe two	23 20.5	29 11.7	
Subscribe three	23 20.5	39 15.8	
Age			0.011
30-50	44 39.3	58 23.9	
51-81	65 58.0	174 71.6	
82-100	3 2.7	11 4.5	
Education			0.073
Less than high school	3 2.7	18 7.3	
High school	37 33.0	101 40.9	
Some college	25 22.3	37 15.0	
College or greater	47 42.0	91 36.8	
Farm size			0.809
10-500	107 95.5	233 94.3	
501-1001	3 2.7	10 4.0	
1002-2500	2 1.8	4 1.6	
Economic Benefits			0.014
Some important	89 82.4	159 69.7	
No important	19 17.6	69 30.3	
Non-economic benefits			0.131
Some what important	103 95.4	213 90.6	
Not important	5 4.6	22 9.4	
Tree specific obstacles			0.046
Some influence	97 90.7	41 7.7	
Not influence	10 9.3	191 82.3	
Economic and information obstacles			0.178
Some influence	94 91.3	33 14.0	
Not influence	9 8.7	203 86.0	

Significance level ≤ .05

Findings

Thirty-one percent of a sample of landowners in Missouri practiced at least one type of agroforestry practice. While incentive programs were not critical to adoption, as only 21% did participate in these, there were differences between adopters and non adopters as the latter in the selected regions don't tend to participate (only 16.6%). This contrasts with regions of crop farming where participation in federal programs is high. It highlights that incentive programs are only one factor. In comparing adopters and non adopters, having contact with other farmers and membership in organizations the former have more connections, which highlights the role of networks and their role in enhancing knowledge and opportunities. The level of connectedness plays a role and should inform the way information on agroforestry technology is delivered. The profile of adopters also indicates that education plays a role, especially those in the category of some college and above. These are more likely to adopt agroforestry. Perception of the economic benefits of trees is also a characteristic more present in the adopters than in the non adopters group.

CONCLUSION AND FURTHER RESEARCH

The objective of this research has been to identify and evaluate those factors influencing the adoption, farmer perception of trees, and knowledge about market. Adopters and non-adopters of agroforestry were compared. It was found that age, contact with farmers, member of organization and number of magazines they subscribed was found to be significantly different between both groups. Using logistic regression, the predominant factors identify affecting adoption are age, contact with farmers, and magazines they subscribed to. Findings point to the need to building strong partnerships and networks among landowners, as a mechanism to increase their knowledge about agroforestry, of the economic benefits it can yield, as their interest in trees is also linked to the economic benefits. There are several areas of further research, which include the development of a model that incorporates continuous variables to measure effect on a logistic regression. While the categorical variables as defined were many of them significant, it may be doing away with the inherent variability. It is possible that effects can be captured if landholding size (farm size), age, education are incorporated as continuous. A procedure to create categorical variables that does not eliminate variability is also necessary for perception questions including Benefits of Trees, economic and non economic, as well as the obstacles to incorporation of trees.

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PATHWAYS TO AGROFORESTRY: LANDOWNER TYPES, LAND USE AND PERCEPTIONS

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Abstract: Land in the United States is predominantly owned by private individuals and families, and has traditionally been used for economic profit through agricultural or timber production. However, U.S. landownership patterns are changing, and an increasing number of landowners are acquiring land for non-monetary, amenity-based reasons. These changes impact landscapes and effective delivery of agroforestry and natural resource-based education and technical assistance programs. This paper explores the relationships between landowner types, land use orientation, perceptions of trees and knowledge and interest in agroforestry practices. The sample (N=298) is divided into three landowner type sub-groups: 1) those who have never farmed; 2) those who have previously farmed; and 3) those who are currently farming.

Results presented are based on a 2006 survey conducted in four counties located in two different ecoregions of Missouri, selected due to proximity to University of Missouri research farms with ongoing agroforestry research. One county in each region was chosen for its rural character; the other included an urban center. The population surveyed included all landowners with 10 or more acres of land.

Key Words: Landowner types, land use orientation, perceptions, knowledge and interest.

INTRODUCTION

The United States presents unique challenges for comprehensive ecosystem management because the majority of its land (over 60%) is privately owned (Lubowski et al. 2006). While private landowners make decisions over their own land use, the environmental impacts of their decisions are felt far beyond ownership boundaries (Agarwal et al. 2002; Theobold 2004). In order to meet growing environmental challenges, landowners must be engaged and empowered to make environmentally-sound decisions (Dutcher et al. 2004). Efforts to encourage landowners to make responsible environmental choices have traditionally focused on conservation practices appropriate for adoption by farmers or others involved in economic transactions with their land, including forestry (Lockeretz 1990; Koontz 2001; Conway et al. 2003). Agroforestry, the integration of trees with farming, is one set of practices promoted to improve production while conserving and improving land, air and water resources (AFTA 2000).

Various studies have shown that involvement in resource extraction occupations have significant impacts on environmental concern. Lower levels of environmental concern have been associated primarily with two groups including 'industrialists,' (private-sector executives, managers or professionals, especially those in resource extraction or manufacturing industries) and workers and self-employed people whose jobs are directly related to resource extraction, including agriculture and forestry (Greenbaum 1995; Jones and Dunlap 2001). Many studies have demonstrated that farmers have lower levels of environmental awareness and concern than their non-farm counterparts, as well as relatively low concern for agriculturally related environmental problems (Buttel et al. 1981). However, the same studies point to great variability among farmers, with many farmers moving toward alternative practices due to health and environmental concerns related to conventional agriculture. The level of economic orientation of farmers is an important determinant of environmental attitudes, with those farmers demonstrating higher economic orientation also demonstrating lower environmental concern (Buttel et al. 1981). Camboni et al. (1990) also discuss the importance of economic benefits and profitability in farmer decision-making.

While agriculture continues to be an important use of land in the United States, landownership trends are changing—there are fewer farmers and increasing numbers of landowners with smaller parcels who consider their land as a place to consume amenities rather than a space for production (Koontz 2001; Brogden and Greenberg 2003; Walker and Fortmann 2003; Smith and Sharp 2005). To create success in addressing environmental concerns, all landowners will play a role. This paper explores the relationships between landowner types, land use orientation, perceptions of trees and knowledge and interest in agroforestry practices.

METHODS

A 2006 survey of landowners was conducted in four counties located in two different ecoregions of Missouri. The counties were selected due to their proximity to University of Missouri research farms with ongoing agroforestry research, increasing the likelihood of landowner exposure to the concepts of agroforestry. One county in each region was chosen for its rural character; the other included an urban center. A random sample was taken of all landowners with 10 or more acres of land, based on county tax assessor records from 2005. Structured face-to-face interviews were used to collect data. The interview instrument included questions on landowner type, farming background, demographics, perceptions of planting trees as well as interest, knowledge and adoption of agroforestry practices. SPSS was used to analyze the data.

RESULTS AND DISCUSSION

Respondents are divided into three categories of landowner types: those who never farmed (n=107), those who previously farmed (n=79), and those who are currently farming (n=112). "Currently farming" includes both full-time and part-time farmers. As seen in Table 1, age and marital status are fairly consistent across all three groups. However, there is a statistically significant difference in education, with those who have never farmed reporting the highest level of educational attainment and those who are currently farming showing the lowest. A statistically significant difference between these groups also exists in terms of gender, demonstrating that women respondents have less farming experience. As may be expected, the number of acres owned, gross revenue from agricultural products and percent of gross income from farming also vary across groups in a statistically significant manner, with those currently farming registering the highest means in all three categories, and those who never farmed reporting the lowest.

Table 1: Demographic and land characteristics by landowner type.

	Never Farmed	Previously Farmed	Currently Farming
Gender**			
Male	62.6%	83.5%	79.5%
Female	37.4%	16.5%	20.5%
Marital Status			
Married	82.2%	77.2%	86.6%
Never Married	1.9%	2.5%	1.8%
Divorced/Separated	8.4%	10.1%	6.3%
Widow/widower	7.5%	10.1%	5.4%
Education**			
Less Than High School	1.9%	8.9%	6.3%
High School	32.7%	41.8%	42.9%
Some College	28.0%	7.6%	17.9%
College or Greater	37.4%	41.8%	33.0%
Number of Acres Owned***			
10-20	34.6%	20.3%	8.9%
21-40	31.8%	15.2%	10.7%
41-80	15.9%	19.0%	20.5%
81-120	8.4%	11.4%	8.0%
121+	9.3%	34.2%	51.8%
Likelihood of Passing Land to Family Member***			
Very Unlikely	44.9%	16.5%	15.2%
Unlikely	12.1%	26.6%	19.6%
Unsure	12.1%	12.7%	10.7%
Likely	7.5%	21.5%	14.3%
Very Likely	22.4%	21.5%	37.5%
MEANS			
Age	56.5	60.7	56.5
Number of Years Land in Family**	25.7	41.1	35.6
Gross Revenue from Agricultural Products***	$194	$3,168	$36,135
% Gross Income from Farming (last 3 years)***	4.4%	13.2%	32.8%

*Significance level ≤ .05
**Significance level ≤ .01
*** Significance level ≤ .001

Generational aspects of land attachment can be an important variable in landowner decision-making and include both landowners' hopes to pass land on to family members and their family heritage of landownership (Richter 2005). In this study, the likelihood of passing land to a family member varies significantly across groups. Those with farming experience show the greatest likelihood of passing land on to a family member, with 51.8% of current farmers and 43.0% of those who previously farmed stating that they are likely or very likely to do so. Only 29.9% of respondents who never farmed reported that they are likely or very likely to pass their land to a family member. The number of years land has been in the family is also statistically significant, with those who previously farmed reporting the highest mean number of years at 41.1. Those who are currently farming report a mean of 35.6 years while those who have never farmed have a mean of just 25.7 years.

Respondents were asked a series of questions about their perceptions of trees, including both obstacles to planting trees and benefits of planting trees. The Likert scale responses were developed into three separate index variables reported in Table 2.

Table 2: Index variables: Perceptions of planting trees.

Variable Name	Survey Question
Perception: Economic Obstacles	The following is a list of potential obstacles to planting trees. Please indicate how much influence each of the factors would have in reducing your interest in planting trees (1=no influence; 5=very large influence).
	-Negative effects on crops (e.g. weeds, pests, shade, nutrient loss)
	-Inadequate market prices for timber
	-Costs of establishing and managing trees
	-Trees are an obstacle for farm equipment
	-Takes too long to make a profit
Perception: Economic Benefits	If you were to consider planting trees on your property, please indicate how important each of the following potential benefits would be to you (1=unimportant; 4=very important).
	-Economic benefits
	-Erosion control
	-Tax benefits
Perception: Amenity Benefits	If you were to consider planting trees on your property, please indicate how important each of the following potential benefits would be to you (1=unimportant; 4=very important).
	-Wildlife
	-Scenic beauty
	-Protect water quality

The results are recorded in Table 3. Both economic perception variables (obstacles and benefits) show statistically significant differences between the three landowner types. More than two-thirds (66.9%) of landowners who are currently farming rate the importance of the economic obstacles to planting trees (Perception: Economic obstacles) as medium or high, whereas those who previously farmed and those who have never farmed rate economic obstacles as being of low importance, 49.4% and 62.6% respectively. Landowners' current or prior experience with farming translates into higher rankings of the importance of economic benefits of planting trees (Perception: Economic benefits), with 63.4% of current farmers and 69.6% of former farmers responding that the economic benefits of trees had medium or high importance. In contrast, landowners who have never farmed found the economic benefits of planting trees as medium or high importance just 56.1% of the time. The difference between groups is even more pronounced when looking exclusively at the category of high importance, where just 14.0% of landowners who have never farmed placed high importance on the economic benefits of trees while those who previously farmed and those currently farming reported high importance 36.7% and 29.5% respectively.

Table 3: Perceptions of planting trees and interest and knowledge in agroforestry by landowner type.

	Never Farmed	Previously Farmed	Currently Farming
Perception: Economic obstacles* **			
Low	62.6%	49.4%	33.0%
Medium	32.7%	32.9%	46.4%
High	4.7%	17.7%	20.5%
Perception: Economic benefits **			
Low	43.9%	30.4%	36.6%
Medium	42.1%	32.9%	33.9%
High	14.0%	36.7%	29.5%
Perceptions: Amenity benefits			
Low	24.3%	17.7%	33.9%
Medium	29.0%	32.9%	31.2%
High	46.7%	49.4%	33.9%
Interest: Economic			
No	72.9%	59.5%	64.3%
Yes	27.1%	40.5%	35.7%
Interest: Conserve **			
No	65.4%	45.6%	48.2%
Yes	34.6%	54.4%	51.8%
Knowledge: Economic **			
Low	92.5%	75.9%	84.8%
High	7.5%	24.1%	15.2%
Knowledge: Conserve			
Low	61.7%	48.1%	53.6%
High	38.3%	51.9%	46.4%

*Significance level ≤ .05
**Significance level ≤ .01
*** Significance level ≤ .001

Perceptions of the amenity benefits of planting trees (Perceptions: Amenity benefits), did not show statistically significant differences across landowner groups. However, those who have never farmed report considerably higher perceptions of the amenity benefits of planting trees than economic benefits, with 46.7% ranking amenity benefits high and just 14.0% ranking economic benefits as high. Interestingly, those who are currently farming report fairly consistent perceptions for both amenity and economic benefits. Those who previously farmed report higher importance on perceptions of the amenity benefits of planting trees (49.4% ranking them high) than economic benefits (36.7% ranking high).

Respondents were also asked to rank their interest and knowledge in six agroforestry practices during the interview process. Interest was measured on a 4 point Likert scale (1=uninterested; 4=very interested); knowledge was measured on a 5 point Likert scale (1=very low; 5=very high). Responses to questions on four of the practices are used in this study. Alley cropping and silvopasture are grouped together to represent agroforestry practices primarily focused on economic factors (Interest: Economic; Knowledge: Economic) because they have stronger income potential and are associated with agricultural production. Riparian buffers and windbreaks are grouped as conservation practices (Interest: Conserve; Knowledge: Conserve) due to their emphasis on conservation and ecological benefits, their association with environmental protection and restoration, and their lower likelihood of resulting in direct economic benefit. Interest in agroforestry conservation practices (riparian buffers and windbreaks) and knowledge of agroforestry economic practices (alley cropping and silvopature) both show statistically significant differences between the landowner groups. Those who previously farmed showed the most interest and the highest knowledge in each category. This may indicate an interest among former farmers to re-enter agriculture if appropriate technology enables them to pursue alternative enterprises consistent with their life stage. Furthermore, it is encouraging to note that landowners report interest in agroforestry conservation practices at roughly the same rate as their knowledge, and their interest in agroforestry economic practices actually exceeds their current level of knowledge on those practices.

According to the bivariate analysis reported in Table 4, age negatively correlates with a number of variables in a statistically significant manner, including interest in both economic and conservation-targeted agroforestry practices, perceptions of both economic and amenity benefits of planting trees as well as perceptions about the economic obstacles to planting trees than their older counterparts. While education levels do not correlate with perceptions of the economic obstacles of planting trees, there is a positive relationship between education and perceptions of the economic and amenity benefits of planting trees, as well as interest and knowledge in agroforestry practices aimed primarily at conservation. Landowner type is positively correlated with the perception of economic obstacles to planting trees, and perception of economic obstacles is positively correlated with the perception of economic benefits of planting trees. Based on these results, it may be worthwhile to target younger, better educated landowners with information about agroforestry rather than focusing on landowner types defined by their orientation toward farming.

Perceptions of the economic benefits to planting trees demonstrate moderate correlation with interest in agroforestry economic practices, and both interest and knowledge in agroforestry conservation practices. There is also a small correlation between perceptions of economic benefits and knowledge of economic agroforestry practices. Perceptions of amenity benefits of planting trees show small to moderate correlations with both knowledge and both interest categories. The strongest correlations are between the two interest categories, the two knowledge categories and the two perceptions of benefits categories. These results may demonstrate that a major strength of agroforestry is its multi-functionality, including both amenity and economic benefits.

Table 4: Correlations between significant demographic variables, landowner types, perceptions, interest, and knowledge.

	Age	Education	Landowner Type	Perception: Economic Obstacles	Perception: Economic Benefits	Perception: Amenity Benefits	Interest: Conserve	Interest: Economic	Knowledge: Conserve	Knowledge: Economic
Age	1									
Education	-.188***	1								
Landowner Type	.000	-.090	1							
Perception: Economic obstacles	-.015	-.077	.299***	1						
Perception: Economic benefits	-.334***	.185***	.104	.193***	1					
Perception: Amenity benefits	-.360***	.319***	-.112	-.045	.684***	1				
Interest: Conserve	-.208***	.149**	.093	.016	.420***	.382***	1			
Interest: Economic	-.218***	.055	.084	.128*	.393***	.291***	.552***	1		
Knowledge: Conserve	-.037	.214***	.065	.025	.318***	.292***	.302***	.105	1	
Knowledge: Economic	-.026	.100	.120	.059	.183**	.148*	.108	.182***	.616***	1

*Correlation significant at .05 level (2-tailed)
**Correlation significant at .01 level (2-tailed)
***Correlation significant at .001 level (2-tailed)

CONCLUSION

This paper examines the relationship between landowner types, their land use orientation, perceptions of planting trees and their interest and knowledge in agroforestry. Both knowledge and interest of agroforestry economic practices and agroforestry conservation practices show strong correlations, indicating that agroforestry may be valued for its integration of economic and amenity benefits. Furthermore, landowners report interest in agroforestry conservation practices at roughly the same rate as their knowledge, while their interest in agroforestry economic practices actually exceeds their current level of knowledge on those practices. While this study does not look at causal relationships between knowledge and interest, this result may indicate that most landowners who have knowledge about agroforestry also demonstrate interest, and there is an opportunity to increase adoption of agroforestry through landowner education.

The results of this study also suggest that younger and better educated landowners place higher importance on both the economic and amenity benefits of planting trees, and demonstrate greater interest in agroforestry practices. There are significant differences between those who are currently farming, those who used to farm and those who have never farmed in a number of important variables. In particular, those who have farming experience and/or are currently farming rank the importance of economic obstacles and benefits of planting trees as higher than those who have never farmed. Those who are not currently engaged in farming report higher importance of the amenity benefits of planting trees than those who are currently farming.

Landowners with current or prior farming experience demonstrate higher rates of knowledge of both economic and conservation agroforestry practices. This may indicate that information about agroforestry practices is primarily distributed through channels traditionally utilized by the agricultural community, such as university extension. In order to create knowledge among non-farming landowners it may be helpful to explore alternative sources for information distribution.

Despite the differences reported in knowledge, however, land use orientation among landowner types does not necessarily translate into statistically significant differences in the knowledge and interest of conservation and economic agroforestry practices. This suggests that orientation toward trees may be more important than a landowner's involvement in extractive industries like agriculture and forestry. Further analysis treating perceptions of trees as a moderating variable between landowner type and interest and knowledge in agroforestry is needed.

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DEVELOPPEMENT DE SYSTEMES DE BOISEMENT ET D'AGROFORESTERIE EN COURTES ROTATIONS A DES FINS ENERGETIQUES : POLITIQUES, LOIS, PROGRAMMES ET FACTEURS SOCIAUX

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Résumé : La viabilité de quatre systèmes de boisement et d'agroforesterie en courtes rotations est examinée sous l'angle du contexte politique, législatif et réglementaire et de l'intérêt des principaux acteurs pour ces nouvelles technologies. Pour ce faire, trois activités sont réalisées au Québec et dans les Prairies, à savoir l'analyse de lois, politiques, règlements et programmes; une série de focus groups auprès de propriétaires terriens; et des entrevues en profondeur avec des acteurs clés.

Les deux premières activités ont permis d'identifier plusieurs enjeux pouvant influer sur le développement et l'adoption des systèmes à l'étude, notamment leur nature ambiguë (agricole ou forestière) dans les lois, politiques et programmes incitatifs; les risques perçus par les propriétaires sur les systèmes de production et les marchés; et les risques environnementaux liés à l'utilisation d'espèces exotiques.

Mots-clés : Agroforesterie, boisement, bioénergie, viabilité socio-économique, politiques, programmes, facteurs sociaux.

Abstract: The feasibility of four plantation/agroforestry systems is examined from the points of view of their policy, legislative and regulatory context, and of the potential interest of key stakeholders for these new technologies. To reach these objectives, three main activities are being implemented in Quebec as well as in the Prairie provinces: an analysis of laws, regulations, policies and programs; a series of focus groups of landowners; and in-depth interviews with key stakeholders.

The first two activities allowed us to identify several issues that could have an effect on the development and adoption of the plantation/agroforestry systems, including their ambiguous status in laws, policies and incentive programs; risks perceived by landowners regarding the production systems and the markets; and risks for the environment linked to the use of exotic species.

Key Words: Agroforestry, afforestation, bioenergy, socio-economic feasibility, policies, programs, social factors.

CONTEXTE ET OBJECTIFS

Dans le cadre d'un projet de recherche entrepris en 2005 par l'entremise du Programme Technologie et Innovation de Ressources naturelles Canada, dix centres de recherche canadiens travaillent de concert afin de développer quatre systèmes de boisement et d'agroforesterie en courtes rotations, dans le but de produire de l'énergie et de réduire les émissions de gaz à effet de serre. Il s'agit de 1) la culture intensive en courtes rotations (3 à 4 ans) du saule et du peuplier hybride, 2) la plantation en blocs du peuplier hybride (rotations de 15 à 20 ans), 3) la culture intercalaire[7] avec saule et peuplier hybride et 4) les bandes de protection riveraines à base de saule.

Un des volets de ce projet consiste à examiner les facteurs sociaux et les politiques qui peuvent influer sur le développement et l'application de ces nouvelles technologies. Ce volet examine la viabilité des systèmes de deux points de vue : 1) le contexte politique, législatif et réglementaire; 2) l'intérêt des principaux acteurs pour les technologies. Pour ce faire, trois activités sont réalisées au Québec et dans les trois provinces des Prairies (Manitoba, Saskatchewan et Alberta) : 1) analyse des lois, politiques, règlements et programmes; 2) réalisation d'une série de focus groups auprès de propriétaires terriens; 3) tenue d'entrevues en profondeur avec des acteurs clés.

À ce jour, les deux premières activités ont permis d'identifier plusieurs enjeux pouvant conditionner le développement et l'adoption des technologies à l'étude. Cette présentation donne un aperçu des résultats obtenus pour le Québec.

LOIS, POLITIQUES, REGLEMENTS ET PROGRAMMES

Les différents outils réglementaires et programmes incitatifs ont été examinés selon les trois niveaux de gouvernement (fédéral, provincial et municipal), permettant ainsi d'identifier des enjeux ayant une incidence sur l'application des technologies (Marchand et Masse, sous presse), notamment :

- Un cadre législatif et politique en plein essor, comme le montrent notamment le nouveau plan d'action 2006-2012 du Québec sur les changements climatiques, l'annonce d'un nouveau plan d'action du Canada sur les changements climatiques et l'annonce d'une stratégie provinciale d'investissements sylvicoles.

- Le manque de souplesse de la plupart des programmes incitatifs actuels (qui s'adressent soit à des producteurs forestiers ou à des producteurs agricoles), en regard du statut imprécis des technologies et de leurs produits se situant à la convergence de l'agriculture et de la foresterie conventionnelles, notamment la culture intensive du saule en courtes rotations (CISCR) et la culture intercalaire.

- La complémentarité de trois programmes incitatifs (Programme Prime-Vert, Programme de couverture végétale du Canada et Programme de mise en valeur de la biodiversité des cours d'eau en milieu agricole) pour les bandes de protection riveraines à base de saule, dont les deux plus récents ont été mis en place en 2005.

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[7] En agroforesterie, la culture intercalaire (*alley cropping*) consiste à disposer des cultures entre des rangées d'arbres ou d'arbustes.

- Un contexte législatif complexe présentant des lois et politiques conflictuelles, particulièrement en matière de boisement de terres en friche en zone agricole (CISCR et boisement en blocs du peuplier hybride).

- Une absence de programmes incitatifs pour la CISCR, malgré l'intérêt manifesté par certaines agences de mise en valeur des forêts privées.

- L'admissibilité du boisement en blocs du peuplier hybride au Programme d'aide à la mise en valeur des forêts privées, encore limitée à certaines agences de mise en valeur des forêts privées; pour la plupart d'entre elles, les normes et objectifs opérationnels pour ce système de boisement restent à préciser.

FOCUS GROUPS REALISES AUPRES DE PROPRIETAIRES TERRIENS

Méthode et approche

Selon Kruger et Casey (2000), la méthode des focus groups possède cinq caractéristiques :

1. des gens;
2. qui possèdent certaines caractéristiques;
3. et fournissent des données;
4. de nature qualitative;
5. dans une discussion centrée (*focused discussion*).

Il s'agit d'une méthode de recherche appliquée, développée en sciences sociales, focalisée sur le contenu de discussions, mais aussi exploratoire, utilisant par conséquent surtout des questions ouvertes.

Toutefois, l'approche retenue pour les focus groups de cette étude comporte certains ajustements et peut être résumée comme suit :

- Groupes formés d'adopteurs précoces potentiels, soit des propriétaires terriens (surtout des agriculteurs) ou leurs représentants (compagnies, municipalités, organismes à but non lucratif).

- Deux à trois technologies de boisement ou agroforestières discutées par groupe de 7 à10 personnes.

- Approximativement deux heures consacrées à chacune des technologies abordées au sein d'un groupe.

- Présentation uniformisée de 15 à 20 minutes précédant la discussion sur une technologie donnée.

- Utilisation de questions écrites à caractère qualitatif (classificatoires, ordinales) ou quantitatif (superficies des prévisions de boisement).

- 80 participants rencontrés de juillet à novembre 2006 au Québec et dans les trois provinces des Prairies.

Résultats préliminaires sur la CISCR au Québec

Au Québec, cinq focus groups totalisant 39 participants ont porté sur la CISCR. Chaque participant a évalué, en début de rencontre, son niveau initial de connaissances sur ce système. Le tableau 1 présente la répartition de ces niveaux initiaux. On observe une distribution négativement dissymétrique, avec 62 % des participants ayant un niveau initial de connaissances bas ou très bas. Cette situation reflète entre autres le caractère novateur de cette technologie au Québec.

Tableau 1 : Niveau initial de connaissances des participants sur la CISCR

Niveau de connaissances	Fréquence
Très bas	48 %
Bas	14 %
Moyen	21 %
Élevé	14 %
Très élevé	3 %

Suite à la présentation vulgarisée, les participants ont été invités à identifier les avantages et désavantages de la CISCR selon quatre aspects : techniques, financiers, légaux et environnementaux.

Les Tableaux 2 et 3 présentent un aperçu des avantages et désavantages de la CISCR tels que perçus par les participants. On y retrouve des avantages qui peuvent être utilisés pour promouvoir la commercialisation de cette nouvelle technologie, comme les cycles de production très courts se rapprochant de l'agriculture et les rendements importants.

Cependant, certains des avantages perçus devront être précisées et validés par des travaux de recherche et développement (R-D) et des analyses économiques. Parmi ces avantages potentiels, mais non encore validés, on retrouve les nombreux marchés, actuels et en émergence, le potentiel de réduction significatif des coûts de production dans un contexte opérationnel à plus grande échelle, et la rentabilité de cette technologie à différentes échelles.

Tableau 2 : Aperçu des avantages de la CISCR perçus par les participants

Avantages
Très forte croissance et importants
Capacité de produire des rejets après
Culture simple, peu
Se prête bien à la
Récolte hors période de pointe en agriculture (tard l'automne et
Possibilité de prendre de l'expansion en produisant ses propres
Avantages
Cycles de production très courts se rapprochant de
Coûts d'entretien diminuant sensiblement après le premier
Nombreux marchés, actuels et en
Potentiel de réduction significatif des coûts de production dans un contexte opérationnel à plus grande
Rentabilité possible à plusieurs
Production pouvant être localisée près des grands centres ou sites
Offre la possibilité de remplacer des cultures agricoles non
Avantages
Exige peu de pesticides comparativement à des cultures comme le
Retombées positives de la séquestration du carbone et de la
Plusieurs usages environnementaux, p.ex. la restauration de sites contaminés et les bandes de protection

Tableau 3 : Aperçu des désavantages de la CISCR perçus par les participants

Désavantages
Peu de données sur l'évolution des productivités après 15 ans
Désherbage exigeant les deux premières années du premier cycle
Y-a-t-il un risque que les racines bouchent les systèmes de drainage?
Peut-on changer facilement de culture si désiré?
Désavantages
Pas d'accès à des programmes incitatifs pour tester une nouvelle technologie
Coût élevé de la machinerie pour mécaniser la récolte
Marchés et rentabilité à préciser; beaucoup d'effort requis en commercialisation
Désavantages légaux
Statut (agricole ou forestier) à préciser.
Contrainte du zonage agricole dans un contexte de boisement
Désavantages environnementaux
Risques liés à l'utilisation d'essences exotiques
Risques associés aux grandes monocultures

Certains des désavantages identifiés s'avèrent aussi des enjeux de R-D, notamment le risque que les racines de saule bouchent les systèmes de drainage et les risques environnementaux associés aux grandes monocultures et à l'utilisation d'essences exotiques.

Fait à noter, la plupart des désavantages perçus représentent des éléments de risques, techniques (p. ex. l'incertitude sur l'évolution des productivités à moyen terme), financiers (p. ex. l'absence de programmes pour partager les risques d'adoption d'une nouvelle technologie), légaux (p. ex. le statut imprécis de la CISCR) et environnementaux (p. ex. les risques liés à l'utilisation d'espèces exotiques).

Par ailleurs, on retrouve parmi les désavantages légaux et financiers certains des enjeux déjà identifiés dans l'analyse des lois, règlements, politiques et programmes, dont l'absence de programme incitatif pour la CISCR et les statuts à préciser (agricole ou forestier) de cette technologie et des produits associés (tiges, fibre déchiquetée, etc.).

En fin de focus groups, on a demandé aux participants s'ils avaient l'intention de cultiver le saule en courtes rotations au cours des cinq prochaines années selon deux scénarios : avec ou sans programme d'aides technique et financière, tel qu'il en existe pour les travaux sylvicoles. Les résultats indiquent l'effet incitatif d'un tel programme. En effet, dans le contexte d'un programme incitatif, 80 % des participants ont indiqué leur intérêt à appliquer cette technologie au cours des cinq prochaines années, sur une superficie moyenne de 21 hectares. En l'absence d'un tel programme, 64 % des participants demeuraient intéressés à le faire sur une superficie moyenne de 5 hectares. On retient que l'absence de programme d'aide fait baisser de 16 % l'intention d'appliquer la CISCR. L'impact est encore plus marqué pour les superficies envisagées puisque qu'on obtient alors une baisse de 75 %.

Par ailleurs, on a demandé aux participants si leur intérêt envers la CISCR avait changé au cours du focus group. Il appert que l'incidence du focus group est notable, puisque l'intérêt a diminué pour 7 % des participants, n'a pas changé dans 36 % des cas (dont une majorité était déjà intéressée), et a augmenté chez 57 % des participants.

Selon plusieurs participants dont l'intérêt envers la CISCR a cru en cours de focus group, deux facteurs principaux expliqueraient ce changement : d'une part les informations et connaissances acquises et, d'autre part, le fait d'avoir pu discuter avec des propriétaires terriens possédant une expérience concrète de la culture intensive du saule en courtes rotations. À cet effet, 90 % des participants disent avoir appris (32 % un peu, 58 % beaucoup) au cours du focus group. La plupart des participants ont également mentionné leur satisfaction d'avoir participé à une telle rencontre.

CONCLUSIONS ET PROCHAINES ETAPES

Les focus groups et l'analyse du contexte réglementaire et des programmes incitatifs ont permis d'identifier deux types d'enjeux pour les technologies à l'étude. D'une part, on retrouve des enjeux de développement des technologies, par exemple l'évaluation des rendements de la CISCR dans un contexte opérationnel à plus grande échelle. D'autre part, on distingue des enjeux d'adoption des technologies, comme l'incidence des programmes incitatifs et l'importance des efforts de commercialisation requis pour cette culture.

Les focus groups se sont également avéré une approche efficace pour estimer l'intérêt envers différents systèmes de boisement et d'agroforesterie en développement. De plus, les focus groups semblent une approche prometteuse pour augmenter les connaissances et stimuler l'intérêt d'adopteurs précoces pour de nouveaux systèmes.

La prochaine étape consistera à compléter l'analyse des résultats des focus groups sur les trois autres systèmes de boisement et d'agroforesterie à l'étude, et ce pour chacune des deux régions (Québec et provinces des Prairies). Sur la base des enjeux identifiés, nous rencontrerons par la suite des intervenants clés de divers domaines (gouvernementaux, industriels, agricoles, etc.) afin de préciser ces enjeux et proposer des éléments de solution. Ces entrevues en profondeur auront lieu à l'automne 2007 et au cours de l'hiver 2007-2008.

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THE BRITISH COLUMBIA AGROFORESTRY INDUSTRY DEVELOPMENT INITIATIVE

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Abstract: The Agroforestry Industry Development Initiative (the "Initiative") is a not-for-profit partnership developed to enhance agroforestry activities in British Columbia to achieve a vision of a dynamic, self-sustaining agroforestry sector. Funding is derived from the Investment Agriculture Foundation (IAF) of BC as trustees of a federal/provincial government Agri-Food Futures Fund; $500,000 has been allocated for cost-share projects with private sector partners (individuals, producer groups, community and non-government agencies). The Agroforestry Management Committee (AMC), a volunteer group of private sector stakeholders oversees the Initiative; advising this group are government agroforestry specialists. The Federation of BC Woodlot Associations administers the Initiative. The Initiative's strategic goals were developed with direct input from current and potential agroforestry practitioners and guide the priorities for developing agroforestry projects: "Building Partnerships" to demonstrate agroforestry practices; "Raising Awareness" through supporting education, training and access to agroforestry information; "Improving Linkages" between producers, processors, wholesalers and consumers; and, "Supporting Marketing" with an agroforestry marketing strategy and brand. Since 2003, the Initiative has hosted or supported a number of information sessions and regional workshops, a website and a quarterly newsletter. The Initiative is also working with partners to develop agroforestry production guides and directories and is developing the BC Agroforestry Information Network, providing stakeholders with access to BC-based contacts with expertise in various aspects of agroforestry applications. There are ten Initiative-sponsored demonstrations underway covering a wide range of practices including silvopasture, integrated riparian management, alley cropping and forest farming.

Key Words: Technology transfer, participatory development, extension, outreach, partnerships.

INTRODUCTION

The Agroforestry Industry Development Initiative (the "Initiative") is a not-for-profit partnership of government, industry and allied non-governmental conservation and community development organizations. It has been developed and implemented to achieve a vision of a dynamic, self-sustaining agroforestry sector in British Columbia (BC). The Initiative was created with direct input from current and prospective stakeholders and has been building partnerships and providing support for the implementation of demonstrations, extension materials and education to advance the adoption of agroforestry practices. In the four years it has been operating, the Initiative has had great success in building awareness about agroforestry opportunities, developing regionally-specific information, and bridging divergent interests among industry, government and conservation groups in partnerships that focus on common goals.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007

DEVELOPMENT

Interest and participation in the development of agroforestry in BC has been growing in past two decades from diverse quarters. Agroforestry activities have emerged from many traditional integrated land use practices in the Province and from increased interest in alternate crops and cropping strategies, niche markets and direct marketing (Sylvis Environmental 2003). To a large extent agroforestry practices and development interests are regional in nature within BC and include the following:

- Silvopasture: stemming from a long history (more than 150 years) of traditional forest grazing by cattle, prescription grazing on forest plantations for vegetation management (primarily using sheep), and small scale silvopasture systems on woodlots;
- Christmas tree production, with or without integration with livestock production (primarily in southeastern BC);
- Non-timber forest products and forest farming: concentrated on Vancouver Island, in the west Kootenay and among the First Nations throughout the Province and,
- Conservation-driven interests for the expanded use of shelterbelts (primarily in the Peace region) and integrated riparian management (primarily in the rural-urban fringes of the Okanagan and Fraser Valleys).

Prior to the development of the Initiative, provincial government specialists from the BC Ministry of Agriculture and Lands (then the BC Ministry of Agriculture, Fisheries and Food) assisted with industry support. The creation of the Agri-foods Futures Fund (AFFF) provided an opportunity to focus support and co-ordinate agroforestry development in the Province. The AFFF is a program of the Canada-British Columbia Framework Agreement on Agricultural Risk Management with the general goals of supporting the development and sustainability of the agri-food industry in BC. With guidance of Provincial government agroforestry specialists, an Agroforestry Steering Committee consisting of industry and academic representatives initiated a consultation process to assess the interests, knowledge and aspirations of stakeholders groups. The planning process included a review of pertinent literature, extension activities, academic initiatives and a survey of over 1,000 current and potential producers and support organizations within BC. The goal of the survey was to identify issues that needed to be addressed for development of agroforestry. The response rate was 18% on a single point contact. Although the industry and conservation interests were diverse, common patterns emerged relating the strengths and opportunities for agroforestry development (Sylvis Environmental 2003):

1. The opportunity for sustainable production of non-timber forest products (as opposed to the prevalent unregulated, unmanaged wild harvest);
2. Sustainability and protection of the natural environment with agroforestry practices that are complementary and potentially restore or enhance natural processes and biodiversity;

3. Diversification of production risks, and better year-round use of labour and capital investment to supplement producer incomes;

4. Increased operator income, resulting in operational stability and ultimately enhanced stability in the industry sectors and communities in which they reside.

Access to practical, regionally-relevant information was seen as the main challenge to agroforestry adoption, because although stakeholder interest and general knowledge about agroforestry concepts was strong, specific knowledge related to production and marketing were limited. Based on the strengths, opportunities and challenges facing agroforestry, the BC Agroforestry Strategic Plan (Sylvis Environmental 2003) was authored identifying four areas of strategic importance. These priorities later formed the basis of the goals for developing and funding agroforestry projects supported by the Initiative:

1. Building partnerships among agroforestry practitioners, industry organizations and affiliated stakeholders such as environmental organizations, governmental agencies, educational institutions and other interested groups. These partnerships are employed to establish on-farm or in-forest operational demonstrations of agroforestry practices that test the economic viability and/or environmental stewardship resulting from integrating agroforestry systems into current production practices;

2. Increasing awareness of the benefits of agroforestry systems through development and delivery of technology transfer materials, tours of demonstration areas, training programs and workshops to producers and potential producers;

3. Establishing the means to link agroforestry practitioners and their products with wholesalers, processors and consumers, and,

4. Developing a "BC Agroforestry" brand identity, synonymous with economic sustainability and environmental benefits. The brand identity will be used for sector marketing to establish higher price points for products derived from agroforestry systems.

On the basis of the strategic planning the Agroforestry Steering Committee secured $500,000 for the implementation of the Agroforestry Industry Development Initiative through 2008. With matching funding and in-kind contributions provided through strategic partnerships with stakeholders, the Initiative has an overall program budget of $1,000,000.

The Initiative was thus formulated to capitalize on the potential opportunities for production and conservation enhancement through wider adoption of agroforestry practices and realize their potential to diversify and strengthen BC's agricultural and small-tenure forestry sectors. The purpose of the Initiative is to assist the development of the agroforestry in BC, and thereby increase production opportunities, promote stewardship, increase producer incomes and enhance community stability.

IMPLEMENTATION

Agri-Food Futures Funds are disbursed in BC in the trust of the Investment Agriculture Foundation of BC (IAF). The IAF is a non-profit organization that invests federal and provincial funds to help the BC agri-food industry adapt to change. The Agroforestry Initiative follows the funding principles set out by the IAF, including:

1. Benefits to industry and the public will exceed the costs;

2. Addressing specific local/provincial/regional needs or opportunities;

3. Respecting the need for equity among regions and within the agri-food sector; and,

4. Including direct industry funding and support of projects.

To guide and oversee the implementation of the Initiative, the Steering Committee was transitioned to create the Agroforestry Management Committee (AMC). The AMC remains an all-volunteer group of industry, community and academic representatives with expertise and experience reflecting the diversity of agroforestry interests in BC. The Federation of BC Woodlot Associations (FBCWA) is administering the Initiative funding on behalf of the AMC. Implementation was initially carried out through the volunteer efforts of the AMC. Professional project development and implementation support was contracted in 2004 to assist with an increasing workload placed on the volunteer positions. Facilitation of project development and implementation has been key to the successful delivery of the Initiative. This process allows for ideas and aspirations of stakeholder groups to set the individual project direction, while at the same time they also receive dedicated professional resources that they may not have within their organization. Facilitation is provided throughout all phases of the project, including assistance with the developing the initial application if desired by the proponents. Facilitation also ensures project ideas brought to the Initiative for funding consideration are strongly aligned to the program's goals.

The Initiative began full operation late in 2003, and since then has supported projects advancing of all its strategic goals. Establishing key partnerships to develop and deliver demonstrations and technology transfer activities has been key to the success of the Initiative. A register of agroforestry stakeholders and associates has grown from the initial consultations during the planning process to more than 1,400 individuals and businesses with an active interest in agroforestry development in BC. Partner organizations have headed the delivery of ten Initiative-sponsored demonstrations completed or underway around the province. The demonstration projects encompass agroforestry practices suited to the varied geography and production potential of BC and include:

1. "Tapping Bigleaf Maple" in partnership with Backlund's Backwoods and other interested woodlot owners on Vancouver Island. This project assisted the development of a regional maple tapping industry utilizing the native bigleaf maple (*Acer macrophyllum*). Workshops and set-up of a commercial evaporator for training and fine-tuning syrup production techniques has supported a 10-fold increase in "sugar-bush" activity since 2003.

2. “Cedars and High-value Hardwoods” in partnership with Fraser-Harrison SmartGrowth in Agassiz. This project involved establishing native western red cedar (*Thuja plicata*) in integrated riparian plantings and high-value hardwoods into under utilized farmland (e.g. along road and fence lines). Hardwood species planted included red oak (*Quercus rubra*), white oak (*Q. alba*), English walnut (*Juglans regia*), black walnut (*J. nigra*), and chestnut (*Castanea* spp.). The plantings were designed to serve both a conservation function and provide for diversification of farm income.

3. “Hawthorn Agroforestry Farm Trials” in partnership with West Kootenay Herb Growers Cooperative in Edgewood. The purpose of this demonstration is to test the viability of growing hawthorn (*Crataegus* spp.) in BC as a new crop within an agroforestry management system to supply the health products market and also provide a riparian conservation function.

4. “Silvopasture: Christmas Trees and Forage” in partnership with Kootenay Tree Farms in Cranbrook. The purpose of this demonstration is to show the potential benefits of integrated production of Christmas trees and forages. Pruning and fertilization used as part of the process of culturing native Douglas-fir (*Psuedotsuga menziesii*) for Christmas trees promotes an abundance of understory forage growth. In turn, livestock production utilizing this understory reduces competition and pest problems around the trees.

5. “Aspen Silvopasture” in partnership with the Peace Cattlemen’s Association on behalf of the Peace Forest District Timber Range Impact Mitigation Committee. This demonstration is showing the benefits of co-operative planning and management of overlapping timber and forage resources in the Peace region. Alleys have been created in dense stands of regenerating aspen, directing livestock use away from the trees into areas of better quality forage with unimpeded access for cattle.

6. “Page Creek Integrated Riparian Management” in partnership with Page Creek Farm in Matsqui. This project is demonstrating the potential for agroforestry to improve riparian protection and the economic viability of small agricultural operations. Red osier dogwood (*Cornus stolonifera*) is being used to restore riparian habitat while simultaneously providing the landowner with an economic return from the sale of stems harvested and sold into the floral greenery market.

7. “Hybrid Poplar Alley Cropping – Peace Region” in partnership with the Doig River First Nation in Fort St. John. This research is testing the cultivation of native and traditional forage seed crops between rows of rapid growing hybrid poplar and hybrid aspen (*Populus* spp.).

8. “Hybrid Poplar Alley Cropping – Fraser Valley” in partnership with the Jayendee Farm and the Abbotsford Soil Conservation Association in Abbotsford. The purpose of this project is to demonstrate the integration manure from of a hog operation to fertilize understory floral crops in a hybrid poplar alley cropping system.

9. “Bigleaf Maple Sap Flow Research” in conjunction with a University of Victoria graduate student and Vancouver Island bigleaf maple tappers. This research seeks to improve our

knowledge and predictability of sap flow from bigleaf maple for the production of Vancouver Island maple syrup and other value-added sap products.

10. "Perigold Black Truffle Production" in partnership with the Truffle Association of BC with sites in the Okanagan, Vancouver Island and Fraser Valley. This project is developing agroforestry systems for the production of this high-value gourmet crop on red oak and hazelnut (*Corylus* spp.) hosts.

The Initiative has also delivered or supported a significant number of technology transfer activities in alignment with increasing awareness about agroforestry and access to agroforestry information and training. Projects in this area include hosting or supporting a large number of information sessions and seven regional workshops, development of a website and publication of a quarterly newsletter: Agroforestry Update. An agroforestry cost-benefit calculator is also under development incorporating social and ecological parameters with conventional economic methods (Sipos 2005). The Initiative has also worked with the Boreal Centre for Conservation Enterprise to develop a boreal agroforestry guide, and the Quesnel Community and Economic Development Corporation to publish a birch tapping and syrup production guidebook and deliver associated training. The Initiative is also developing the "BC Agroforestry Information Network", providing stakeholders with an outlet to access BC-based contacts with expertise in various aspects of agroforestry applications.

To support marketing and branding of agroforestry the Initiative has developed a logo and has supported the publication of a regional directory of agroforestry enterprises in conjunction with the Boreal Centre for Conservation Enterprise.

CONCLUSIONS

The BC Agroforestry Industry Development Initiative is achieving its goals of developing a dynamic, self-reliant agroforestry sector. The model of participatory agroforestry development is working because it remains primarily driven by stakeholder interests supplemented with organizational, technical and extension support provided by the Initiative. Inclusion of paid administration and project facilitation support has helped to avoid volunteer "burn-out" and thus a high level of commitment to program guidance has been maintained by the all-volunteer AMC. From the outset, industry development has been seen as complementary to community development, producer stability, environmental protection and enhancement. The priorities originally drawn from surveying stakeholder interests have been reassessed annually through a variety of formal and informal feedback mechanisms to iteratively adjust program activities and thus keep them relevant.

Building a sector identity and organizational structure for future industry development has led to broader participation and greater self-reliance among previously unaligned stakeholder groups. Moreover, through the participatory approach of the Initiative, demonstration and technology transfer projects undertaken are building the capacity and expertise for the sector to become self-sustaining.

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THE EFFECT OF LAND FRAGMENTATION ON HABITUS, FIELD, AND AGROFORETRY IN THE MIDWEST

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Abstract: A process of structural change in agriculture is increasing land tenure fragmentation, as well as the number of landowners who depend on farming for their livelihoods in the US. Previous studies of interest in agroforestry, with data from 1998-1999, found that knowledge was a significant factor in the likelihood of being interested in agroforestry practices. Changes of the stewards of the land in the past seven years may also bring about change of the main sources of information for decisions about the landscape. A household survey implemented in three distinct regions of Missouri in 2006 – 2007, with a sustainable livelihoods framework, provides data to define field and habitus. The relationship between natural capital (land and trees), social capital (networks), and institutions accessed by landowners are analyzed. Using Bourdieu's concepts of field and habitus we analyze the effect of structural change, expressed in reduction of land size and reduction of the relative importance of farming in income generation, on how agroforestry practices are perceived, and the sources of information trusted by decision makers –the networks of information. Almost fifty percent of the landowners faming the land in east Missouri in 1998-1999 were full time farmers. We analyze the impact of change observed in the last agricultural census, by defining who the landowners are, their values, and the institutions they relate to for decisions about trees and agroforestry. We expect to identify pathways to increase knowledge, which has been shown to increase the likelihood of interest in adopting agroforestry practices.

Key Words: Habitus, field, information, perceptions, agroforestry, landowners.

INTRODUCTION

Context

The US has a large diversity of farms. A study published by the Economic Research Service of the United States Department of Agriculture (ERS USDA) found that most (98% in 2003) are family farms (Hoppe and Banker 2006). These small farms (defined by annual sales of less than US $250,000) represent 91.2% of all farms, deriving income from farm and non-farm activities. While holding almost 72% of all farm assets, 70% of all the land owned, but their total value of production was only 27% of total in 2003. Hoppe and Banker's report (2006) also highlight that 82% of the land enrolled in Conservation Reserve and Wetland Reserve Programs belong to small farms, especially what they define as retirement, residential/lifestyle, and low sales small farms who received 64% of conservation payments in 2003. On the other hand, the medium sales and large scale farms received almost 75% of the supply support transfers.

Changing structure

Between 1995 and 2003 (see Table 1) the number of farmers in the small family farms with sales of less than US$10,000 has increased from 48% of all small family farms, to 57.2%, while those in the sales range of 10,000 to 249,999 decreased from 44.2% to 34% (Hoppe and Banker 2006).

Table 1: Farms (number) and value of production (%) in the US: 1995 and 2003

Item	**1995**	**2003**
Number of farms	2,068, 000	2,121,107
Small farms	1,915,246	1,213,109
Less than 10,000 in sales	1,000,825	1,213,378
$10,000 - $249,999 sales	914,422	721,731
Large scale family farms	121,563	150,950
Non family farms	31,190	36,048
Distribution of value of production		
Small farms	37.6	27.1
Less than 10,000 in sales	2.0	1.6
$10,000 - $249,999 sales	35.6	25.5
Large scale family farms	48.0	59.1
Non family Farms	14.5	13.7

Source: Hoppe and Banker 2006. Structure and Finances of US Farms: 2005 Family Farm Report ERS/USDA.

Small farms

The number of landowners in small farms is very large and can significantly mitigate agriculture's negative environmental impacts. Significant characteristics of these farms are income diversification, and small share of income from farming. This, and the variety of agroforestry practices, may lead landowners to seek these practices for environmental benefits or economic motives, such as high value products.

Understanding landowners characteristics and interests, and how they access new information, can assist in targeting extension programs and policies to facilitate adoption. The diversity of landowners may be matched to agroforestry practices leading to both environmental but economic benefits.

AGROFORESTRY AND FRAMEWORK

Agroforestry research

Research on the praxis of farming, forestry, and agroforestry (Valdivia, Hodge and Raedeke 2002; Raedeke et al. 2003), finds *habitus* (the taken for granted social processes, values, beliefs, and behaviors shared), and *field* (external dimensions or the relations that make the "game" possible, the rules of the game), a useful framework in identifying factors affecting decision makers interested in agroforestry. These concepts developed by Bordieu were applied in understanding a typology of landowners in Europe (Schucksmith 1993) and later applied in our studies of landowners in Missouri's East (Raedeke et al. 2003; Arbukle et al. 2005; Flower et al. 2005; Valdivia and Poulos 2005; Dorr 2006). Several adoption and interest in agroforestry studies were carried out with two data bases gathered in 1999, which captured landowners and farm operators land use practices, household characteristics and attitudes towards trees, farming and agroforestry in northeast and southeast Missouri. The sample frame of landowners was obtained from government offices serving farmers. A high percent of those in the lists had been or were actively involved in full time and part time farming at the time of the survey. The studies conducted estimated factors affecting interest in various agroforestry practices, in the concept of agroforestry, by landowners farming and not engaged in farming.

The working hypothesis of the research is that adoption and diffusion of agroforestry practices and systems by landowners in an agroecosystem depends upon a complex set of factors, including the natural resource base, social and economic characteristics, the policy incentives, institutions and culture.

Framework and approach

Landowners and farm operators pursue diversification to increase income while reducing covariant risk (Knutson et al. 1998; Skees et al. 1998; Just and Pope 2003; Valdivia and Konduru 2003), maximize resource use (Ellis 1998; Gardner 2000; Valdivia 2001), increase profitability of the operation, and as a matter of preference or lifestyle. Agroforestry practices can be a new economic opportunity (Gold et al. 2000), non-covariant with the income and risks attached to commodity farming. These practices may also be a combination of environmental improvement (natural capital), and commercial venture. Alley cropping, forest farming and silvopasture are seen as commercial, profit seeking practices, while windbreaks and riparian buffers have been traditionally thought of as environmentally significant practices. While this is true, depending on the policy environment, the latter practices can also be designed to yield short, medium and long term economic benefits.

The household portfolio approach (Schucksmith 1993; Valdivia et al. 1996; Bebbington 1998; Valdivia 2001) shows how agroforestry practices may contribute to the rural livelihoods of farm operators and land owners (Ellis 1998; Valdivia et al. 2002; Raedeke et al. 2003). The household survey implemented in 1999 and the recent one of 2006 incorporate this approach.

Motives and attitudes are sought through a set of questions about landowners' perceptions to elicit understanding of habitus. Questions about familiarity with markets, organizations in farming and forestry, as well as incentive programs lead to participation in the fields of farming, forestry and agroforestry. Profit seeking behavior, household and individual goals and preferences are shaped by the life cycle stage, attitudes towards farming and life in rural areas, the environment, quality of resources, and wildlife (Schucksmith 1993; Raedeke et al. 2003). External factors also shape household decisions. Incentives and information are factors in developing interest in new practices.

INTEREST IN AGROFORESTRY – 1999

Findings landowner/operator survey of southeast and northeast Missouri

Two surveys were conducted in 1999 of landowner operators and of landowners not farming the land. The data bases were used in four studies. One focused on adoption of riparian buffers and forest farming using two different models (Flower et al. 2005; Valdivia and Poulos 2005). A third study focused on the landowner survey (Arbuckle et al. 2005) using agroforestry rather than individual practices as the dependent variable. A fourth study pools the landowner surveys, analyzing four practices, alley cropping, silvopasture, forest farming, and windbreaks (Dorr 2006). Flower et al. (2005), studying interest in riparian buffers and forest farming find lifestyle, captured by interest in having someone visit and give advice about planting trees, highly significant and positive. The accumulator attitude was also positive and significant in the case of forest farming. On the other hand, farm operators with a high value of their assets in farming had a negative and significant effect on forest farming interest, while positive in Riparian Buffers. Conservative was significant at a ten percent in the case of riparian bidders, at a 10% level, again pointing to traditional farmers interest in the productive value of their land. In both knowledge of the practice was a strong and positive influence in the likelihood of being interested in the practice. Number of magazines had a positive effect on Riparian Buffer interest, while participation in informal groups had a similar effect on Forest Farming. Concern with erosion was a highly significant and positive effect on interest in riparian buffer interest.

Valdivia and Poulos (2005) also estimating the interest in riparian buffers and forest farming, find that age has a negative effect on interest in either practice. Knowledge on the other hand has the strongest effect, consistent with the findings by Flower et al 2005. Perception of the value of trees to future generations and to scenic beauty had positive and highly significant effects in both riparian buffers and forest farming. Physical characteristics, such as having trees on the land in the case of forest farming, and erosion problems in the case of riparian buffers were significant and positive.

Arbuckle et al 2005 find there are opportunities to promote agroforestry with landowners who place high value on environmental and recreational benefits of land, especially people who do not depend on the land for their livelihoods. In a regression analysis of interest in agroforestry, contact with natural resources professionals is positive and significant in higher interest in implementing agroforestry. Economic value of the land is significant and negative in interest, pointing to the need to improve information on the economic value of these practices.

Dorr's (2006) research using a Logit regression analysis pooling the data sets of non-operator landowners and of farm operators in NE and SE Missouri in 1999, finds attitudinal, structural, and physical characteristics significant in determining interest. Habitus variables defined in her research include lifestyle, conservative and accumulator. Her research finds lifestyle landowners (those who like for someone to come to their land to teach about planting trees) more likely be interested in silvopasture, alley cropping, riparian buffers and silvopasture. It also finds that a conservative attitude, defined by landowners with a large share of assts in farming, capturing commodity farmers engaged in traditional farming, lowers the likelihood of interest in forest farming, alley cropping, riparian buffers and silvopasture. The accumulator attitude (captured through awareness of timber markets, was not significant. A consistent finding, with previous research and critical to extension activities is that own knowledge of the practice increases the likelihood of interest in all practices. Perception of a physical problem in the landscape and presence of characteristics akin with the practice, are key in interest in implementing practices such as windbreaks and silvopasture. Other characteristics, such as age have a negative effect on forest farming, alley cropping and windbreaks.

In summary, with data from 1999, studies of interest in agroforestry find that values about the environment and future generations, and knowledge of the practice have a positive effect on likelihood of being interested. Landowners for whom economics is an important factor in farming, or who have a large proportion of assets in farming are less likely to be interested. Understanding the economic value of the practice may lead to greater interest. Currently those interested are mostly landowners who significant sources of non farm income. Presence of physical characteristics is critical to some practices such as forest farming and silvopasture, while physical problems with the landscape are also significant in interest riparian buffers. Advice from a natural resource professional is highly significant and positive, so was being a college graduate, and owning land for environmental and recreational reasons.

THE 2006 SURVEY

Profiles developed of each research center and surrounding counties (Valdivia et al. 2005) was the source of information for designing the sample frame and selection of sample. Finding, such as little involvement with farm and conservation programs led us to use tax assessors' landowner lists, rather than the FSA landowner lists, as a better approximation of the number of landowners in each county. The sample included landowners with 10 or more acres of land in family farms.

The survey instrument, following a similar format to the 1999 instrument, was developed to capture the following:

- Attitudes towards agroforestry practices (interest and knowledge) in the context of assets, markets and institutions.
- Household farming systems and government supply support and conservation programs.
- Income diversification and economic characteristics.
- Information about the *fields* and *habitus* of landowners which include perceptions of the benefits and costs of trees, of the value of the environment and the benefits of the land.
- Networks and organizations landowners belong to.

Survey development, locations, and sample frame

Public and private organizations serving landowners were interviewed, such as the Farm Service Agency (FSA), Natural Resources Conservation Service (NRCS), the Missouri Department of Conservation (MDC), and Soil and Water Conservation Districts (SWCDs), and the University of Missouri Extension. A profile was developed for each region where University of Missouri Research Centers is located. This included the county where the center is located and surrounding counties. Data analyzed in this paper focuses on two sites. Budget constraints determined that the sample frame would be limited to two counties. The research center county was chosen. The criteria for the second county selected included agroecological diversity, and location of cities. County's Tax Assessor's lists of landowners with ten or more acres were chosen, excluding city, state, and development companies owning land. Two research centers, one in central Missouri, and one in the Ozarks were chosen. A random sample with replacement selected 360 landowners from Howard and Boone counties (1592 and 6272 respectively) and Crawford and Phelps (3892 and 1675 landowners respectively). The sample frame drawn for HARC region and Wurdack can be seen in Table 2.

Table 2: HARC and wurdack interview sample distribution, Missouri, 2006.

Category		Crawford	Phelps	Total	Howard	Boone	Total
Interviews completed	# %	113 24.3	63 35	176 27.3	60 26.9	124 23.6	184 24.6
Not reached: no phone	# %	107 23	48 26.7	155 24	31 13.9	76 14.5	107 14.3
Identified but no answer	# %	73 15.7	23 12.8	96 14.9	27 12	93 17.7	120 16
Total sub- sample from frame	# %	465 100	180 100	645 100	223 100	525 100	748 100

FINDINGS

Landowner characteristics – Typology

The typology of landowners is derived from self identification. We difference between those landowners who live in urban counties vs. rural counties, as land values and access to information may differ. Table 3 presents the main economic characteristics of landowners that reflect the structure of agriculture. The share of income derived from farming, as well as the level of sales of farm products are two distinct characteristics. Non-farm income is also important in both part time farming and with landowners not farming. This relates to the practice of farming, in the sense that the greater the share of income from farming the higher the identity with farming and therefore farming values. On the other hand, households that derive most of their income from non farm activities may be more identified with living in a rural area, and closer to the attitudes of lifestyle rural type owners. This group places a larger value in scenic beauty and the environment as well as the future generations when thinking of planting trees (Valdivia and Poulos 2005). We consider the share of income from specific farming activities such as crops and livestock, as well as the assets owned debt free.

The last row of Table 3 tests differences between means within a column, ANOVA tests. This indicates that landowner type does identify distinct groups with regard to these categories. In terms of the distribution by landowner types it should be noted that the random sample use the Tax Assessors' Lists yielded a distribution that is different from the 1999 survey with a small amount of full time farmers. This is consistent with the size of landowners in the sample, and with the fact that it was in the Southeast where there are more landowners (proportionally) because of the high returns to row crop production in that region. This is not the case in Wurdack, especially. Close to a third of landowners are farmers of some sort. Even in the case of full time farmers, average income from farming is only close to 60%. The average revenue classifies them as small family farmers selling less than $100,000 in sales, but more than $10,000. Gross income from livestock is significantly different from other groups, and consistent with operations that may be livestock or crop livestock. Part time farmers receive only 25% of their income from farming in the last three years, while in 2005 almost 80% was from non farm sources. The revenue from farming is 26,911, which qualifies this group as small farms and in the same group as the full time farmers. While in our previous study full time farmers had sales closer to the $ 100,000, this is not the case in these two regions. On the other hand landowners not farming the land fall in the small farm category identified as growing in studies of changing structure (Hoppe and Banker 2006).

Table 3: Mean values of landowner characteristics by type, 2005.

Land owner type (self defined category)	Number of land owners in the group (%)	Percent of gross income from farming (last 3 years)	Share of gross income non farm 2005	Share of gross income from crops 2005	Gross revenue from agricultural products sold 2005	Percent of assets owned debt free 2005	Percent of gross income from livestock 2005
Full time farmer	30 (8.4)	59.97	40.20	26.53	69,589	9.3	39.81
Part time farmer	93 (25.9)	25.45	79.96	13.10	26,911	9.7	21.17
Landowner in rural counties not farming	77 (21.4)	14.84	88.49	13.23	1,170	17.4	11.93
Landowner in urban counties not farming	104 (29)	3.87	94.30	5.79	492	11.9	5.84
Landowner living away from the land	55 (15.3)	12.10	88.76	16.06	3,129	11.2	10.91
Total ANOVA test	359	17.76 ***	83.97 ***	12.59 ***	13,659 ***	12.2 n.s.	14.73 ***

Source: Landowner Survey of 2006. Center for Agroforestry, University of Missouri Columbia. Type is self identified. *** <000

Interest in agroforestry practices

Responses were elicited by showing pictures of the different practices with brief description. Landowners were asked to rate their interest and knowledge. Adoption indicated the landowner had implemented the practice in his or her land. If we evaluate Table 4 by column, comparing adoption interest and knowledge we find the following. In the case of alley cropping only two have implemented this practice, both are landowners not farming in rural and urban counties. Similar numbers of landowners (part time and living in rural) are interested in the practice, while the urban county landowners are slightly more (though their absolute numbers are also higher). Silvopasture has been adopted in all types, the highest being part-time farmers. Interest is the highest among landowners not farming in urban counties and part time farmers. In both cases it is closely related to knowledge (consistent with findings in Valdivia and Poulos 2005; Flower et al. 2005; and Dorr 2006). Practices with the higher level of adoption and consistent with policies of the last thirty years are windbreaks, where part time farmers have incorporated, and knowledge is high. Landowners not farming also have high adoption and knowledge rates, the latter especially in the urban counties. In the case of Riparian Buffers, both part time farmers and landowners not farming in urban counties have the highest rates of adoption, knowledge and interest. This is also consistent with the structure of agriculture where the investment in farming is lower, and other sources of income are very significant. In the case of forest farming the adopters are not full time farmers. And the knowledge and interest mainly resides with landowners in urban and rural counties, who are at present not farming the land.

Part time farmers and landowners who do not farm and live in urban counties have the highest adoption levels. By type those with highest proportions of adoption are part time farmers, full time farmers, and landowners living in urban counties.

Sources of information

Research with landowners and farm operators using the 1999 NRCS landowner lists showed the University Extension and the agency were the mains sources of information sought for planting trees. Table 6 presents the total numbers of landowners indicating their preferences for the first three and the first source of information they seek for planting trees. In the case of farmers, both full and part time landowners University Extension is the first source of information sought. Landowners living in urban and rural counties and those living away seek advice of their state institutions, primarily of Missouri Department of Conservation, which targets small landowners. We separated Federal and State to identify changes in sources, especially those that do not belong to the field of farming, but mostly of the environment and conservation. Small landowners seek these and the university as a second source.

Flower et al. (2005) showed that number of conservation and environment magazines have an effect on interest in riparian buffers. Table 7 shows the average number of magazines per landowner type, and significant differences are found between farmers and non farmers, especially with full time farmers. Farmers have a higher number of subscriptions to farming magazines, while landowners not farming the land have a greater amount of subscriptions to conservations magazines. Part-time farmers straddle the farming and rural fields and this is reflected in the large amount of both farming and conservation magazines.

Table 4: Adoption, interest and knowledge in five agroforestry practices by landowner type (numbers) 2005.

PRACTICE	Alley cropping	Silvopasture	Riparian buffers	Wind breaks	Forest farming
Landowner type	Adoption interest knowledge	Adoption interest knowledge	Adoption interest knowledge	Adoption interest knowledge	Adoption interest knowledge
Full time farmer	0 3 4	4 11 5	9 13 11	3 10 18	0 7 4
Part time farmer	0 14 27	6 28 24	21 30 37	24 33 57	2 32 23
Landowner not farming rural	1 14 8	2 13 17	3 18 26	13 21 41	2 27 18
Landowner not farming urban	1 20 34	4 26 22	21 32 48	18 35 74	1 46 35
Landowner living away from land	0 10 11	2 14 9	5 19 19	4 12 28	0 26 16
Total	2 ns 61 ns 84 ***	18 ns 92 ns 77 ns	59 *** 112 ns 141 ns	62** 111 ns 218 *	5 ns 138 ns 96 ns

Source: Landowner Survey 2006. Center for Agroforestry, University of Missouri Columbia.

Table 5: Adoption of agroforestry by landowner types (numbers) in 2005.

Type/ Adoption	Full time farmer	Part time farmer	Landowner rural	Landowner urban	Landowner living away
Adopted	10	40	17	35	10
Not adopted	20	53	60	69	45
Total	30	93	77	104	55

Source: Landowner Survey 2006. Center for Agroforestry, University of Missouri Columbia. Chi-Square Test: 13.727, significant differences .008

Table 6: Preferred sources of information about trees by landowner type 2005 (total of the first three mentioned by landowner; first source of information).

Type/ Magazines	Full time farmer	Part time farmer	Landowner rural	Landowner urban	Landowner living away
University extension	20 14+	51 27+	44 21	65 33	32 15
Other farmers	14 5	41 16	31 11	45 8	21 6
Federal institutions	24 2	52 8	45 6	60 13	33 9
State institutions	14 4	68 27+	53 25+	82 39+	43 18+
Forestry	9 2	42 10	30 6	33 4	24 3

Source: Landowner Survey 2006. Center for Agroforestry, University of Missouri.

Table 7: Agriculture forestry and conservation magazine subscriptions by landowner type 2005 (total numbers of subscriptions)

Type/ Magazines	Full time farmer	Part time farmer	Landowner rural	Landowner urban	Landowner living away
Average number ***	2 a	1.49ab	1.11b	1.19b	1b
Farming	34	67	20	15	21
Rural ^	11	29	16	28	12
Conservation	15	43	50	79	26
No magazines	9	29	26	25	21

Source: Landowner Survey 2006. Center for Agroforestry, University of Missouri Columbia. ^ includes hunting and environment.

SUMMARY AND CONCLUSIONS

Results from the recent landowner survey show consistency with both Census and other studies that underline changes towards concentration on the top and increased numbers of landowners with very small sales from agriculture (less than $10,000). Agroforestry practices are of interest, and have been adopted in the two regions of study. If knowledge of the practice is again an important factor in interest and adoption understanding the changes in the critical institutions providing information is crucial. We find a larger reliance than in previous studies on Conservation institutions at the state level, like the Missouri Department of Conservation, as well as the importance of university extension. Information from other farmers is also important, and if consistent with previous studies, should be an element in designing technology transfer programs. Networks of landowners, as well as connections to trusted sources like extension and MDC indicate that training at these trusted sources is critical. Because off farm income is critical, as it was noted in Arbuckle et al. (2005) and Hoppe and Banker (2006), economics, and tax incentives, require more analysis (Godsey 2001; 2003; Gold et al. 2003). This is only a preliminary analysis of what is a very comprehensive data base on institutions, perceptions and attitudes, as well as physical economic and demographic characteristics of landowners. Further studies on adoption and profiles of the various landowner types will be developed. See also Fregene and Valdivia (in these proceedings), and pathways to agroforestry by Jill Lucht (in these proceedings).

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DEVELOPING A VISION AND STRATEGY FOR AGROFORESTRY IN NORTHEAST SASKATCHEWAN

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Abstract: Parkland Agroforestry Ltd, a group of area farmers, received funding for this project through the Saskatchewan Forest Centre (SFC) Forest Development Fund. There has been considerable interest in Saskatchewan in agroforestry for its potential in alternate cropping rotations, community economic development, environmental protection and future land use systems. Traditional annual crops, on some soil types, have not been returning a profit to farmers in the past several years. The land should be returned to a permanent cover. Parkland Agroforestry Inc. believes that agroforestry should be a part of future land use changes in northeast Saskatchewan.

The Government of Saskatchewan has announced a vision to convert 10% of the arable farm land back to trees in the next twenty years. There is currently no strategy as to how this will be accomplished. Parkland Agroforestry Ltd. believes this initiative is achievable but believes a strategy is necessary to make it happen in northeast Saskatchewan. Using this strategy document, they believe it will be a tool to approach government with a plan for orderly development.

Orderly development will involve the integration of current crops and livestock production, new crop development, woody crops, intensive livestock operations, water and wildlife protection, livestock and municipal waste management. An integrated systems approach is seen as the best way to incorporate agroforestry for future community economic development and environmental protection.

The vision and strategy was built during the fall and winter of 2006-07. The development process relied very heavily on input from area farmers, local business and ratepayers, First Nations, conservation groups (such as Ducks Unlimited Canada) and industry. Focus groups were held, a technical committee organized, a SWOT analysis (Appendix 1) completed and an inventory and environmental scan of the area concluded.

INTRODUCTION

The project steering committee included representatives from Saskatchewan Agriculture and Food (SAF), the Conservation Learning Centre, Ducks Unlimited Canada, Forintek Canada Corp, University of Saskatchewan, First Nations Agricultural Council Saskatchewan (FNACS), Parkland Agroforestry Inc. and the Saskatchewan Forest Centre (Appendix 2). The group engaged the services of Barry Swanson, P.Ag to develop and deliver a regional agroforestry opportunities report to facilitate the growth of the agroforestry industry in Saskatchewan.

In Olivier, A. and S. Campeau, eds. 2007. *When Trees and Crops Get Together.* Proceedings of the 10th North American Agroforestry Conference, Québec City, Canada, June 10-13, 2007

The initial project area included farms and communities bounded by Highway 2 on the west, east to the Manitoba border and by Highway 5 in the south. This area was selected because of the history of agroforestry activities in that area of Saskatchewan. As the project developed, the information gathered pertained to all areas in Saskatchewan.

Agroforestry has been defined simply as "the integration of trees onto farms, including afforestation". Many of the activities associated with agroforestry lead to economic returns from lumber, value-added wood products, horticulture plants, fruit and forest products. Trees and tree products have traditionally come from three sources – provincial forest, Crown agricultural land or private farmland. The availability of trees to harvest in the provincial forest has a number of restrictions due to long term supply agreements with industry. Access to the provincial forest is not currently considered a realistic base for the growth of agroforestry value added activity in Saskatchewan. Hence, the focus on farm land and rural communities – trees as a crop with huge potential for regional development.

There are many indicators that an expanded agroforestry industry has potential to provide diversification options for farmers and economic opportunities for communities (Appendix 3). End products may be lumber, planting stock, horticulture crops, processed wood products, biomass for energy production, forest grown products and ecotourism. In all stages, employment creation, economic growth and environmental sustainability are the major factors.

Farmer interest in growing trees is reflected in the success of the federally funded Forest 2020 program delivered by the Saskatchewan Forest Centre in Prince Albert. Over 80 farmers expressed interest in the planting project with 340 acres eventually planted to hybrid poplar and conifers on private land. Six First Nation Bands planted 500 acres of hybrid poplar on reserve land (3).

The success of the agroforestry industry might be modeled after the development of the canola industry in western Canada. Farmers viewed canola as a diversification option with a natural fit in Saskatchewan due to climate and soil type. Demonstrations, government lobbying and market development followed. Similarly, research, technology transfer and market development are key to reach the goal of accepting trees and tree products as a crop n Saskatchewan.

In the fall of 2005, Premier Lorne Calvert announced a vision to convert 10% of the arable agricultural lands to trees over the next 20 years. This would be approximately four million acres of trees and would mean planting 200,000 acres a year. A large land conversion to trees would create a significant new rural industry and diversification option for farmers.

AGRICULTURE SCAN

Rural Saskatchewan suffers from declining farm numbers, eroding rural population, loss of community services and the continuing outward migration of young people. There is ongoing instability in primary agriculture (grain and livestock) caused by rising input costs, machinery costs and the downward pressure on commodity prices, usually resulting in low or negative income margins for farmers.

The province of Saskatchewan is comprised of 65.2 million hectares (ha) of land, of which about half are cultivated (arable). The two options have been to seed annual crops or perennial forage. By comparison, there are 35 million ha of forest lands in the province, although not all this is available or suitable for timber harvest (1). The average Saskatchewan farm size is 500 ha and increasing yearly. There are approximately 47,000 farmers in Saskatchewan, with an estimated 7000 in the northeast study area. Sask. farmers seed an average of 30 million ha of crop each year (1). The average age of a Saskatchewan farmer is 49 and increasing yearly (12).

Saskatchewan farmers carry a significant debt load, estimated to be seven billion dollars at present. Fluctuating interest rates create a serious financial risk for farmers (1). This trend has led to the off-farm migration of many farmers. The loss of the Western Grain Transportation Agreement (WGTA), more commonly known as the Crow Benefit (that especially affected the northeast), eroding grain prices and extreme weather conditions all create opportunities for tree production and eventual value added processing in Saskatchewan.

The appreciation of the Canadian dollar results in a position of disadvantage when exporting to the USA, Canada’s largest trading partner. Foreign subsidies continue to pressure global grain prices downward. These are ongoing issues.

Soils in northeast Saskatchewan were formed under tree cover and are therefore suitable to return to afforestation or replanting for future fibre production. Typical soil typess in the northeast are clay, clay loam and grey wooded.

Innovative farmers (forage seed, dehydrated alfalfa production, pea production and processing, biofuel development) indicate the depth of farmer innovation in the northeast Saskatchewan project area.

The current agricultural issues in rural areas have created a demand for new crops and the development of new economic opportunities. Agroforestry can be a fit on many farms in Saskatchewan, particularly the northeast.

AGROFORESTRY SCAN

Saskatchewan producers are looking for viable crop options that will help develop stability on the farm. Agroforestry, the growing of trees on farmland and further value added activities, may be part of the solution producers are seeking. At present, the Saskatchewan agroforestry industry is in its infancy when compared to other places in the world; hence, there is much development that could take place. Agroforestry also has the potential to offer economic, social and environmental benefits to rural areas.

The recent focus in agroforestry is the production of hybrid poplar. The largest hybrid poplar tree plantations in Saskatchewan are approximately 34 ha, but most are much smaller. In comparison, large wood plantations in the world are thousands of hectares in size. There are approximately 60 producers with hybrid poplar stooling beds throughout the province, about half this group are located in the northeast study area. The Saskatchewan Forest Centre has established 50 agroforestry demonstrations across Saskatchewan, about two-thirds are in the northeast study area. Additional hybrid poplar demonstrations have been established in cooperation with Saskatchewan Environment and the Forest 2020 program as previously mentioned (3).

Agroforestry research in Saskatchewan has included fertilizer trials, herbicide trials, density trials, variety trials, weed control trials and hog effluent application.

Agroforestry related associations that exist include the Saskatchewan Fruit Growers Association, the Saskatchewan Christmas Tree Growers Association and Parkland Agroforestry Products Inc.

Saskatchewan Agriculture and Food indicates 840 ha dedicated to fruit tree crops in Saskatchewan in 2006, a substantial increase from 148 ha in 2004. Increased acres of all types of tree fruit (mainly dwarf sour cherry, haskap, dwarf apple and Saskatoon) are expected in 2007.

In the northern farmland fringe zone of the province, 1.28 million ha of farm land have been identified as highly suitable for hybrid poplar plantations, 0.6 million ha as suitable and 0.56 million ha as moderately suitable (3). The introduction of other tree species, such as willow and pine, could substantially increase the area suitable for tree production.

The number of saw mill operators in Saskatchewan has dropped from over 200 to 60 in a period of 10 years (3). It is recognized that the benefits from further value added activities requires capital, labour and market access.

ENVIRONMENTAL SCAN

The northeast agricultural area of Saskatchewan is located in the Boreal Transition Ecoregion. This interface between forest and farmland has shifted in the last 50 years from forest to a mix of grain and livestock operations (5). The climate in northeast Saskatchewan tends to moderate temperatures, high moisture and low evaporation during the growing season compared to the southern prairies.

Studies indicate the best locations for hybrid poplar are on soils classified as sandy loam, clay loam or loam with a soil pH 5.5 to 7.5 (3). These characteristics are typical of soils in northeast and other parts of Saskatchewan.

About 80% of Saskatchewan surface water originates in the Rocky Mountains in Alberta and feeds the Saskatchewan River system. These rivers are the most stable water source in the province (11). Farm water is often from wells or dugouts which may be enhanced with the introduction of trees and watershed management. The increase of tree planting activities can intercept, buffer and filter surface water to reduce runoff and sediment concerns. Trees on riparian areas protect water bodies while producing a marketable end product.

Trees are considered a natural part of a healthy environment and generate little conflict in the genetically modified organism (GMO) debate. Up to 295 kg of carbon can be stored in a mature hybrid poplar tree which is a significant factor in carbon storage and trading strategies (6).

Tree planting provides wildlife habitat and contributes to eco-tourism opportunities in Saskatchewan. Agroforestry allows for the restoration of previously wooded areas with a future expectation of economic and/or environmental benefits. Tree planting integrated with intensive livestock facilities can reduce odor transmission and provides an option for effluent management. Trees of all species are being considered as a source of biomass for ethanol production and electricity production.

Several First Nations groups have expressed an interest in agroforestry opportunities. For example, Yellow Quill First Nation has an agreement with Saskatchewan Environment regarding harvesting rights on Crown land (non-Crown forest) in the Kelvington area (7).

The northeast study area has seen much landscape change since settlement. Ecological habitat has been disrupted with land cultivation and wetland drainage. An expanded agroforestry industry has the potential to mitigate any negative or unintentional environmental damage with the establishment and management of trees in the landscape.

CHALLENGES AND OPPORTUNITIES

Wood markets and trends in the wood industry have changed considerably in the last 10 years. The instability in the wood markets is not an indicator of a sector in decline but rather a sector in transition. The transition is driven by growing environmental awareness and the pressure of competitors resulting from global trade. Pulp and paper industries are shifting production away from North America to locations in South America and Asia. The reasons include climate, lower labour costs and access to ocean ports and export markets.

The rising production costs of solid wood lumber products are leading to the increased use of engineered wood products. Engineered wood product mills in North America doubled in the 1990s from 54 to 109 (8). Companies are also more actively managing their byproducts (sawdust, trim, bark etc.) to create additional revenue streams. Opportunities also exist for cogeneration, wood pelleting and ethanol production.

The Food and Agriculture Organization (FAO) predicts world wood demand to increase by more than 40% by 2010 (3). As companies reposition themselves in the market, there is a concerted effort to further process products and increase profits. The target is to increase product value with the potential of decreased transportation costs. Further value added opportunities exist in peeling/slicing facilities, laminated veneer lumber, wall paneling and finger jointed lumber. Demand for modular and wood panels is predicted to dominate the housing industry in North America (8).

It is estimate that a 2400 ha annual harvest is needed to support a small pulp mill, medium oriented strand board (OSB) mill or several small hardwood mills in today's Canadian economy (8). The large capital investment required in a pulp mill or OSB plant, combined with transportation and market issues, has limited the growth potential of this industry in Saskatchewan. New products and processing technology may reverse this trend.

Production of veneer products present opportunities for high value processing of tress in Saskatchewan. Estimated costs for a veneer plant are from three to six million dollars and may employ up to 35 people depending on the process. Markets are extremely attractive with returns from a high quality veneer log (birch, cherry, oak, maple) significantly increasing in value compared to dimensional lumber (3).

Fruit production and processing including sour cherries, dwarf apples and haskap (blue honeysuckle berries) is a rapidly expanding sector in Saskatchewan (4).

Wood biomass has a growing potential as a source of feedstock for ethanol production and generation of electricity. The Nipawin Ethanol Project is an example of a community based project with tremendous spin-off potential for the region.

The potential for ecotourism continues to grow in Saskatchewan and could be enhanced with further development of community based tree planting and related industries. International "green consumerism" favours environmentally friendly projects and business processes. Agroforestry and tree related industries would be a good fit in this category. Trees are considered to be an excellent carbon "sink" and should have a strong fit in future Kyoto and/or clean air legislation. Related issues such as the Mountain Pine Beetle infestation experiences in the forests of British Columbia may provide a "grown in Saskatchewan" opportunity for a wood supply that is currently imported from other provinces. By 2050, it is estimate that 85% of North American wood supply will come from planted sources, a strong market indicator for agroforestry development.

SOURCES

(1) Saskatchewan Agriculture and Food (SAF) – 05/06 Annual Report, Statistics Handbook

(2) Econex – Growing the Rural Environment

(3) Saskatchewan Forest Centre (SFC)

(4) Saskatchewan Fruit Growers Association (SGGA)

(5) Ducks Unlimited Canada (DU Canada)

(6) Agriculture and Agri-Food Canada (AAFC)

(7) Saskatchewan Environment

(8) Forintek Canada Corporation

(9) Saskatchewan Agrivision Corporation Inc.

(10) Action Committee on the Rural Economy (ACRE) Final Report

(11) Saskatchewan Watershed Authority (SWA)

(12) Statistics Canada

(13) Alberta Agriculture, Food and Rural Development (AAFRD)

(14) Premier's Task Force on Forest Development

APPENDIX 1

Swot analysis

Producer, industry and community focus group events were held in five locations: Melfort, Sturgis, Kelvington, Nipawin, Prince Albert in November, 2006. The purpose of each session was to consult those involved in agroforestry enterprises and/or community development to identify strengths, weaknesses, opportunities and threats (SWOT) in the industry in Saskatchewan. A SWOT analysis was conducted with each group. The discussions, issues and opportunities are reflected in this document:

<table>
<tr><td>Strengths
current farm income struggle
farmers receptive to new ideas
productive land base
good farmer knowledge base
innovative farmer attitude
good climate for trees
government initiatives positive
carbon program opportunities
biomass energy opportunities
demand for wood ongoing
current crop systems not sustainable
model group Parkland Agroforestry Products
support for Sask Forest Centre</td><td>Weaknesses
lack of available capital
market transportation costs
lack of incentive programs
farmer age increasing
grain 1st mentality of farmers
shortage of farm labor
restricted crown wood supply
soft markets for traditional products
market signals not clear
lack of economic information
lack of support/insurance programs
limited species genetics
lack of producer group
lack of a community model</td></tr>
<tr><td>Opportunities
Kyoto friendly/carbon credits
low environmental foot print
alternate to crown wood supply
trees can be managed
producer control of crop
one more crop alternative
opportunity for community model</td><td>Threats
global weather changes
disease/fire threat
government regulations
increased grain prices
substitute products
20 year income lag</td></tr>
</table>

Following is a vision statement developed at the end of the community focus group sessions held in the five locations:

Vision Statement

To develop the agroforestry industry as a regional business opportunity, involving individuals and communities, incorporating:

- Economic return;
- Regional development;

- Community stability;
- Environmental sustainability;
- Social goals.

APPENDIX 2

Agroforestry project support and information

Saskatchewan Forest Centre, Prince Albert
www.saskforestcentre.ca

Saskatchewan Agriculture and Food
www.agr.gov.sk.ca

Centre for Northern Agroforestry and Afforestation, University of Saskatchewan
www.saskagroforestry.ca

Centre for Studies in Agriculture, Law and Environment (CSALE), University of Saskatchewan
www.csale.sask.ca

Forintek Canada Corporation
www.forintek.ca

Saskatchewan Research Council
www.src.sk.ca

Agriculture and Agri-Food Canada
www.agr.gc.ca/pfra

Parkland Agroforestry Products Inc.
www.parklandagroforestry.com

APPENDIX 3

Developing a regional / community agroforestry project

Steps (may vary depending on community structure):

1. Initiate steering committee and/or project leader: villages, towns, Rural Municipalities, Regional Economic Development Authorities, community groups;

2. Identify project team: gather vested individuals and/or groups;

3. Priorize opportunities in area: what could/should/can be developed?

4. Define project area: geographic boundaries;

5. Establish partnerships :other agencies such as lenders, government agencies, economic development groups, service & community clubs;

6. Identify a Vision and set Goals: group exercise, get everyone on the same page, consider using a facilitator;

7. Community consultation: information nights, town hall meetings;

8. Gather relevant information on resources available;

9. SWOT Analysis: review regional potential, both plus and minus;

10. Develop an Action Plan: what to do, who does it, by when;

11. Implement activities: get started, deliver the Action Plan;

12. Evaluation: what worked, what didn't, why?

SHELTERBELT ENHANCEMENT PROGRAM (SEP)

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Abstract: The Shelterbelt Enhancement Program (SEP) began in 2002 through the Government of Canada's Action Plan 2000 on Climate Change. It was a five year program designed to help reduce green house gas (GHG) emissions. The goals of the SEP were 1) to reduce GHGs by 0.3 megatonnes by 2010; 2) plant 8,000 km of shelterbelts by 2006 in addition to the Centre's annual planting commitments; 3) help fulfill Canada's commitment to the Kyoto Protocol.

The program enhanced the Prairie Shelterbelt Program in Manitoba, Saskatchewan, Alberta and the Peace River Region of British Columbia. Weed control, and its associated costs, have been identified as the most limiting factor in establishing shelterbelts across the Prairie region of Canada. The aim of the SEP was to improve shelterbelt planting success, while reducing weed control costs to the landowner.

Through the SEP, clients had access to technical and material assistance that improves shelterbelt planting success. Clients were supplied with plastic mulch for installation on new seedlings acquired through the Prairie Shelterbelt Program, as well as specialized equipment for the installation of the plastic mulch.

In the end, we fell short of our goal of 8,000 km of trees, as there was a total of 5,202 km planted. However, we still feel that the program was a success, the 5,202 km will sequester approximately 0.2 GHGs by the year 2020 when the trees mature, as well as a great deal more awareness of weed control in general when establishing shelterbelts.

Key Words: Shelterbelt Enhancement Program.

AGROFORESTRY EXTENSION PROGRAM AT THE SFC: DEVELOPMENT OF AN AGROFORESTRY MANAGEMENT COURSE

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Abstract: Essential elements for successful extension programs include a wide variety of material and events to optimize learning and accessibility to knowledge. The Agroforestry Unit at the Saskatchewan Forest Centre (SFC) has created an extension program 'from scratch', centred on the small knowledge base of the Prairie Farm Rehabilitation Administration (PFRA) and on the knowledge base created through programs and research at the SFC. The program developers at the SFC recognize that farmers prefer to gather information by a hands-on approach and value having access to experts for discussion in groups and one-to-one. The SFC has incorporated these concepts into its agroforestry extension program that includes one-on-one access, field days, focus group meetings, small workshops and an annual two-day conference. It developed a participatory research model for expanding the agroforestry demonstration network. The SFC, the farmers and the researchers all work together to increase information about agroforestry. Studies show that involvement builds commitment and leads to adoption.

The success of the program at the SFC led to client demand for a formal agroforestry management course, the first of its kind on the prairies. The process has been a participatory venture that was producer driven and partnership based. Enough knowledge about growing trees on the prairies is now available to provide a four module, two day course that is flexible on subject and time, and can be tailored to meet client needs. The development of the course would not have been possible without the collaboration of several agencies, farmers and researchers.

Key Words: Extension, adoption, agroforestry, decision making, technology transfer, participatory research.

INTRODUCTION

The complexity of decision making at the farm level can not be underestimated (Stonehouse 1994). The decision by farmers and other landowners to plant trees on their agricultural land as crops is especially interesting as it is a new concept for Saskatchewan landowners. Adoption of new technology is dependent on several factors that are micro- and macro-structural in nature. Figure 1 shows the complex interaction of different factors that affect on-farm decisions for conservation adoption. Studies show that access to extension is an important factor in rational decision making at the farm level and contributes to adoption (Kowalski 1998; Marsh 2000).

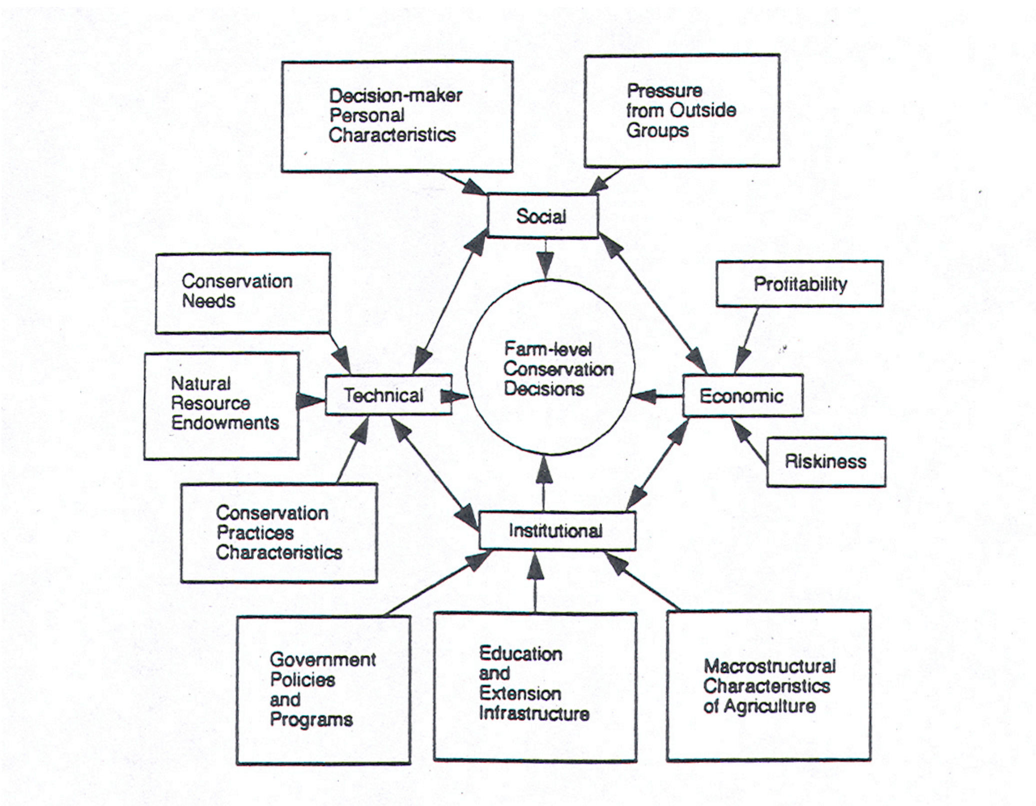

Fig. 1: Overview of factors affecting adoption and use of conservation practices. Source: Stonehouse (1994).

Agroforestry systems are designed for optimal environmental benefit, whether to reduce and control wind and water erosion (as in the case of shelterbelts and riparian areas) or to reduce greenhouse gas emissions and/or sequester carbon (as in tree crops). They are, by definition, conservation practices and can be treated as such in view of adoption decisions. To further strengthen the role of agroforestry in conservation, planting trees qualifies under the federal Greencover Program and in Environmental Farm Plans. In addition to environmental benefits, planting trees as crops proves to be economically sound decision making. Trees will return more per acre than annual crop production.

In agriculture, as in all areas, learning leads to skills improvement and reduces uncertainty, improving decision making (Marra et al. 2001). The quality and type of information matters as well as access to diverse resources. Farmers look at two main types of information: direct, as in profitability estimates, and indirect, as in how popular the technology is in a certain area (Green 2005). They will take account of neighbours' decisions and experience, and seek the opportunity to interact with researchers. Farmers prefer to see for themselves whether something works. Therefore, extension programs that include field days and demonstration sites are both popular and effective. A comprehensive extension program that provides an array of material enhances accessibility and adoption.

A study that looked at the influence of extension on the adoption of conservation practices held forth four recommendations to maximize accessibility and adoption (Kowalski 1998). These four recommendations were to:

1. Provide information on wide-ranging issues. Too much conflicting information can get in the way of decision making and confuse decision makers. Farmers are able to critically evaluate technology but expanded knowledge allows skillful application.
2. Hold local events. Farmers are time and labour savers, and travel cuts into both. If events are held locally, there is higher uptake and a learning opportunity to evaluate local conditions and their relationship to the broader issues is provided.

3. Retain and expand field days and demonstrations. These are useful in two ways: the ability to see first hand how things work, and the chance to discuss the technology with researchers and other farms.

4. Support and promote on farm research. This enhances two-way communication, a key for good extension. As farmers participate in the research, researchers can benefit from their on site knowledge and insight into local problems. This again gives farmers access to researchers knowledge.

THE SASKATCHEWAN FOREST CENTRE EXTENSION PROGRAM

The Saskatchewan Forest Centre's mandate is technology transfer: to promote the acquisition, creation and dissemination of knowledge to expand a socially, ecologically and economically sustainable forest sector. In the original SFC Strategic Plan 2002-2006, each work unit was directed to integrate technology transfer activities into their work plans. These activities included one-on-one access, field days, focus group meetings, publications, small workshops and conferences. In the case of the Agroforestry Unit, a two-day conference has become an annual event. Through the SFC Forest Development Fund, projects have seen the SFC partner with various research agencies to further the knowledge base in agroforestry; these agencies include Agriculture and Agri-Food Canada-Prairie Farm Rehabilitation Administration (AAFC-PFRA), Saskatchewan Research Council (SRC), Prairie Adaptation Research Collaborative (PARC), Saskatchewan Agriculture and Food, Ducks Unlimited Canada and the College of Agriculture and Bioresources at the University of Saskatchewan. An extensive agroforestry demonstration site network developed over the years now encompasses over 1400 acres on over 50 sites.

The literature is rich with studies that link use of and accessibility to extension programs to the adoption of conservation practices and new crops and technology (Kowalski 1998). Although understanding and use of agroforestry on a large scale was in its infancy in the province when the Saskatchewan Forest Centre was established in 2001, the SFC recognized that agroforestry was an important part of the forest sector and was designated to be one of the three work units, alongside value added and fire and forest science. There was a dearth of information on agroforestry systems so the Agroforestry Unit set out to acquire what existed and to create its own. Dissemination began as the Unit members developed an extension program targeted at farmers and landowners who were seeking knowledge on growing trees.

The extension framework built by the SFC for agroforestry was based on diversity of information sources and delivery, and allowed for a feedback loop through producers and agencies with experience in the sector. Through the one-on-one contact, focus groups, field days and workshops, the Agroforestry Unit was able to identify information and learning needs of the client base. Publications were built based on SFC and client identified subject matter. Demand was client driven and influenced what and when information would be available. In the spring of 2006, the SFC and clients recognized that the time was right for a comprehensive management course in agroforestry.

THE AGROFORESTRY MANAGEMENT COURSE

Development of the SFC Agroforestry Management Course was producer driven and partnership based (see Appendix 1). It is the first to be focused on and offered on the Prairies. The course is designed in four modules that are based on issues identified in the literature and by the SFC, as derived from clients, as essential and preferred information for growers. Each module is provided in a half day session over two days (Appendix 2). However, the course is designed to be flexible to client needs and can be condensed into a one day session or expanded to four days. Each module can be provided as a stand alone session.

An Agroforestry Management Course Handbook provides instructors with a guideline and participants with take-home information. Certificates of achievement are granted by the SFC and the Centre for Studies in Agriculture, Law and Environment (CSALE) to each participant. The Course qualifies under Agriculture and Agri-Food Canada's Canadian Agriculture Skills and Service (CASS) Program. From the AAFC web site: "The Canadian Agricultural Skills Service (CASS) program will provide funding to beginning and established farmers and their spouses to develop a learning plan and take courses to help them gain the skills they need to reach their goals. CASS will assist farm families to acquire on-farm skills, or skills and training to pursue other income options, or both" (Agriculture and Agri-Food Canada 2007).

The course curriculum development took place over the summer of 2006 (May to September). A pilot session was held in October and participants provided valuable feedback that was used to improve course delivery. Several sessions were planned for various locations in the province during the spring of 2007. A variety of instructors are qualified to deliver the course which allows for adaptability and originality. This means that the course can be adjusted to take advantage of instructor's particular expertise, while still providing basic information. Interaction between participants and instructors and among participants is encouraged and enabled. Evaluation results from each session show that this approach has been successful.

The course is a good example of how incorporation of valued elements of accessible information are used for the culmination of client demand. It provides information on broad issues related to agroforestry management. The sessions are held in various locations across the province to optimize participation at a local scale. Requests for the course to be held for agencies' client base are undertaken. The Saskatchewan Forest Centre will continue to update curriculum for the course as research provides new information.

The Saskatchewan Forest Centre Agroforestry Management Course combines components that allow for a comfortable and accessible learning environment for growers with and without experience. Encouraged participant interaction supports the reality that farmers like to learn from researchers and each other. The learning environment permits the discussion and observation that are deemed vital to encourage adoption.

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APPENDIX 1

Original Course Development Group

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APPENDIX 2

Agroforestry management course modules

Module One:
Industry and Marketing Analysis of Agroforestry Systems in Saskatchewan
Overview of the agroforestry industry: Six ways to incorporate trees into farm plans
Situation analysis of markets for agroforestry products
- Understanding marketing approaches and competition
- Industry trends/outlook and demographic profile

Developing a marketing plan. What you need to consider.
Wood and non-timber forest product opportunities

Module Two:
Production and Management of Agroforestry Systems in Saskatchewan
Why might you consider agroforestry?
Assessing and developing what you have
What products might fit with your resources and objectives?
- Discussion of alley cropping, silvopasture, riparian buffer strips, woodlots, non forest products, shelterbelts, afforestation and alternate crops such as fruit and nuts.

An example of a production system using hybrid poplar
- Optimal soils, site preparation, crop planting, crop maintenance
- Disease control, weed control and fertilization
- Costs, cash flow and risk management
- Understanding growth and yield

Module Three:
Processing and Value Added Strategies for Agroforestry Systems in Saskatchewan
Pre harvest planning, sales options, contracts
The harvest process, harvesting options
Primary and secondary processing. What you need to know
Case study: Small sawmill operation. What's involved?
Products and value added applications

Module Four:
Environmental Issues Regarding Agroforestry Systems in Saskatchewan.
Environmental benefits from agroforestry
Carbon sequestration
Environmental Farm Plans and agroforestry
Programs, policies and other resources available: The Canada/Saskatchewan Farm Stewardship Program

AGROFORESTRY DIVISION OF AGRICULTURE AND AGRI-FOOD CANADA'S - PFRA: WHO WE ARE AND WHAT WE DO!

Laura Poppy

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Abstract: The Agroforestry Division develops science, technology transfer materials and incentives to support the understanding and adoption of agroforestry science and practices by Canadian farmers. The Division is based out of the Agriculture and Agri-Food Canada (AAFC) – Prairie Farm Rehabilitation Administration (PFRA) Shelterbelt Centre in Indian Head, Saskatchewan and staff and resources are devoted to activities within and beyond the Canadian prairie region.

AAFC's role in tree planting is focussed on agricultural lands where the activity has potential to benefit the agricultural sector. The aim is to benefit crop & livestock production and mitigate the impact of agriculture on the environment.

The Agroforestry Division has the responsibility for the delivery of the ongoing, regional 'Prairie Shelterbelt Program' and is involved in national and international research projects. In support of these activities information tools are being developed that support agroforestry adoption in Canada. The AAFC's-PFRA Agroforestry Division has the knowledge, experience and mandate to bring agroforestry solutions and opportunities to Canada's agricultural sector.

Key Words: Agroforestry, research, programs, development, Canada.

THE CANADIAN PRAIRIES SHOULD BE AN IDEAL PLACE FOR AGROFORESTRY AND AFFORESTATION TO GROW

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Abstract: This poster will touch on the physical attributes such as soil suitability, and climatic conditions that favour tree establishment on the Canadian prairies. It will also consider societal attitudes that could be beneficial to integrated agroforestry adoption. Agroforestry research capabilities have been ongoing for over fifty years and continue to support agroforestry gaps. To distribute this information, Saskatchewan has two facilities dedicated to extension in agroforestry, the Saskatchewan Forest Centre and the Agricultural and Agri-Food Canada's PFRA Shelterbelt Centre. Furthermore, programs such as the National Farm Stewardship program and SaskPower's Shand Greenhouse tree program, the Greencover program and the PFRA Prairie Shelterbelt program support agroforestry initiatives through funding and distribution of trees and services. Taking all these factors into account, agroforestry on the prairies should be thriving. Unfortunately, of the five agroforestry practices, planting of windbreaks is the only one commonly practiced on the prairie landscape. Since the Canadian prairies have been a leader in the establishment of windbreaks but have lagged behind in the incorporation of other agroforestry and afforestation, something must be lacking. This poster will discuss possible hindrances such as policy and tax implications that need to be changed and programs that need to be implemented if Saskatchewan is to become a leader in planting trees on agricultural lands.

Key Words: Soil suitability, policy, research, programs, windbreaks.

CENTRE FOR NORTHERN AGROFORESTRY AND AFFORESTATION

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Abstract: Saskatchewan has a long history of tree planting going back to 1870 when the government wanted to plant a third of the prairies to trees to increase rainfall for agriculture. In 1901, the Shelterbelt Centre in Indian Head was established to provide seedlings for settlers and they have shipped over half a billion trees to date. In 1997, the term agroforestry was included in Saskatchewan's State of the Environment Report and funding set aside to develop sustainable agroforestry systems for the economic diversification of farms. In 2001, the Federal and Provincial governments announced the opening of the Saskatchewan Forest Centre in Prince Albert which has a mandate for promoting agroforestry in the province. More recently, the Premier announced in 2005, his vision to transform 10% of the arable land to agroforestry. In order to accomplish this vision we felt that a strong research program was needed and the Centre for Northern Agroforestry and Afforestation was established at the University of Saskatchewan in 2006. Research projects investigating the cultural practices for establishing hybrid poplar plantations, fertilizer trials of hybrid poplar clones, nutrient cycling studies and the beginning of a willow biomass program have been conducted by the Centre. The Centre has also been involved with developing an agroforestry strategy for the province. The strategy proposes developing markets, improved tree breeding programs, changing policies to promote agroforestry and developing risk sharing programs as well as improving extension and communications programs to farm groups. This poster will highlight the Centre's activities.

Key Words: Centre, Research, Agroforestry Strategy, Hybrid Poplar, Biomass Energy

AGROFORESTRY POTENTIALS IN MINNESOTA: PERCEPTIONS OF LANDOWNERS AND NATURAL RESOURCES EXTENSION PROFESSIONALS

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Abstract: Innovative agroforestry practices and systems offer much potential for adoption in Minnesota because of the state's unique geographical locations where forest and prairie meet, well developed agriculture and forest based industries and market, and environmental concerns. The first step in developing an agroforestry extension and training program involve compilation, synthesis, and analysis of the current knowledge on existing practices. Equally important is to understand the perceptions of landowners and natural resources extension professionals of agroforestry as a land use option. Despite the potential for agroforestry adoption in the Minnesota, no systematic efforts have been made to assess the critical issues in Minnesota about agroforestry adoption. Therefore, needs assessment surveys were developed based on literature review pertaining to Minnesota landscape as well informal site visits and with people engaged in natural resources and land use in the state. Surveys of landowners and natural resources professionals throughout Minnesota were initiated. In addition to getting insights into the perceived benefits and concerns about agroforestry practices, results showed that the extent of alley cropping, silvopasture and forest farming practices were less anticipated. Windbreaks and riparian forest buffers were the most widely used forms of agroforestry in Minnesota. Improved water quality, soil protection and increased financial security were the most prominent reasons for agroforestry adoption in the state. Survey results also showed that lack of financial incentives and familiarities with agroforestry practices as well as non-recognition of agroforestry in the farm bill were the main obstacles in the adoption of agroforestry practices in Minnesota. The survey results are now bases for developing relevant agroforestry extension activities and programs in Minnesota.

Key Words: Agroforestry, need assessment, survey, farm bill.

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