

13th North American Agroforestry Conference

Conference Proceedings

LAURA POPPY, JOHN KORT, BILL SCHROEDER, TRICIA POLLOCK AND RAJU SOOLANAYAKANAHALLY, EDITORS

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Agroforestry – Innovations in Agriculture

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Charlottetown, Prince Edward Island, Canada

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Chairman's Message – on behalf of AFTA

This book contains the proceedings of the Thirteenth North American Agroforestry Conference (NAAC). The conference has been organized under the auspices of the Association for Temperate Agroforestry (AFTA).

The mission of AFTA is to promote the wider adoption of agroforestry by landowners in temperate regions of North America. Formed in 1991, AFTA is a private, non-profit, organization based at the University of Missouri Center for Agroforestry at Columbia. Since 1989, it has co-sponsored the biennial North American Agroforestry Conference series - a major scientific forum for those involved in agroforestry research, extension and application in the US, Canada and overseas.

The 13th NAAC featured over sixty oral presentations as well as over 25 poster presentations covering the range of agroforestry subjects such as riparian buffers, alley cropping and inter-cropping, greenhouse gas mitigation, non-timber forest products and silvopasture.

The pre-conference and conference tours also provided delegates an opportunity to view first hand some of the work that is currently underway in the discipline of agroforestry in Prince Edward Island and the neighbouring province of New Brunswick.

Of course, a successful conference involves more than formal presentations and posters. It represents an opportunity to meet new colleagues and develop new networks. Therefore, a social function featuring local fare and entertainment was arranged to allow time to make new friends and also experience some genuine maritime food and culture. It is an Atlantic Canadian tradition that when friends and family gather at a home, it is usually in the kitchen. These gatherings almost always include music and good food making it a "Kitchen Party".

The organization of this conference required the dedicated effort and hard work of many people and several partners including Agriculture and Agri-food Canada, the Prince Edward Island Department of Agriculture and Forestry, the PEI Federation of Agriculture, the Poplar Council of Canada and the PEI Soil and Crop Improvement Association. To these organizations and other individuals who helped with making this conference a success, we thank you.

Last but not least, we also thank our invited plenary speakers as well as those who presented papers and posters.

We wish you all an exciting conference and a memorable few days on beautiful Prince Edward Island, Canada's "Garden Province".

Chris Pharo, Co-chair,
13th NAAC Committee,
Kentville, Nova Scotia

John Kort, Co-chair,
13th NAAC Committee,
Indian Head, Saskatchewan

Poplar Council of Canada Foreword

The Poplar Council of Canada is pleased to be able to join the 13th Biennial North American Agroforestry Conference (NAAC) in Charlottetown, Prince Edward Island (PEI) and in conjunction, hold our 35th annual general meeting. This meeting will highlight much of the recent work being conducted on willows including biomass, carbon and ecosystem services projects.

Having the opportunity to come to PEI for a conference, combined with the pre-conference tour starting in Fredericton, New Brunswick will allow attendees to see and explore the unique nature of two of our maritime provinces. The chance to visit the Canadian Bioenergy Centre and the Wood Science Technology Centre at the UNB will also be highlights.

In 2014 the Poplar Council of Canada will be joining the 6th International Poplar Symposium (IPS VI) being hosted by and held at the University of British Columbia in Vancouver, British Columbia. The IPS meetings are held every four years and it is a great honour to have the 2014 meeting in Canada. Please visit the web site at www.2014ipsvi.com for more details on the July 20-23 meeting.

Finally I would like to thank the organizing committee for preparing a comprehensive set of presentations, and what looks to be a great field tour day and evening 'Kitchen Party'. I look forward to exploring the University of PEI campus and encourage everyone to seek out and make new contacts and friends this week. Please join us at our AGM meeting Wed. June 19th from 5-7pm if you are interested in learning more or becoming involved in the Poplar Council of Canada or check us out at www.poplar.ca.

Barb Thomas, PhD
Chair, PCC

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HEDGEROWS AS PROVIDERS OF SERVICES IN AGRICULTURAL LANDSCAPES

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ABSTRACT

Hedgerows and shelterbelts, have been planted and managed for millennia to provide services to society, provision services such as timber and firewood, cultural services such as property limits and beautification, regulating services such as combating erosion, protecting against the wind, providing refuge for beneficial insects, etc.. Trees and shrubs of hedgerows can be shaped and managed in many different ways so that the same species may have a different architecture for different purposes. Networks of hedgerows may also have different patterns which change over time. Therefore, hedgerows and hedgerow networks can evolve to fulfill novel services expected by society, e.g. protection of biodiversity, amenities. Examples from Western Europe will be used to illustrate those services and shifts in demands.

Keywords: biodiversity, hedgerow network, erosion, society

INTRODUCTION

In Europe, hedgerows, shelterbelts, windbreaks and other linear features made of shrubs and trees have been planted for millennia (Marguerie et al. 2003). They have been removed too. These dynamics depend on the services or dis-services they provide to the local societies. Though the processes depending on hedgerows and hedgerow networks remain more or less similar, the services based on the outputs of those processes widely change. This is especially true nowadays that local landscapes and their fate depend on the expectations of an increasingly urbanized society (Baudry et al., 2000; McCollin, 2000). I will present the various services provided by hedgerows and the associated processes (Baudry and Jouin, 2003). Most of our research is done on a long-term ecological research site, the “Zone atelier Armorique” in northern Brittany (http://osur.univ-rennes1.fr/za-armorique/), which is a bocage (hedgerow network) landscape (figure 1).

SERVICES AND PROCESSES

The cultural services

Hedgerows are visible; therefore they play an important role in landscapes. The diversity of species and management techniques are cultural features which vary from region to region. The loss of hedgerows may be seen as a loss of identity or a sign of a better use of the land by farmers (Burel and Baudry, 1995). In any case, the presence of hedgerows and their aspect are foremost perceived as cultural signs. In Europe, many hedgerows have been planted to indicate property limits or as fences to exclude wild beasts or contain cattle.

Song birds, insects such as butterflies, flowers also provide cultural services when the general public has access to the wider landscape.

Low density bocage (60 m hedgerows per ha)	High density bocage (120 m hedgerows per ha)

Figure 1: contrasted landscape in the Zone atelier Armorique

Low trimmed hedge (Normandie)	Ancient chesnut (Brittany)	Shredded oaks (Brittany)

Figure 2: a diversity of hedgerows

The production services

Hedgerows can produce wood for a variety of uses: firewood, timber, fence posts etc. They have been the only source of energy for a long period, especially in regions where forests were scarce. Hedgerows also have an effect, well known in the Great Plains, on crop production. The increase in farm areas and the lesser need for firewood have led to many hedgerow removals (Petit et al, 2003).

Hedgerows and the services related to biodiversity

The loss of biodiversity as a consequence of hedgerow removal is a major argument for hedgerow conservation. Hedgerows provide habitats that are shadier and more humid than the surrounding fields. The research in this area develops along two main axes: 1) what are the factors which allow the presence of species in hedgerows and 2) what are the services a farmer can expect from the species thriving, at least part of their life cycle, in hedgerows?

Until the development of landscape ecology, hedgerow structure (tree and shrub cover and density, presence of a ditch, an earthen bank etc.) was the factor believed to determine the presence of plant and animal species in hedgerows (Hinsley and Bellamy, 2000). Landscape ecologists first demonstrated the importance of network connectivity: species can move among connected hedgerows when open fields are a barrier (Burel et al. 1998). Small mammals, birds, ground beetles benefit from connectivity; it is still debated for plants, but newly planted hedgerows connected to older ones are more readily colonized than isolated ones. Hedgerows are also a barrier for butterflies inhabiting grassland. Thus, the landscape mosaic and agricultural practices in fields were shown to also control biodiversity and population kinetics. Grain (the area of open land under the influence of hedgerows) is also a controlling factor as it changes the local climate. Fine grain landscapes are less windy than coarse grain ones. Permanent grassland is less a source of disturbance in hedgerows than annual crops (Le Coeur et al., 2002). The wider the hedgerow, the less important the landscape context is for "interior" habitat, and, as in woodlots, the edge effect may be minimized.

Habitat provisioning is the first service provided by hedgerows; plants and animals, *per se*, have an ecological and often a societal value. They also provide services such as pollination, pest control, water purification, carbon sequestration.

Hedgerows offer both food (nectar and pollen) and nesting sites to solitary bees and bumblebees, the latter because the ground is undisturbed. Beneficial insects (predators, parasitoids) use hedgerows as wintering habitats or a source of food (adult syrphidae). But current research on pest control emphasizes the fact that hedgerows may impede the movements from field to field of predators overwintering in fields. This may be the case for carabid beetles, such as *Pterostichus melanarius*. Hedgerows also harbor pests such as aphids and voles. The whole food web is present and we still lack knowledge on how to enhance pest control.

Trees and shrubs need nutrients to grow, which means they provide a water purification service. In early spring, when the sap starts flowing, the amount of nitrate in the ground water below hedgerows is significantly lower than in the absence of a hedgerow (Caubel-Forget, 2001). This buffer effect translates at the landscape scale, as watersheds with a higher density of hedgerows export less nitrates than those with a low density. This is only valid when the subsurface flow of water is important (Mérot, 1999).

Carbon sequestration occurs through two processes. First the sequestration in trees and shrubs as long as they are not harvested, which may be in conflict with firewood production; leaves decomposing in the soil are also a source of carbon. Second is erosion control, as the top layer of soil is richer in carbon. Not only do hedgerows perpendicular to the slope arrest eroded particles, they also slow down run off, thus decreasing the energy which triggers erosion.

CONCLUSION

Hedgerows have many functions, which have changed over time: biodiversity, landscape amenities, water quality are issues which triggered little to no interest a few decades ago. Hedgerows are important for landscape resilience as novel services can be drawn from them. The new plantations are a sign of a new trend in agriculture modernization, as were the enclosures in Great Britain. From an ecological stand point, the maintenance of older hedgerows in the landscape insures the recolonization of the new ones by plants and animals.

Public policies regarding hedgerows show dramatic shifts. In the 1960s, there was a phase of subsidies to remove hedgerows when fields were really too small for machinery, with no recognition of any of their functions. Currently, subsidies support plantation and the Common Agricultural Policy of the European Union acknowledges their environmental role.

ACKNOWLEDGEMENTS

This research is supported by the Zone atelier Program of CNRS and INRA, by the ministry of Environment and various projects of the National Research Agency. The work was made possible thanks to the cooperation of the researchers, PhD students and interns of the Zone Atelier. I thank Sandrine Baudry for English editing.

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AGRICULTURAL GREENHOUSE GASES – CANADIAN AND INTERNATIONAL DEVELOPMENTS AND ISSUES

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ABSTRACT

Among the many global challenges facing the agriculture sector over the coming century, climate change may be the most profound. In some regions, it will provide opportunities, while, in others, it could seriously limit agricultural production. Because agricultural production is so vulnerable to the impacts of climate change, there may be no other sector in which mitigation and adaptation are so closely linked – effective mitigation can reduce the need for adaptation.

Global efforts to limit serious climate change, which began with the creation of the Framework Convention on Climate Change, have raised public awareness of the issues but global emissions are still rising. In agriculture, mitigation research and improved scientific knowledge and understanding are leading to production systems that produce more food with less greenhouse gas emissions. For example, the Global Research Alliance on Agricultural Greenhouse Gases (GRA) is an example of a global voluntary organization intended to improve the greenhouse gas efficiency of agricultural production to address climate change and address food security issues. GRA member countries undertake collaborative research activities with the aim of reducing duplication and getting improved production practices to producers more rapidly. Canada's major domestic contribution to the GRA, the Agricultural Greenhouse Gas program, involves academia and industry-led mitigation research livestock and crop production systems, including agroforestry.

TEMPERATE AGROFORESTRY IN THE 21ST CENTURY: A NORTH AMERICAN PERSPECTIVE

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ABSTRACT

The scientific foundation that has been laid, over the past decade in particular, has elevated agroforestry's role as an integral component of a multi-functional working landscape in North America. Recent trends in the agriculture sector necessitate farm diversification as an essential strategy for economic competitiveness in a global market. The realization that agroforestry systems are well suited for diversifying farm income while providing environmental services and ecosystem benefits has increased receptivity on the part of some landowners. Agroforestry systems offer great promise for the production of biomass for biofuel, specialty and organic crops, pasture-based dairy and beef, among others. agroforestry also offers proven strategies for carbon sequestration, soil enrichment, biodiversity conservation, and air and water quality improvement for not only the landowners or farmers, but for society at large. in an era of environmental sustainability and green business, the realization that agroforestry is an environmentally sound, ecologically sustainable, and economically viable alternative to traditional farming will propel its adoption to newer heights in the coming decades.

NEW IMPERATIVES AND OPPORTUNITIES FOR SCALING-UP TEMPERATE AGROFORESTRY: VIDEO PRESENTATION

Dr. Dennis P. Garrity

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ABSTRACT

Key arenas of global crisis are driving more serious investments in agroforestry than ever before. These include the imperative to "turn down the heat" and avoid the specter of a 4 degree warmer world. Agriculture is now challenged to increase food production but to do so by intensifying in a more agroecological direction. The new Rio+20 global goal to achieve a land degradation neutral world by 2030 is also driving innovation in land use. A Global partnership for Forest and landscape restoration has been launched, whose Bonn Challenge is to restore 150 m ha of degraded lands, of which 50 m ha is programmed for evergreen agriculture, the incorporation of trees in association with crops. Twenty countries in Africa and Asia are now gearing up for a massive expansion of evergreen agriculture, which has driven the development of a global partnership to support evergreen agriculture upscaling. In Europe, recent studies have shown that agroforestry exhibits 90% of the total GHG emissions reduction potential in agriculture, with an estimated value of $ 367/ha/yr in GHG emissions reductions. Agroforestry will be expanded to a very large extent in the coming decades in Europe, and in the rest of the world. This will transform rural landscapes across the globe. Question: is the North American agroforestry community prepared to lead in achieving this transformation?

CONCURRENT SESSIONS

Agroforestry and Greenhouse Gases

FINE ROOTS DISTRIBUTION, LIGHT CONDITIONS AND YIELD IN A TREE-BASED INTERCROP SYSTEM IN SOUTHERN QUEBEC, CANADA

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INTRODUCTION

In tree-based intercrop systems (TBI), trees are planted in widely spaced rows to allow agricultural activities to continue. These agroforestry systems are new in Québec but well known in Europe, USA and China (Baldy *et al.*, 1993; Rivest and Olivier, 2007). The integration of trees into an agroforestry system has the potential to enhance soil fertility, reduce erosion, improve water quality, increase biodiversity and aesthetics, and sequester carbon (Jose, 2009; Montagnini and Nair, 2004). However, the presence of trees also results in aboveground and belowground interspecific interactions with crop, which can include competition, facilitation or complementarity (Jose *et al.*, 2004; Rivest and Olivier, 2007; Van Noordwijk *et al.*, 1996). In theory, TBI systems can be more productive than the respective monocultures if trees have the capacity to take resources like water and nutrients in deeper soil layers than those used by crops (Cannell *et al.*, 1996).

OBJECTIVES AND METHOD

Spatial distribution of fine roots were studied in a replicated TBI system with *Quercus rubra* L., *Populus deltoides* x *nigra* (DN3570) and hay species in southern Québec (Canada), including monoculture controls. The study site is located in a marginal area for agriculture, where the soil is acidic and relatively poor. Fine root length density (FRLD) of trees and crop were determined at different distances from the tree line to a depth of 100cm using the trench profile and core break methods (Böhm, 1976; Mulia and Dupraz, 2006; Van Noordwijk *et al.*, 2000). The impact of trees on light availability and crop yield were also analysed.

RESULTS AND DISCUSSION

Results didn't show deeper root profiles for trees in TBI. Profiles were superficial as commonly found for tree species grown in conventional plantations or in natural ecosystems in a humid temperate climate (Achat *et al.*, 2008; Bakker *et al.*, 2008; Schmid and Kazda, 2002). More than 95% of fine roots were found in the first 25cm and 45cm for red oaks and hybrid poplars, and in 35cm for hay, respectively. The soil acidity, low fertility and a possible aluminium toxicity could also explain the observed shallow root systems (Ryan *et al.*, 1993). However, greater spatial separation exists between red oaks and hay fine roots as red oaks allocated fewer fine roots in the top 10cm of soil, and more between 10cm and 30cm. Hybrid poplar fine roots didn't show any adaption when intercropped with hay and a high value of FRLD in top soil layer near the tree line (~ 40km.m^{-3}) reduces pasture FRLD by 45%, suggesting strong competition for resources. Differences in ecological succession status between hybrid poplar and red oak may explain differences in fine root architecture, as pioneer species (hybrid poplar) tend to produce thinner and more branched roots (Bauhus and Messier, 1999; Finér *et al.*, 1997). Fodder yield analysis in the TBI system revealed biomass reduction near trees, particularly near PEH. However fodder yield in mid-alley was similar with yield obtained in the no-tree controls. The results of a principal component analysis indicated a stronger negative effect of light reduction on pasture yield than the presence of tree fine roots.

CONCLUSION

Hybrid poplars, a fast growing species, have stronger impacts than red oaks on pasture yield but will be harvested sooner and larger alleys should benefit the intercrop. However, their larger and denser root system could be beneficial for environmental issues, such as limitation of soil erosion, improving water quality or enhancing carbon sequestration. The dynamic aspect of TBI systems is close to natural ecosystems and should be further investigated for future success.

ACKNOWLEDGEMENTS

This study contributes to a larger project aiming at determining the potential contribution of agroforestry systems to climate change adaptation capacity of agroecosystems and was financed by Ouranos, consortium on regional climatology and adaptation to climate change, and the *Fonds vert*, from the Action Plan 2006-2012 on climatic changes of government of Québec.

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ROOT BIOMASS AND SOIL CARBON STOCK DISTRIBUTION IN HYBRID POPLAR BUFFER, HERBACEOUS BUFFER AND NATURAL WOODLAND RIPARIAN LAND USES

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ABSTRACT

This study compares root biomass and soil carbon distribution in 3 types of riparian land uses across 4 sites: (1) hybrid poplar buffers (9 years-old); (2) herbaceous buffers; (3) riparian forests (varying in tree species and age). For all land uses most root biomass was within 0-20 cm depth. Total coarse root biomass ranged from 8.7-73.7 t/ha in forests, 0.6-1.3 t/ha in herbaceous buffers, and 9.1-27.3 t/ha in poplars. Total fine root biomass ranged from 2.67-8.63 t/ha in forests, 2.60-3.29 t/ha in herbaceous buffers, and 1.86-2.62 t/ha in poplars. Total root biomass was similar or higher in poplar buffers compared to a 27 year-old grey birch forest. Highest coarse root biomass at 40-60 cm was observed in a poplar buffer. Generally, fine root biomass in surface soil was lower in poplar than in herbaceous buffers; the reverse was observed at greater depth. at some sites, carbon stocks were higher in the surface and intermediate soil depths of herbaceous buffers than in those of poplar buffers. a significant and positive relationship between total fine root biomass and total soil carbon stocks was found (p<0.001, R^2=0.35). Surface fine root biomass probably declined as a result of hybrid poplars shading the herbaceous vegetation. However, fine root biomass increased at depth, and coarse root biomass increased in the entire profile, under poplars (important for nutrient uptake, biological activity, carbon and nutrient storage). Hybrid poplar buffers accelerated colonisation by roots in riparian zones compared to natural succession over 27 years after abandonment (grey birch forest).

Keywords: agroforestry, coarse roots, fine roots, carbon sequestration

EXCAVATION BASED COARSE ROOT BIOMASS ESTIMATES IN MATURE HYBRID POPLAR AGROFORESTS USING ALLOMETRIC RELATIONSHIPS WITH DIAMETER

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ABSTRACT

Allometric relationships with tree diameter for estimating coarse root biomass in mature poplar plantations are rare. We collected the coarse roots of 36 hybrid poplars (DBH range = 10.2-37.6 cm) at 4 sites (2 moderate fertility; 2 high fertility) with 13 year-old plantations. Excavation pit dimensions were1.5m x 2m x 0.6m depth, representing 25% of the surface area occupied by each tree. The data were used to develop a general allometric relationship: $Y = 0.1599\ x^{1.5317}$ (R^2=0.71, n=36), where *Y* is the *Coarse root biomass* (kg/tree) and *x* is the *DBH* (cm). Because site fertility typically affects the shoot:root ratio, we developed two additional allometric relationships, using the same data, one for moderate fertility sites ($Y = 1.6564x$ -12.779, R^2=0.73, n=18) and one for high fertility sites ($Y = 1.6628x – 21.783$, R^2=0.83, n=18). Coarse root biomass estimates using the general relationship range from 9.81-17.77 t/ha. They range from 12.49-16.29 t/ha when using the relationships developed for the two site fertility classes. The use of the general relationship may overestimate coarse root biomass by 8-14 % on fertile sites, and underestimate it by 25-27 % on moderate fertility sites. At the stand level, shoot:root ratio ranged 9.09-9.36 on high fertility sites and from 5.49-6.03 on moderate fertility sites. Positive relationships were also observed between Ca or NO_3 supply rate in soils and shoot:root ratio. These results highlight the need to develop separate allometric relationships for roots in several segments along the soil fertility gradient.

Keywords: site fertility, shoot:root ratio, belowground biomass

MAPPING SHELTERBELTS IN SASKATCHEWAN: A LIVING LEGACY OF THE AGRICULTURE AND AGRI-FOOD CANADA PFRA SHELTERBELT CENTRE

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ABSTRACT

The farm assistance programs of the Prairie Farm Rehabilitation Administration (PFRA) affect >80% of Canada's agricultural land base. One important aspect of these programs was shelterbelt tree-planting to protect the soil from wind erosion. The objectives of this paper were to identify manageable number of homogenous land units across agricultural Saskatchewan for shelterbelt analytical purposes; and to quantify and map all shelterbelts planted in Saskatchewan from 1925 to 2009 with emphasis on six common shelterbelt species: caragana (CG), green ash (GA), Manitoba maple (MM), Scots pine (SP), white spruce (WS), and hybrid poplar (HP). A clustering approach was used to group 106 agricultural ecodistricts into 31 sub-soil-zone clusters by similarity in forty-two variables within five soil zones of Saskatchewan. Province-wide georeferenced shelterbelt tree orders from PFRA were analyzed in combination with >3,000 Km of manually digitized shelterbelts which were identified on-screen using recent high-resolution aerial photographic imagery. Digitized shelterbelt length was strongly correlated with PFRA tree orders (R-sqr=0.70) and, therefore, allowed for length estimation and mapping of shelterbelts. Overall shelterbelt mapping accuracy was 79%. Province-wide, there were approximately 35,306 Km of CG shelterbelts followed by GA (5,841 Km) > HP (4,146 Km) > MM (2,646 Km) > SP (1,573 Km) > WS (991 Km). To our knowledge, the decadal time-lapse maps and species-specific shelterbelt maps produced here capture the progression of shelterbelt establishment for the first time at province-wide scale, and give new perspective, in map format, of the expansive impact of the living legacy of the AAFC-PFRA shelterbelt centre.

Keywords: Prairie Farm Rehabilitation Administration (PFRA), time-lapse maps of shelterbelt establishment, expected species-specific shelterbelt length

EVALUATING TREE ROOT DISTRIBUTION IN A TREE-BASED INTERCROPPING SYSTEM WITH USE OF GROUND PENETRATING RADAR

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ABSTRACT

Within agroforestry systems, tree root architecture is a driver of important ecological processes such as belowground nutrient flows and C storage. Yet the belowground component of trees remains largely under-studied due to methodological restraints. Conventional subsurface sampling can overlook the heterogeneity of root systems, while complete excavations are destructive and unrepeatable. Thus, there is a need to develop non-intrusive technologies, such as ground penetrating radar (GPR), to measure root systems *in situ*. In this study we used GPR to detect coarse root distributions below five tree species (*Quercus rubra*, *Juglans nigra*, *Populus* sp., *Picea abies*, and *Thuja occidentalis*) at a temperate tree-based intercropping site in Guelph, Ontario. GPR geo-imaged transects were collected in 4.5 × 4.5m grids that were centered on 15 individual trees. Subsequently, tree roots were identified across all geo-images (visualized as radar signal reflections) providing 3-dimensional root distribution data for each target tree. Roots detected by GPR accounted for approximately 80% of large coarse roots (≥1cm) and 40% of small coarse roots (<1cm) that were later exposed in a subset of matched soil profiles. Significant inter-specific variations of coarse rooting depth preferences were detected. Additionally, preliminary analyses indicate different tree rooting patterns below the crop rows. To determine fine root distributions, fine roots were extracted from soil cores collected from the tree root study plots. Preliminary analysis indicates fine root length densities vary across species predominately in the upper 20cm. Limitations will be identified and applications will be discussed of GPR to answer ecological questions within agroforestry systems. Notably, we will highlight results from our complementary study that used the same GPR data to effectively estimate belowground biomass.

Keywords: tree root distribution, ground penetrating radar, carbon sequestration, belowground biomass

INTRODUCTION

Root systems constitute over 20% of total tree biomass (Brunner and Godbold 2007) and are critical for incorporating organic matter belowground (Jobbágy and Jackson 2000, Rasse *et al*. 2005). Within tree-based intercropping (TBI) systems, variations in root system biomass allocation and distribution may be dictated by site conditions and management practices (Kuyah *et al*. 2012). However, estimations of the belowground extent of tree root systems are conventionally applied from root:shoot ratios and allometric equations according to forest type and biome (e.g. Jackson *et al*. 1996, IPCC 2006). Thus tree species and site-specific belowground data are required for more accurate calculations of carbon dynamics and improved tactical approaches for TBI site design and management.

Knowledge of belowground dynamics in TBI systems is restricted in large part by the methodological limitations of studying roots *in situ* (Norby and Jackson 2000). Therefore, there is a need to develop techniques that measure belowground biomass non-destructively and also capture the heterogeneity of tree root systems. Ground penetrating radar (GPR) has been used as a non-intrusive geo-imaging tool to detect the presence of coarse roots *in situ* (Hruska *et al*. 1999, Butnor *et al*. 2001, Isaac and Anglaaere 2013). Radar signals can reflect where there is sufficient difference in dielectric permittivity such as at the root-soil interface, or more specifically, when water content within the root is greater than the surrounding soil (Hirano *et al*. 2009). The GPR unit emits radar pulses into the ground and records any reflected return signals. While the unit is moved across a buried coarse root, the successive reflected radar signals produce a hyperbolic reflection visualized in the interpreted geo-image of the subsurface.

The objective of this study is to assess the root distributions for five intercropped tree species (*Populus deltoides x nigra* DN-177 (poplar hybrid), *Quercus rubra* (red oak), *Juglans nigra* (black walnut), *Picea abies* (Norway spruce), and *Thuja occidentalis* (white cedar)) within a TBI system in southern Ontario. To do so, we identify the coarse root distribution in the subsurface by analyzing geo-imagery produced from GPR and we determine fine root distribution with the use soil core sampling.

METHODS

The study site is located at the University of Guelph Agroforestry Research Station, Ontario, Canada (43°32′28″N latitude, 80°12′32″W longitude). The five intercropped tree species selected for the study (*Populus* sp., *Q. rubra*, *J. nigra*, *P. abies*, and *T. occidentalis*; *n*=3) were approximately 25 years old. The trees were planted in rows with 6m stem spacing (except *T. occidentalis* with 1m spacing). Crop rows are 12.5 or 15m wide and under an annual rotation of *Zea mays* (maize), *Glycine max* (soybean), *Triticum aestivum* (winter wheat) or *Hordeum vulgare* (barley) (Thevathasan & Gordon 2004). Soil at the site is sandy loam, which is conducive for GPR study.

We used a 1GHz GPR unit (Noggin plus, Sensors and Software Inc., ON, Canada) to geo-image the subsurface surrounding the base of each tree. Geo-image data were collected in a 4.5 × 4.5m grid design with 10 cm transect spacing, equating to 92 geo-images that were orientated either perpendicular to the tree and crop rows or parallel to the rows. Radar signal reflections from coarse roots were visually identified in the geo-images (EKKO_Interp, Sensors and Software Inc.) providing x, y, z point pattern data for distribution analyses (Isaac and Anglaaere 2013). Accuracy of coarse root detection was tested with exposed soil profiles that matched a subset of geo-images. The velocities of radar signals through the subsurface were measured near each target tree (0.06 to 0.10m ns^{-1}) and used to calibrate the vertical scale of geo-images for accurate interpretation of depth to detected coarse roots.

The fine root distribution was determined from soil cores collected within the tree study plots to a depth of 60cm. Fine roots were removed from soil through wet sieving (Livesley *et al*. 1999) and subsequently measured for root length density with the use of a flatbed scanner and image analysis software (WinRHIZO, Regents Instruments Inc., QC, Canada).

RESULTS AND DISCUSSION

During this study, GPR detection rates of coarse roots were approximately 40% for small coarse roots (<1cm) and 80% for larger coarse roots (≥1cm) with errors highlighting GPR detection limitations relating to root diameter, orientation, depth, and proximity to adjacent roots. There were significant inter-specific variations between the rooting depth preferences for the deeper root systems of *J. nigra* and *Q. rubra* and the shallower root system of *T. occidentalis* (P<0.05). Interestingly, a different pattern emerges for rooting depth preferences for detected coarse roots below the crop rows, with preliminary results indicating significant inter-specific variations only at depths of 40 to 60cm. Moreover, exploratory spatial analyses indicate differences in rooting patterns between the treed and cropped rows. The fine root distribution data complete the quantification of the root system extent with preliminary results indicating fine root length density variations between species, most notably in the top 20cm of soil.

Overall, the utility of GPR proved effective for non-intrusive study of coarse root distribution and has potential to be functionalized in future research for answering important ecological questions within TBI systems. Currently, root carbon analysis and the results from a companion study, which used the same GPR data to estimate belowground biomass, can further enhance our understanding of belowground biomass and carbon dynamics in this TBI system. Other applications include predicting water uptake zones with the use of GPR detected root distribution in complement of isotopic signatures ($\delta^{18}O$) of the soil profile and non-photosynthetic tree tissue (Isaac and Anglaaree 2013).

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IMPACT OF RIPARIAN ZONE LAND-USE AND REHABILITATION ON ORGANIC MATTER INPUT, SOIL BIOCHEMICAL CHARACTERISTICS AND GREENHOUSE GAS EMISSIONS

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ABSTRACT

Riparian plantings support many critically important ecological functions. As such, the rehabilitation of riparian zones in North America is encouraged to enhance the ecological integrity of the aquatic ecosystem. However, riparian plantings may also enhance soil biochemical characteristics and mitigate greenhouse gases in the terrestrial component. The objectives of this study were to quantify the effect of riparian rehabilitation (RH) after 25-years of tree planting compared to a grassed (GRS) and an undisturbed forest (UF) riparian zone. Biomass, carbon (C) and nitrogen (N) input (g m^{-2}) from herbaceous vegetation was significantly greater ($p<0.05$) in the GRS riparian zone. Autumnal litterfall (biomass, C and N) input (g m^{-2}) was significantly greater ($p<0.05$) in the RH compared to the UF riparian zone. Soil bulk density (g cm^{-3}) was significantly greater ($p<0.05$) in the RH, but values of soil organic C and soil total N (g kg^{-1}), C/N, and soil organic C and N stocks (g m^{-2}) were significantly lower in the RH compared to the GRS and UF riparian zones. Soil CO_2 production rates were significantly lower ($p<0.05$) in the RH (169 mg C m^{-2} h^{-1}) compared to the GRS (194 C m^{-2} h^{-1}) riparian zone. The lowest ($p<0.05$) CO_2 production rates occurred in the UF (106 C m^{-2} h^{-1}) riparian zone. Soil CO_2 production rates were significantly correlated with soil moisture and soil temperature in all three riparian zones. Community level physiological profiles indicated a significantly different ($p<0.05$) response of the microbial metabolic diversity in the RH compared to the GRS and NF riparian zones. Principle component analysis showed a distinct clustering between the three riparian land-use systems.

X-RAY COMPUTED MICRO TOMOGRAPAHY MEASURED PORE CHARACTERISTICS OF SOILS IN AN AGROFORESTRY INTERCROPPING SYSTEM

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ABSTRACT

Agroforestry management is expected to increase organic matter input and, consequently, improve soil structure. The objective of this study is to quantify selected soil microstructural indices in the surface 3.5cm of agroforestry soils, using high-resolution X-ray Micro-Computed Tomography (μCT) imagery. Undisturbed soil cores (64mm x 150mm) were collected from a long-term tree-based intercropping site at the University of Guelph. The trees are intercropped with maize (*Zea mays*), soybean (*Glycine max*), and winter wheat (*Triticum aestivum*) or barley (*Hordeum vulgare*) in a three-year rotation. Sampling occurred at 3 locations around tree trunks; 2 meters east and west into soybean crop alleys and 2 meters north along the tree row. Three replicates of each tree type were sampled: (*Juglans nigra* (black walnut), *Populus* sp. (poplar – hybrid), *Quercus rubra* (red oak), (*Picea abies* (Norway spruce) and *Thuja occidentalis* (white cedar)). The soil type is Grey-Brown Luvisol situated on top of morainal deposits.

Each soil core was imaged using an EVS MS-8 Micro CT Scanner. Images were analyzed for soil pore parameters at a 60μm resolution using *ImageJ* software. Small pores (< 8 voxels^3) will be analyzed for the percentage of total porosity they account for. Medium pores (> 8 voxels^3, <150,000 voxels^3) will be analyzed for percentage of total porosity, pore size distribution, and pore shape. The pores which are large (>150,000 voxels^3) will be analyzed for the amount of branching. These μCT measured parameters will allow for the quantification of the effects of tree species, and location on soil structure.

Keywords: X-ray μCT, soil porosity, agroforestry intercropping

SEASONAL FLUCTUATIONS OF MICROBIAL BIOMASS CARBON IN TBI SYSTEMS IN SOUTHWESTERN ONTARIO

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ABSTRACT

The University of Guelph's Agroforestry Research Station consists of a 30 ha site, located in Wellington County (43 16'N 89 26'W), established in 1987 to evaluate the potential for a long-term tree based intercropping system to sequester organic C.

Previous studies have reported an increase in soil organic carbon (SOC) from poplar litterfall. Studies have also shown that SOC concentrations are affected by distance from the tree, which have changed as the trees have matured.

This study aims to provide an update on soil organic matter (SOM) distribution and accumulation of a tree-based intercropping site and compare with a conventional cropping system. Further, this research aims to establish a best approach for carbon stabilization within tree-based intercropping systems by comparing 4 different tree species for 2 seasons. Tree species examined are poplar hybrid (Populus sp.), Norway spruce (*Picea abies*), red oak *(Quercus rubra)* and Black Walnut *(Juglans nigra)*.

Soil organic carbon accumulation will be measured in cores taken during the Summer 2012. Cores were extracted in a grid surrounding each tree to a depth of 40cm depth. Seasonal changes in the constituents of SOM, will be measured by a comparison of soils collected in Summer and Fall 2012 and Spring 2013. Four samples have been taken at a 15cm depth at distances 2m N, E, S and W; and will include, microbial biomass C, light fraction C, litter and crop residues.

Keywords: microbial biomass

COMPARISON OF SOIL CARBON POOLS UNDER THREE AGROFORESTRY SYSTEMS AND THEIR ADJACENT AGRICULTURAL ANALOGS THROUGOUT CENTRAL ALBERTA

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ABSTRACT

Agroforestry systems contain higher quantities of soil carbon (C) than their agricultural counterparts, which can be attributed, in part, to the continuous deposition of plant residue. However, the degree to which C is sequestered in the soil will depend on the net C balance between accumulation and decomposition processes, including the extent of physical protection of soil organic C (SOC) with smaller particle-size and heavy density fractions. Thus, the objective of this work was to evaluate and compare the impact of three agroforestry systems (shelterbelt, natural hedgerow, and grazed aspen woodland), and their adjacent contemporary agricultural analogs (either annual cropland or pasture), on soil organic C distribution in relation to particle-size and density classes. Thirty-five sites (2 plots at each site in a pair-wise comparison of the agroforestry and agricultural system, for a total of 70 plots), forming a north-south agro-climatic gradient, were selected for study. Physical and density fractionation methods were used to separate mineral soil samples (0-10 cm layer) into three size and density classes, and the C content in each fraction determined. We found that average soil C content within the agroforestry systems were significantly greater than in their respective cultivated fields. Increase in C in the agroforestry systems, as revealed by the soil fractionations, was due to the retention of more SOC in silt- and clay-size fractions and mainly from the accumulation of more SOC in coarse-sized fraction. In general, our results demonstrate the potential of agroforestry as a C sequestration strategy. To make broader conclusions, soil C in deeper soil layers also need to be examined.

Keywords: agroforestry system, carbon sequestration, fractionation

CARBON SEQUESTRATION POTENTIAL OF A 27-YEAR-OLD TREE-BASED INTERCROPPING SYSTEM IN SOUTHWESTERN ONTARIO

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ABSTRACT

This study aimed to quantify carbon (C) pools and fluxes in a 27-year-old tree-based intercropping (TBI) system as compared to a conventional agricultural system at the University of Guelph's Agroforestry Research Station (43° 16'N 89° 26'W) (established 1987). Tree species quantified during this study include poplar hybrid (*Populus* spp.), Norway spruce (*Picea abies*), red oak (*Quercus rubra*), black walnut (*Juglans nigra*), and white cedar (*Thuja occidentalis*). In the TBI system, above- and belowground biomass, along with soil organic carbon (SOC) concentrations, litterfall, litter decomposition and soil respiration were quantified. In the conventional agricultural field, SOC, litter decomposition and soil respiration were quantified. Preliminary results indicated higher C sequestration potential rate with faster growing species such as poplar, and slower potential rate for slower growing species such as spruce and cedar. SOC accumulation was highest in the predominant wind direction (east), closest to the tree rows (0.5 m), and at shallower depths (10-20 cm) for all species. SOC accumulation was highest under poplar tree, followed by spruce, oak and walnut. Quantities of litterfall followed similar pattern and decomposition rates are still being analyzed. Soil respiration rates were higher in TBI systems and at distances closer to the tree row. Further results will be presented on the total measured C pools and fluxes and the importance of C sequestration potential of a 27-year-old TBI system to sequester atmospheric C and mitigate climate change. Accumulation of SOC can also have implications on crop yields and long term stability of TBI soils.

Keywords: agroforestry, soil organic carbon, litterfall, litter decomposition, soil respiration

INTRODUCTION

With an increase of 30% atmospheric carbon dioxide (CO_2) in the last 50 years (IPCC, 2001), and its associated increased in temperature, anthropogenic emission sources from agricultural practices contribute one quarter of these contributions to global warming (Duxbury *et al.* 1993). In attempt to mitigate these CO_2 emissions, efforts to reclaim some of this forested land have been put into effect, including tree-based intercropping (TBI). TBI, a form of agroforestry land use management, consists of widely spaced tree rows planted among agricultural crops. These trees provide additional above- and belowground biomass to sequester atmospheric carbon and return nutrients to the soil in the form of litterfall. Along with economic and ecological benefits, TBI systems can act as a long term carbon (C) sink and enhance nutrient cycling. These additional nutrients also reduce our dependence on fossil fuels for fertilizer, and thus greenhouse gas (GHG) emissions.

This study aimed to quantify (C) pools and fluxes in a 27-year TBI system as compared to conventional agricultural. Research was conducted at the University of Guelph's 30 ha Agroforestry Research Station located in Guelph, Ontario (43° 16'N 89° 26'W). Established in 1987 on calcareous parent material, this site has a sandy loam soil and tree density of 111 ha^{-1}. Tree species quantified during this study include *Populus* spp. (poplar hybrid) *Picea abies* (Norway spruce), *Quercus rubra* (red oak), *Juglans nigra* (black walnut), and *Thuja occidentalis* (white cedar), species commonly found in TBI and other agroforestry systems.

MATERIALS AND METHODS

Above- and Belowground Carbon Pools

In order to quantify above- and belowground carbon pools from biomass, three replicates of the five tree species were destructively harvested at the TBI site. Tree components were divided into categories of leaves, twigs, primary and secondary branches, trunk and belowground roots. These were weighed for oven dry biomass, and analyzed for carbon concentration, as outlined by Gordon *et al.* (2005).

To quantify belowground soil organic carbon (SOC) pools, three replicates were collected at the TBI site in the east and west direction, at 0.5, 1.0, 1.5 and 2.0 m from the tree row to a depth of 0-10 cm, 10-20 cm, and 20-40 cm for all tree species. Soils collected at a conventional agricultural field were collected in the same respective pattern. Soils were sieved to 2 mm to remove fine root matter and then further ball milled to 0.125 mm. Soil was then fumigated with 12 M hydrochloric acid (HCl) for seven days to remove inorganic carbon (IC) and then analyzed for organic carbon (OC) with the LECO CR-12 Carbon Analyzer (LECO Corporation, MI, USA).

Litterfall and Litter Decomposition

Litterfall was measured using 1 m^2 litter traps (mesh size 0.2 cm^2) placed at various distances from the tree row in the TBI site to suit tree orientation and spacing. For poplar, walnut and oak species, litter traps were placed at 1 m in the north, east, south and west direction and at 4 m in the east and west direction. For spruce trees, litter traps were placed at 1 m in all directions, and for cedar trees litter traps were placed at 1 m in the east and west direction. Annual litterfall was collected between September and December, 2012 and weighed for oven dry biomass.

Litter decomposition was measured at both sites with 30 cm^2 decompositions bags (mesh size 0.2 cm^2), filled with a known oven dry mass of litter from each tree species and buried at ~20 cm below the soil surface. Decomposition bags were retrieved seven times a year between October 2012 and September 2013, cleaned, dried and reweighed to compare mass loss. Upon final collection, decomposition rates will be expressed as a decay function of remaining mass over time.

Soil Respiration

CO_2 evolution of both systems was quantified using the soda lime (lime $Ca(OH)_2$) with 5-20% sodium hydroxide (NaOH)) absorption method, outlined by Edwards (1982). Three replicates of respiration chambers were placed at 0.0 m (within the tree row), 2.0 m and 4.0 m into the alley crop row for poplar, walnut and spruce trees in the TBI site. Respiration chambers in the conventional agricultural field were set up at the same corresponding distances. Measurements were taken at least once per month between June 2012 and May 2013.

RESULTS AND DISCUSSION

Above- and Belowground Carbon Pools

C content, as determined by the concentration of C (%) multiplied by the oven dry biomass (kg) was determined for each tree species. Aboveground tree components had higher C concentration (%) when compared to belowground by 1 – 3%, but all ranged between 43 – 55%. Poplar had significantly higher C content, both above- and belowground as compared to walnut, oak and spruce, all of which were also significantly higher than the C content of cedar. While these results can be expected, they aid us in determining which trees have higher sequestration potential – an important factor when establishing TBI systems (Peichl *et al.* 2006).

SOC concentrations were consistently found to be higher in the east direction (the predominant wind direction), at distances closer to the tree row (0.5 m) and at shallower depths (0-10 cm). Overall, poplar had the highest SOC concentration, followed by spruce, oak and walnut (cedar concentrations are still to be determined). As SOC accumulation is a result of input from litterfall and fine root turnover, it is expected that trees such as poplar, with higher growth and assimilation rates would have higher SOC concentrations than slower growing species such as spruce (Peichl *et al.* 2006). SOC concentrations in the control field were found to be higher than the TBI system at a depth of 10-20 cm depth. While this is unexpected, it could be due to smaller sample sizes, and different land management practices and crop rotations than the TBI site. Peichl *et al.* (2006) and Bambrick *et al.* (2010) found SOC levels to be 0.6 and 12% higher, respectively, in the same TBI site under poplar trees when compared to conventional agricultural systems at 17 and 21 years after establishment. For this reason, re-sampling will occur to verify current data. By accumulating long term SOC accumulation, this will allow TBI systems to continue to support nutrient cycling and uptake for agricultural crops and allow for crops yields comparable to conventional agriculture. This SOC accumulation contributes to overall ameliorated soil conditions and long term soil stability.

Litterfall and Litter Decomposition

Higher amounts of litterfall biomass were found in the east direction (the predominant wind direction), and within the first metre surrounding the tree. In 2006, Oelbermann *et al.* found C input to be significantly higher at 1 m from the tree row compared to 11.5 m from the tree row. While this study does not account for as far into the crop alley, we expect higher concentrations at 1 m as well. Litter decomposition rates are still being analyzed but are expected to follow a constant decay rate which will help to determine the rate at which nutrients are being released back into the soil in order to contribute to long term SOC accumulation.

Soil Respiration

Preliminary analysis of soil respiration rates indicated higher respiration between July and December. At the same site at 13 years after establishment, Gordon *et al.* (2005) found annual yearly emissions to be 732.50 ($\pm$ 31.0) g/m^2) and 400.65 ($\pm$ 17.2) g/m^2) for the TBI and conventional agricultural system, respectively. Similar results can be expected from this study, as respiration rates are expected to be higher most likely due to the presence of trees. Trees provide higher C inputs from leaf litter which favour higher tree root respiration and microbial respiration and therefore CO_2 evolution (Brady and Weil 1996, Matteucci *et al.* 2000, Peichl *et al.* 2006).

Next Steps: Allometric Equations and C Modeling

Data presented in this study will next be applied to the improvement and accuracy of allometric equations and C modeling systems. These equations and models are currently in place to account for site characteristics, biophysical properties of tree species, and quantification of C pools and fluxes to predict biomass measurements and total C sequestration potential. While allometric equations currently exist for natural forest systems, their application for agricultural systems is questionable due to the forms of management and species presence (Kuyah *et al.* 2012). In addition to allometric equations, data can also help to refine C models, such as that presented in Peichl *et al.* (2006). These models can now be run with data from a 27-year-old system where certain tree species, such as poplar, have reached maturity and are at the end of their life cycle. By modeling amounts of C being sequestered in a TBI system and comparing it to conventional agriculture, we can put a monetary value on the benefits of TBI systems to mitigate climate change. This can provide support for the implementation of carbon credits and tax incentives from the government to landowners to increase the adoptability of TBI systems.

CONCLUSIONS

Conventional agricultural systems are known to clear natural forests, degrade land, and contribute to GHG emissions through excessive use of fertilizers. TBI systems may be the solution to slow these effects by providing a natural source of nutrients back into the soil and sequestering atmospheric CO_2 to act as a C sink and a form of land remediation. It can be concluded that the incorporation of fast growing tree species can sequester a significant amount of CO_2 emissions caused by the clearing of natural forests for agriculture. The accumulation of C in the soil, via litterfall, otherwise absent in conventional agricultural systems, can help to slow land degradation as a result of agricultural practices. TBI systems not only provide ecological and economic benefits, but will almost become more attractive with the idea of carbon credits, which will provide monetary compensation and thus more incentive for landowners to invest in C storage alongside agriculture.

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A COMMON FRAMEWORK FOR GHG ASSESSMENT PROTOCOLS IN TEMPERATE AGROFORESTRY SYSTEMS: CONNECTING VIA GRACEnet?

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ABSTRACT

There are technical and financial advantages for pursuing agroforestry-derived mitigation and adaptation services simultaneously, with a recognition that carbon (C) payments could assist in supporting the deployment of adaptation strategies (Matocha *et al*. 2012). However, we lack the repeated/repeatable data required for accounting and reliably managing for these C contributions, as well as for other GHGs, in temperate agroforestry. Despite a significant increase in the research and our understanding of how these systems work in North America, the efforts are disconnected and use disparate sampling protocols; greatly limiting our capacity to build a regional understanding and C accounting of these systems. In the U.S., efforts are being initiated to see whether and how agroforestry can be linked into USDA Agricultural Research Service's (ARS) GRACEnet (Greenhouse gas Reduction through Agricultural Carbon Enhancement network) effort. GRACEnet's goal is to identify and develop agricultural strategies to enhance soil C sequestration and reduce GHG emissions and to provide a scientific basis for C credit programs, to reduce net GHG emissions and to improve environmental quality. Central to this effort is a national coordination of research and use of consistent protocols for soil, trace gas and plant sampling. Agroforestry, by its very nature, obviously adds a high level of spatial and temporal complexity. On-going work focused on developing suitable monitoring /measurement approaches utilizing GRACEnet protocols will be discussed, as well as other activities focused on framing the data needs necessary to advancing the incorporation of agroforestry into U.S. farm-level GHG assessment tools.

Keywords: greenhouse gas, climate change, mitigation, carbon sequestration, climate-ready agriculture

GREENHOUSE GAS EMISSIONS AND AGROFORESTRY – COMET 2.0 AND COMET-FARM

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ABSTRACT

As the greenhouse gas balance of agroforestry and other types of land use becomes better understood, a need has emerged for decision support tools to assist farmers, ranchers, and land managers in assessing the greenhouse gas consequences of land use decisions. The COMET 2.0 and COMET-FARM tools have been developed to meet that need. COMET 2.0 is a free, web-based tool based on the CENTURY model. It was released in 2009 to assess the greenhouse gas benefits of conservation scenarios in the U.S., including agroforestry, fertilizer management, and reducing tillage. COMET-FARM is a free, web-based upgrade from COMET 2.0, utilizing the DayCent model. Released in June, 2013, it includes a mapping interface, the ability to map and simultaneously assess multiple fields and parcels, along with new features for assessing detailed cropping sequences and multiple interacting conservation improvements. We will describe the tools and show examples where they have been applied in assessing the greenhouse gas balance of conservation scenarios, while explaining planned improvements for assessing agroforestry systems.

WILL CLIMATE CHANGE DRIVE TEMPERATE AGROFORESTRY SYSTEMS TOWARDS INCREASED COMPETITION OR COMPLEMENTARITY? A MODELLING APPROACH

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ABSTRACT

Although the practice of agroforestry in temperate regions has recently grown in Europe and the United States, we find significant gaps in the current literature on agroforestry practices relating to the cool continental climate typical of many parts of southern Canada. Since agroforestry is an uncommon practice in this region and field experiments are rare and limited by the slow maturation of trees, modeling is all the more necessary to improve our understanding of tree-crop associations and to develop productive agroforestry systems. Climate change raises concerns and uncertainties regarding tree growth and crop output highlighting the need to further our understanding of agroforestry systems and our capacity to predict future output.

We adapted the Hi-sAFe model (Dupraz *et al.* 2005), a mechanistic, biophysical model developed under the assumption that the sharing of resources (light, water and nitrogen) in an agroforestry system is the major determinant of its productivity. Using daily time steps, Hi-sAFe simulates a 3-dimensional agroforestry environment by modeling resource-sharing between trees and crops. The productivity of the system was measured using an adapted form of the Land Equivalent Ratio (LER) developed by Mead and Willey (1980). The integrated LER proposed by Dupraz (1998) is calculated from the cumulative yields over the span of a tree rotation and is favoured because it takes into account variations due to the natural succession of the agroecosystem and changes due to climate and stress over the entire productivity rotation of the system (Talbot 2010).

Using data from an experimental agroforestry site in Quebec, as well as data from the literature, the model was parameterized and validated for hybrid poplar (more species will be added in a near future). The simulation model was first used to evaluate the potential productivity of intercropping practices using current temperate southern Canadian climate and secondly using climate change scenarios.

Using different climate change scenarios, we explored theoretical hypotheses on complementarity and competition in plant communities. Our results indicate that agroforestry systems can be relatively more productive relative to pure crop or tree systems (measured using the integrated LER) both using actual and simulated future climate data. The relative yields of crops and trees differ significantly depending on the climate scenarios simulated reflecting a change in the types of interaction processes occurring within the plant community. While system productivity was found to be higher using current climate data (compared to the productivity

under future climate), our results indicate that productivity under climate change conditions was more stable.

Keywords: agroforestry systems, climate change, agroforestry productivity modeling, Hi-sAFe, Land Equivalent Ratio

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Poplar, Willow and Biomass

POPLARS AND WILLOWS: TREES FOR SOCIETY AND THE ENVIRONMENT

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ABSTRACT

Poplars and willows, the members of the Salicaceae family, are trees and shrubs with many valuable characteristics which have led to multiple beneficial uses for society and the environment. The accumulated global knowledge and information on poplars and willows could fill many volumes. In 1980 the Food and Agriculture Organization (FAO) of the United Nations published a comprehensive volume on poplars and willows. That book is now out-of-date and out of print. As a project of the International Poplar Commission (IPC), a new book entitled 'Poplars and Willows: Trees for society and the environment' is being produced. This is a co-publication of FAO, of which IPC is a part, and CABI, a UK-based scientific book publisher specializing in agricultural and environmental topics.

Keywords: poplar, willow, science, operations, environment, utilization, international

POPLAR AND WILLOW BOOK

The forthcoming book offers a worldwide overview and guide to the basic characteristics, cultivation and use of poplars and willows, as well as issues, problems and trends relating to them. It synthesizes the latest knowledge and technology in current research on poplars and willows, linking these to implementation achievements to meet sustainable livelihoods, land-use and development. It greatly expands the scope of previous publications, to include more information on willows, as well as thorough and up-to-date treatment of taxonomic and classification issues, more global reporting, and evaluation of applications to provide industrial, environmental, social and economic development benefits.

The primary audience for the publication is seen as decision-makers and policy-makers in agriculture, forestry and the environment in both public and private sectors in countries throughout the world, particularly where poplars and willows are or could be grown. It also provides a starting point for foresters, ecologists, botanists, agriculturists and environmental engineers in any search for information on poplars and willows.

The book, presently in press and expected to appear in fall 2013, has more than 600 pages and is illustrated in black and white, with three sections of colour plates. The 13 chapters of the book, prepared by nearly 70 contributing authors from 15 countries worldwide, cover all aspects of poplar and willow taxonomy, ecosystems, physiology, genetics and breeding, operational production, environmental applications, abiotic stresses, diseases, insect pests, products and utilization, markets and trends, as well as their importance for rural livelihoods and sustainable development. An outstanding feature of the book is its nearly 2500 references. It also includes an up-to-date taxonomic treatment of the Salicaceae.

Chapter 1, 'Introduction' by J.G. Isebrands and J. Richardson, provides background information on the publication, history of previous poplar and willow publications, and an overview of the scope and content.

Chapter 2, 'Poplars and willows of the world, with emphasis on silviculturally important species' by Don Dickmann and Julia Kuzovkina, includes descriptions of all major poplar and willow species. It offers a proposed taxonomic classification of the genus *Populus* and an up-to-date taxonomic treatment of the genus *Salix* by world region. This chapter is used as a taxonomic reference for all other chapters.

Chapter 3, 'Ecology and physiology of poplars and willows' by J. Richardson, J.G. Isebrands and J. Ball, discusses the natural occurrence, life history and current status of a number of ecologically important species, including 12 poplars and six willows. The information in this chapter complements that in Chapter 2.

Chapter 4, 'The domestication and conservation of *Populus* and *Salix* genetic resources' by Brian Stanton, Michelle Serapiglia and Lawrence Smart, provides an overview of domestication and conservation approaches. This includes genetic systems; breeding strategies; controlled crossing techniques and crossability; testing, selection and deployment; certification, regulation and international trade; molecular approaches; and conservation. Domestication and conservation programs in 26 countries worldwide are described, with input from 55 different contributors.

Chapter 5, 'Operational poplar and willow culture' by John Stanturf and Cees van Oosten, describes current operational practices in different regions of the world for stand establishment, stand tending and production of poplars and willows. The focus is on practical techniques and successful practices. This chapter benefits from 33 contributors worldwide.

Chapter 6, 'Environmental applications of poplars and willows' by J.G. Isebrands and 26 co-authors worldwide (including 11 from North America), covers the most important uses of poplars and willows with benefits to the environment. These include windbreaks and shelterbelts, soil erosion control and riparian buffers, land restoration, phytoremediation, and ecosystem services.

Chapter 7, 'Abiotic stresses' by Nicolas Marron and 9 co-authors, deals with edaphic stresses such as water deficit, desertification, salinity and soil nutrient status, as well as atmospheric stresses including ozone, carbon dioxide, increased temperature and photo inhibition. A key feature of this chapter is a comprehensive annotated list of studies conducted over the period 1987 to 2006.

Chapter 8, 'Diseases of willows and poplars' by Mike Ostry, Mauritz Ramstedt, George Newcombe and Marijke Steenackers, covers selected leaf, stem and root diseases in detail, including *Melampsora* leaf rust, *Marssonina* leaf spot and blight, *Venturia* leaf blight, bronze leaf disease, *Septoria* leaf spot and canker, *Hypoxylon* canker, as well as other branch and stem cankers, bacterial diseases and root diseases. The chapter also discusses disease prevention through disease resistance, use of clonal mixtures, and biological control.

Chapter 9, 'Insects and other pests of willows and poplars' by John Charles, Sylvie Augustin, Ludovic Nef and 11 other co-authors, describes all types of pests including leaf feeders, leaf miners, sucking insects, gall formers, bud and young shoot feeders, wood borers, root feeders, disease vectors, and other animal pests. This is supplemented by more detailed treatment of 16 selected examples of insect pests of poplars and willows. Integrated pest management, invasive species, and international exchange of plant materials are also covered.

Chapter 10, 'Properties, processing and utilization' by John Balatinecz, Patrick Mertens, Lieven De Boever, Hua Yukun, Juwan Jin and Joris Van Acker, discusses the macroscopic and microscopic properties of poplar and willow wood, as well as their physical, mechanical and chemical properties and natural durability. Processing technology and uses for the Salicaceae in lumber, wood-based composites and panels, glued structural products, pulp and paper, and biomass energy are presented, as well as integrated poplar utilization and willow utilization. Trends in utilization are also noted.

Chapter 11, 'Markets, trends and outlook' by Qiang Ma and Arvydas Lebedys, describes overall global market trends in wood products before focusing on poplar and willow resources, and production and trade of such resources. Specific treatment is given to the evolution of markets for poplar products in China and Europe. The economic importance of poplar and willow plantations is discussed with reference to poplar plantations in China, willow for energy in Sweden and basket willow cultivation in Chile.

Chapter 12, 'Poplars and willows for rural livelihoods and sustainable development' by Walter Kollert, Jim Carle and Linda Rosengren, discusses a range of production systems in which poplars and willows are used, including native forests, large- and small-scale plantations, agroforestry, trees outside forests, and bioenergy. Protection of livelihoods is seen through protection of the environment, as well as the contribution of poplars and willows to rural landscapes and urban amenity. The chapter includes 22 case studies from 12 countries worldwide.

Chapter 13, 'Epilogue' by J. Richardson and J.G. Isebrands, briefly summarizes the book and looks to a future built on the solid groundwork laid by those who have gone before. It is offered in the belief that poplars and willows, as trees for society and for the environment, can help us move forward sustainably and on a sound scientific basis.

THE EFFECT OF MESH SHELTERS AND NITROGEN FERTILZER ON GROWTH FOR BIGTOOTH ASPEN WILDLIFE PLANTINGS

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ABSTRACT

Bigtooth aspen (*Populus grandidentata*) is a good species for use in conservation plantings in the agricultural landscape of Central Wisconsin. The buds and twigs are utilized as forage by a range of species in winter. The species is easy to manage with coppice and the resulting pulpwood finds a ready market. Early establishment of plantings can, however, be plagued by excessive browse damage. Our objective was to determine if nitrogen fertilization, poultry mesh tree shelters or a combination of both would increase aspen seedling growth rate. We planted 8 split plots of 12 bigtooth aspen seedlings (1-0 stock) (96 total seedlings). Four of the plots were fertilized with polymer coated urea at a rate of 90 Kg N per hectare and four were controls. Half of the trees in each split-plot were caged with 5 foot tall poultry mesh shelters (5 inch diameter) and half were uncaged. The poultry mesh shelters increased seedling growth. Overall, sheltered seedlings averaged 91 cm while unsheltered averaged 51 cm, with or without fertilization. However, the combination of both shelters and fertilization (107 cm) had a much greater impact than either fertilizer alone (54 cm) or shelter alone (75 cm) or the control (47 cm). At this point, all seedlings are still within the browse height of deer; however, it appears that the impact of fertilization alone is not sufficient to help the trees outgrow deer browsing although the addition of fertilizer with the use of tree shelters results in significantly increased growth.

Keywords: urea, browse, deer, poplar

INTRODUCTION

Aspen is second only to maple in industrial roundwood use in Wisconsin; indeed, of all species groups in Wisconsin, the aspens are the only species that are being harvested at a higher rate than current growth (Perry et al. 2009). Annual growth in excess of a cord/acre/year are possible (Perala 1978) under extensive management conditions. Aspen is very easy to manage after establishment. Overstory removal often results in vigorous coppice from root sprouts. These coppices are strongly favored by grouse as part of their habitat requirements (Kubisiak 1985). For these reasons, aspen is a good species for use in farm forest plantings.

Farm forest plantings are often plagued by excessive deer browsing. In portions of the Wisconsin landscape, deer are far in excess of population goals (WI DNR 2011). Deer are a known to impact tree competitive ability due to selective browsing of preferred species (Stromayer and Warren 1997, Strole and Anderson 1992) and specifically to target aspen under some conditions (Prachar and Samuel 1988, Inouye et al. 1994). On our study site, we have seen multiple *Populus* species (both planted and natural) targeted heavily by deer.

Tree shelters may be a viable method of protecting seedlings aspen from deer browsing; however, the cost is generally high. Our per seedling cost of tree shelters (not including labor) was approximately $1.00. There is a sizable literature on the impacts of tree shelters on seedlings; however, the literature on mesh shelters is more limited. Sharpe et al. (1999) showed tree shelters to be potentially viable method of reducing deer browsing and tree mortality, with wire shelters the overall best choice. The use of shelters would likely be the most foolproof method of reducing deer browse on seedlings.

Fertilization has also been tried as a method of increasing seedlings growth. Van de Driessche et al. (2003) found the combination of irrigation and fertilizer to significantly increase aspen growth (78% more growth than the control). Czapowskyj and Safford (1979) used fertilization in an aspen-birch-red maple stand to increase growth. Bigtooth aspen was one of the most affected species with the combination of nitrogen, fertilization and lime increasing volume growth of aspen by 7 times over the control.

Our objective was to determine if nitrogen fertilization, poultry mesh tree shelters or a combination of both would increase aspen seedling growth rate.

METHODS

On April 23, 2011, 96 bigtooth aspen seedlings (1-0 stock from Wisconsin DNR nursery) were planted in plots adjacent to a pasture and among other tree plantings in Belmont Township, Portage County, Wisconsin, USA. The previous ground cover was sod, which was scalped in the planting plots prior to planting. The planting arrangement was 8 split plots of 12 bigtooth aspen seedlings each. Four of the plots were fertilized with polymer coated urea at a rate of 90 Kg N per hectare and four were controls. Half of the trees in each split-plot were caged with 1.5 m (5 ft) tall poultry mesh shelters 0.13 m diameter (5 in) tied to a wooden lath and half were uncaged. The sheltered seedlings were co-located all in the same portion of the planting plot to avoid having the closely spaced adjacent cages reducing the browsing on uncaged seedlings. The seedlings were planted at a spacing of approximately 0.6X0.6 m (2X2 ft). This close spacing was intended to create "clumps" of aspen for grouse habitat. At this stage of growth, this close spacing is most likely not having much impact on the growth of the seedlings. Periodically, plots were monitored and damaged shelters were corrected (a strong freezing rain storm in winter 2011-2012 required many of the shelters to be returned to vertical. This had minimal impact on browsing because although the seedling was bent over to the ground in some cases, it was still encased in the shelter. Seedling height was measured on Oct 16, 2011 and Oct 22, 2012. Split plot ANOVA was used to analyze the data.

RESULTS

The poultry mesh shelters increased seedling growth. Overall, sheltered seedlings averaged 91 cm while unsheltered averaged 51 cm, with or without fertilization. However, the combination of both shelters and fertilization (107 cm) had a much greater impact than either fertilizer alone (54 cm) or shelter alone (75 cm) or the control (47 cm) (Table 1). At this point, all seedlings are still within the browse height of deer; however, it appears that the impact of fertilization alone is not sufficient to aid the trees in outgrowing deer browsing although the addition of fertilizer with the use of tree shelters results in significantly increased growth.

Table 1. The impact of mesh shelters or fertilizer on the height of bigtooth aspen seedlings after two years of growth. Means expressed ± standard error.

		N	Mean
No fertilizer	No shelter	24	47±4
	Shelter	24	75±4
Fertilizer	No shelter	24	54±3
	Shelter	24	107±7

DISCUSSION

The impact of deer on the success of tree plantings is hard to overstate. With deer populations in excess of management goals in much of Central Wisconsin, alternative methods may be necessary to establish seedlings in new plantings. Preferential deer browsing has been shown to shift species diversity in favor of species with lower browsing preference (Strole and Anderson 1992; Stromayer and Warren 1997). With the overall ease of management of aspen after establishment as well as the significant wildlife benefits of the species, it may be justified to invest the effort to establish these plantings even in the presence of significant deer browsing.

We found that relatively inexpensive shelters increased the growth of seedlings by the end of the second year. The use of fertilizer also increased growth in combination with the shelters but was of minimal impact on seedling growth without shelters.

Through time, we will monitor the growth of these seedlings. In addition to determining the impact of shelters and fertilizer on seedlings success, we hope to determine whether these "patch plantings" will expand using root sprouts and whether patch planting may be an approach to converting marginal farmland into aspen cover.

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WHAT DOES IT TAKE TO MAKE PLANTATION FORESTRY SUCCESSFUL? A COMPARISON OF ALTERNATIVE ESTABLISHMENT SYSTEMS ON HYBRID POPLAR PERFORMANCE

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ABSTRACT

Hybrid poplar plantations are recognized as an important source of fiber products and they also have potential environmental benefits including carbon sequestration. Conventional establishment protocols for hybrid poplar plantations strive for maximum weed control founded on the concern that even low weed densities can reduce tree performance and result in fiber yield loss. This leads to intensive and costly management practices including repeated herbicide application and soil cultivation. Alternative systems may reduce the need for silvicultural inputs while simultaneously offering environmental benefits. Despite this, little is known about the overall effect of these alternative systems on tree performance.

The objective of this study was to test alternative management strategies that could be used to optimize weed control, increase tree growth and survival, and increase environmental benefits compared to current establishment systems. We are examining the effect of four different establishment systems on early aboveground growth of two hybrid poplar (*Populus* spp.) clones (‘Walker’ and ‘Okanese’) in plantations recently established on two sites previously used as perennial grassland. Establishment systems included: (1) a full year of fallow prior to planting; (2) sowing of a cover crop mixture into fallowed fields between tree rows; (3) planting of poplars into untilled fields following localized vegetation suppression using herbicide; and (4) conventional repetitive cultivation and ongoing weed suppression as the control treatment.

We will present results for abundance and composition of herbaceous vegetation and growth of the two hybrid poplar clones during their first growing season – as influenced by these alternative establishment systems. Our goal is to contribute to the understanding of key factors influencing hybrid poplar tree performance. The area of land in poplar plantations is likely to increase and this research can lead to target-oriented vegetation management practices for plantations, thereby increasing fiber production, and associated plantation profitability, as well as reducing environmental costs.

Keywords: hybrid poplar, competition, vegetation management

BIOMASS PRODUCTION, CHEMICAL COMPOSITION, AND ENERGY VALUES OF HYBRID AND NATIVE WILLOWS PLANTED IN LOW-INPUTS AGRICULTURAL SYSTEMS

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ABSTRACT

The increasing cost of fossil fuels such as petroleum, and a desire to curtail greenhouse gas emissions are driving the expansion of bioenergy. Plant biomass, including short rotation woody crops, are potential energy sources. We examined the biomass production, chemical composition (i.e., cellulose, hemicellulose, lignin, ash), and energy content (btu) of selected hybrid and native willows with great potential for agroforestry application in Minnesota planted in low-input systems. Two separate experiments were set-up as follows: 1) growth comparison performance of native and hybrid willow using SUNY's (State University of New York) willow program recommended planting methods, and 2) growth and performance comparison of hybrid willows varieties using three different planting arrangements/methods employ by farmers. Research results show variations in survival, performance, and biomass production between native and hybrid willows; however, no significant differences exist in energy content (btu) among varieties at a plant level but differences exist among them in calculated theoretical ethanol production. Further, biomass production of hybrid willows planted in different planting arrangements also varied ($p = <0.0001$) suggesting management implications of willow based on current/existing operations of the landowners. We suggest that willow offer promising potential as alternative sources of renewable energy. Results of our study indicate that low-input systems can be utilized as an alternative source of biomass for energy and it could facilitate commercial production of the crops.

NEWBIO: GROWING BIOENERGY ON MARGINAL LANDS

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ABSTRACT

Biomass has been a resource for energy and materials in the northeastern U.S. for hundreds of years, and has the potential to dramatically increase its role in the decades to come. The region has high agricultural productivity, well-developed transportation and fuel distribution infrastructure, technologically adept human and financial resources, and substantial demand for advanced biofuels, biopower, and bioproducts. Perennial energy crops, especially willow and warm-season grasses grown on abandoned and marginal agricultural and mine lands, can play a central role in creating a sustainable bioenergy future for the region. A recent project in the northeastern U.S. (NEWBio) http://www.newbio.psu.edu proposes to develop thousands of hectares of these crops and develop concurrent energy businesses and biorefineries.

A major critique of large scale biomass production is competition for land between food and energy crops. A commonly suggested solution is to limit energy crops production to marginal lands. Physical marginality (soil quality, slope and location) is often used when discussing marginal lands. However, as important is the economic marginality (breakeven prices). One of the benefits of bioenergy crops is that they grow well on marginal lands. By combining economical margin with biophysical margin, we can provide a comprehensive map of marginal lands for food crops, and in so doing identify lands targeted for energy crops. This paper will briefly discuss the NEWBio project, and then focus on assessing marginal lands. This discussion will also infer how agroforestry systems can contribute to achieving bioenergy crop production.

Keywords: bioenergy, energy crops, NEWBio, marginal lands

The Northeast Woody/Warm-season Biomass Consortium (NEWBio)

Increasing demand for bioenergy has fueled interest in sustainable bioenergy feedstocks. Energy crops, such as switchgrass (*Pancium virgatum*), miscanthus (*Miscanthus x giganteus*) and willow (*Salix spp*), are currently at the center of considerable attention due to their fast growth, high yield and environmental benefits (Perlack & Stokes, 2011). However, concern arises when commercial energy crop plantations intensify land competition and displacing food crops (Field, Campbell, & Lobell, 2008) and place greater cost burden on farmers (Duffy & Nanhou, 2001; Volk *et al*., 2006). A commonly suggested solution to these two problems is to limit the plantations to 'marginal' lands (Bryngelsson & Lindgren, 2013, Gelfand, I, *et al.* 2013).

The Northeast Woody/Warm-season Biomass Consortium (NEWBio) is a regional network of universities, businesses, and governmental organizations dedicated to building robust, scalable, and sustainable value chains for biomass energy in the northeast. It is a 5-year USDA funded project with the objective of expanding the sustainable and ecologically sound production of perennial grasses and short rotation woody crops as a feedstock for fuel production and other uses. The project has research, extension and education components and is developing large scale regional demonstration sites as a platform for scaling up a network of biomass production and conversion facilities across the Northeast.

The focus of the project is on the three dedicated energy crops mentioned above**. Shrub willow** is a very attractive biomass crop because it is high yielding, fast growing, requires few inputs, has multiple stems and re-sprouts after being cut. They grow very well on underutilized and marginal fallow land and can improve soil conditions and microbial diversity. Significant gains have been made in breeding cultivars for improved yields. The shrub willow reaches heights of 5 to 7 meters (15 to 25 feet) in 3 years and averages 10-15 dry tons per hectare (4-6 tons per acre) per year.

Switchgrass is a warm season bunch grass has gained importance as an energy crop because of its high yields, adaptability to marginal lands, and relatively low establishment and management costs. It is a hardy deep rooted perennial grass that grows to as high as 2 meters in a year (6 feet) and can also produce 10-15 dry tonnes per hectare (4-6 tons per acre). Switchgrass does well on a wide variety of soil types, including wet, shallow or rocky soils and is drought-tolerant. Its deep roots can break through tough soil layers improving long term soil structure. It is also excellent for wildlife habitat, providing seeds, browse, and shelter for a variety of species. Switchgrass requires little maintenance, no annual planting and only one harvest per year.

Giant Miscanthus, a sterile hybrid, is among the highest yielding perennial energy crops, producing an annual average of up to 19-29 dry tonnes per hectare (8-12 tons per acre). It requires little maintenance, no annual replanting and only one annual harvest. It has excellent traits as an energy crop on marginal land due to its high productivity in colder climates, its deep roots exploiting soil nutrients and its high water-use efficiency. However, there are some constraints with planting material availability and costs, planting costs, and ensuring first year winter survival. However, over a life of 20 years, the returns for growing Miscanthus are favorable compared to other crops. For more details about the crops visit (NEWBio fact sheets: http://www.newbio.psu.edu/Extension/resources.asp)

One of the keys to these using these energy crops is their ability to help restore degraded or 'marginal' lands that otherwise would not be used for crop production. All three crops require little maintenance, provide favorable economic returns over a life of about 20 years, and provide important environmental benefits, including biodiversity, wildlife and land remediation (Abrahamson, L, et al. 1998, Heaton, 2006). Farmers can make use of these lands that are low in productivity and potentially have environmental concerns. The hypothesis is that these energy crops can improve land quality over time. These crops have shown to grow well in low soil quality and, water logged conditions. The also maintain yields in drought years. The deep roots, especially of the perennial grasses are able to penetrate hard compact (poor drainage) soils. By doing so they improve the soil structure to allow roots and water to further infiltrate the soil profile. This in turn helps control soil erosion and excessive water runoff, improving the hydrology on site both vertically and horizontally. These crops also can grow on nutrient poor soils and require low amounts of fertilizers compared to most other crops. In addition roots store carbon which in turn increases soil microbes leading to more turnover in nutrients. Therefore, in an agroforestry context these crops can complement other crops and trees across the landscape, and improve the Land Equivalent Ratio especially in alley cropping situations (Vandameer, 1989).

Although the Northeast is heavily forested (about 67 percent of the land area), there is also a large amount of idle or unused (or as some call it 'marginal' land).The word 'marginal' lacks clarity, is not well defined, in part because the question is marginal for what? Marginal lands are intuitively regarded as the lands with barren soil. Soil quality of marginal lands such as soil texture, soil drainage, have been deeply examined by the previous studies (Kang et al., 2013). . Other biophysical factors, such as slope, erosion risk, and hydrologic regime also appear in different studies to define marginal lands. However, biophysical factors can only partially interpret the word "marginal".

Economically Marginal Lands

From and economic perspective, these lands are idle or underutilized because they are not productive for farming certain crops and the returns are less than the cost of growing the crops. Since there are alternative uses for any piece of land the economic rent (return to the landowner) determines the highest and best use of the land. These crops have shown to provide positive returns on these 'marginal' lands compared to food crops because of their adaptability to poor growing conditions. The question is whether energy crops will compete with for example, high yielding corn on good lands. This will be determined by the price for energy crops, which is not competitive at this time. However, the objective of NEWBio is to focus on developing these energy crops on the 'marginal' lands not conducive to food crops, and therefore avoid the political issue of food vs. fuel competition.

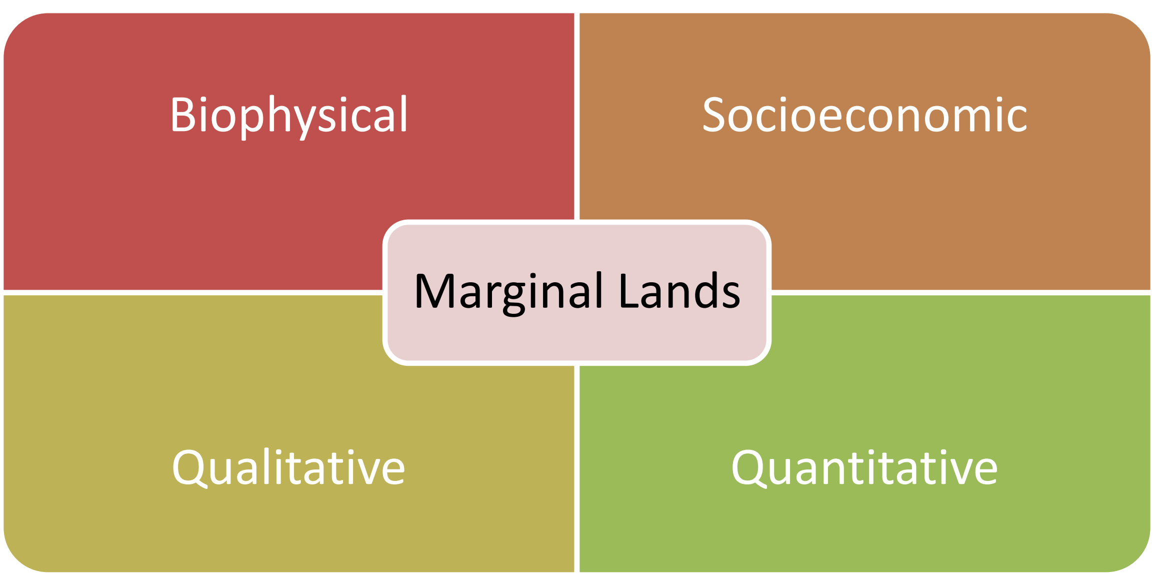

Figure 1: Multi-component analysis for marginal lands

Due the varied definitions of marginal lands, this research is a multi-component assessment of marginal lands as depicted in Figure 1. This figure implies a sustainable and comprehensive view on defining marginal lands. The sustainable assessment for marginal lands will expand the research scope by involving socioeconomic factors, which means it will examine the human role in defining and utilizing marginal lands. Profit, cost, price are the socioeconomic factors contributing to the word "marginal" and, thus, need more attentions.

The combined qualitative and quantitative analysis describes the research methods to assess marginal lands. The qualitative analysis aims to do a complete, detailed description. It focuses on a small but representative sample that contains rich information. On the other hand, the goal of quantitative analysis is to develop and apply mathematical or statistical models explaining phenomena from large samples. The combination of qualitative and quantitative analysis will present a clear picture of marginal lands with a detailed description and an accurate measurement.

The biophysical-focus studies (Gopalakrishnan, Cristina Negri, & Snyder, 2006; Tang, Xie, & Geng, 2010) create the gap to assess the socioeconomic factors. Therefore, this study starts with the exploration for defining the economically marginal lands. The history of defining marginal lands from socioeconomic perspective can be dated back to 1930s, when Peterson and Galbraith (1932) define marginal land as land at the extensive margin of production. That is the land where revenue from optimal production just equals the cost (profit equals to zero), while the estimated profit used to classify a site as being "marginal" for one crop may result in land being considered profitable for another crop. Thus, specifying crops to land which are classified as marginal is prerequisite.

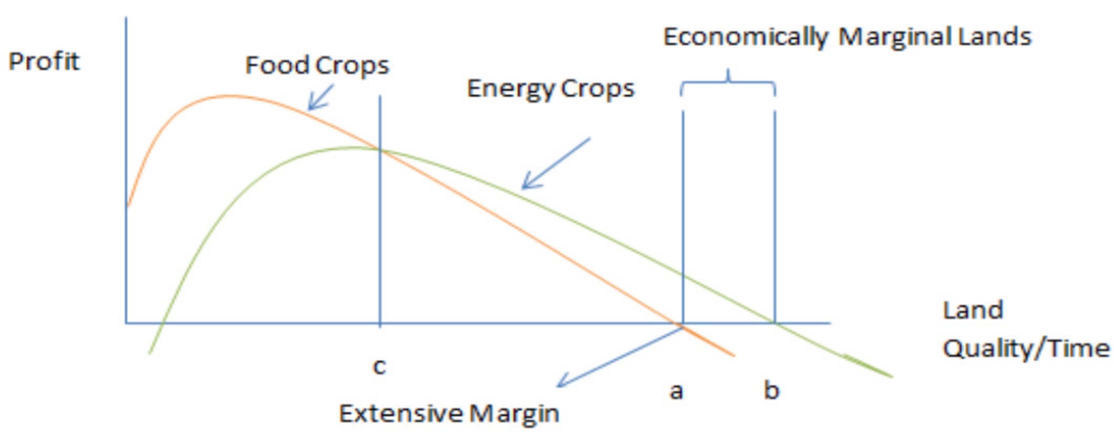

Figure 2: economically marginal lands (adapted based on Von Thunen model and Swinton et al. (2011)

In this study, "economically marginal lands" are interpreted as lands which are marginal to food crops but not marginal to energy crops. Graphically, it is the lands at the extensive margin of food crops but before the extensive margin of energy crops (the line segment between ab in Figure 2). Therefore, the key for identifying economically marginal lands is to determine the extensive margins (break-even points) for food crops and energy crops. Estimating the break-even points of these different crops using the following equation(Jain, Khanna, Erickson, & Huang, 2010):

$$P_e[\sum_{t=0}^{T}\frac{Y_t}{(1+d)^t}] = \sum_{t=0}^{T}\frac{C_t}{(1+d)^t}$$

Where T is the life of the crop; Ct is the unit production cost of crop in period t; Yt is yield in year t and d is the discount rate. Thus, the follow-up research will focus on the estimation of production costs and yields for energy crops and food crops given the incomplete information on prices of energy crops. The study sites will be across the northeastern region of the United States.

The objective of this study is to examine the marginal lands from a socioeconomics perspective and quantitatively identified economically marginal lands by doing profit analysis. It aims to answer two basic questions: what the economically marginal lands are and how many of the economically marginal lands are available. The answers to these questions will land the basis for further analysis on farmer's willingness to supply energy crops from the economically marginal lands.

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BIOMASS POTENTIAL AND STANDSTRUCTURE OF NATIVE WILLOWS ON THE CANADIAN PRAIRIES

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ABSTRACT

Many small wetlands are scattered across the Canadian Prairies. These wetlands are often surrounded by a phreatophytic shrubs, of which willows are the dominant genus. Because the willows grow in a circular form around wetland these communities are also call willow rings. Many willow rings have been removed to facilitate farming activities. The willows that are left are heavily degraded due to the lack of disturbance factors such as buffalo herds and wild fires. Even though these willow rings are currently degraded, they are still of great value as a carbon depth free biomass resource. Our study had the objectives to examine the effects of age on biomass potential, stand structure and species distribution of five native willows (*Salix bebbiana*, *S. discolor*, *S. eriocephala*, *S. interior* and *S. petiolaris*) in 12 willow rings and studied the distribution of the same willows in relation to a moisture gradient. Annual biomass production ranged from 1.9 to 16.2 odt ha^{-1} yr^{-1} for the 12 sites that were between 9 and 34 years old. Currently standing biomass was estimated at 239.2 odt. With age stand structure changed from multiple small diameter stems to fewer big diameter biomass producing stems, and at the same time the species distribution shifted from one dominated by *S. petiolaris* to being dominated by *S. discolor*. Additionally the sympatric willows showed a distribution along a moisture gradient, with *S. discolor* dominant in the dry locations and *S. petiolaris* in the wetter locations.

Keywords: moisture gradient, productivity, *Salix*, stand structure, succession, wetland

ESTABLISHMENT AND EARLY PRODUCTIVITY OF PERENNIAL BIOMASS ALLEY CROPPING SYSTEMS IN MINNESOTA, U.S.A.

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ABSTRACT

In May 2010, alley cropping systems consisting of four herbaceous biomass crops planted between multi-row strips of two short-rotation woody crops were established at Empire and Granada, Minnesota, U.S.A. Crop establishment and productivity were characterized for each species over two growing seasons and at two distances from the tree-crop interface. Prairie cordgrass (*Spartina pectinata*) and a native polyculture were among the most productive herbaceous crops at both sites, averaging between 7.1 and 11.9 Mt ha^{-1}, and have shown no evidence of competition for resources along the tree-crop interface thus far. Basal stem area was similar at Empire for poplar hybrid NM6 (*Populus maximowiczii* x *P. nigra*) (1,744 mm^2 $tree^{-1}$) and willow cultivar Fish Creek (*Salix purpurea* x *S. purpurea*) (1,609 mm^2 $tree^{-1}$), but was greater for NM6 (1,045 mm^2 $tree^{-1}$) than Fish Creek (770 mm^2 $tree^{-1}$) at Granada. Across species, basal stem area was greater in edge row than center row trees at Empire, whereas the opposite was true at Granada. This difference in edge-row effects may be due to differences in alley orientation and light availability between sites. Results suggest that alley cropping provides suitable conditions for establishment of short-rotation woody and certain herbaceous biomass crops, and that many of these crops may be well suited to the alley cropping environment. However, more research is needed to explore the effects of alley orientation on light dynamics, and also to evaluate overall resource availability within the alley system and its effects on crop persistence and productivity over time.

Keywords: alley cropping, biomass, establishment

PRODUCING TRANSPORTATION FUELS FROM SUSTAINABLY GROWN HYBRID POPLARS: A PACIFIC NORTHWEST INITIATIVE

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ABSTRACT

Advanced Hardwood Biofuels Northwest (AHB) is a USDA-funded consortium of university and industry partners working to develop a Pacific Northwest (PNW) biofuel industry that provides 100% renewable and infrastructure-compatible transportation fuels derived primarily from sustainably grown short-rotation (2-3 years) hybrid poplars. The partners are divided into five teams (Feedstock, Conversion, Sustainability, Education, and Extension) to support all the required research and preparation needed to speed up commercialization of the biofuel system to convert poplars into liquid biofuels, including gasoline, diesel, and jet fuel. Feedstock and Extension teams are playing an important and foundational role in preparing the PNW for growing hybrid poplar to produce biofuels. GreenWood Resources Inc. is leading the feedstock team to investigate suitability and productivity of different poplar clones, spacing, planting, harvesting and other plantation management practices in four geographically variable sites throughout the Northwest. As a conduit between researchers and communities, WSU Extension is using an effective biofuels outreach and education program that brings research-based information to key community stakeholders, including citizens, land managers, and policy makers. This AHB initiative envisions to lay the foundation for an industry that will meet 75% of the PNW region's 2022 renewable fuel standard (RSF2), revitalize the region's rural communities, support large and small growers, and create new jobs and economic opportunities.

Keywords: hybrid poplar, biofuel, Pacific Northwest

CANADA-WIDE GENETIC VARIATION OF SALIX ERIOCEPHALA POPULATIONS

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ABSTRACT

Willows (*Salix spp.)* are a naturally occurring species in areas adjacent to wetlands, rivers, and lakes within the Canadian landscape. In the last decade, increased awareness and use of willow in biomass cropping systems has contributed to its North American rise in cultivation. Genomic research is currently ongoing into the creation of new varieties suited to high biomass production and environmental applications. Studies to date have extensively explored the genetic structure of growth and phenological traits in *Salix viminalis* populations but little research has been focused on native species (e.g. *Salix eriocephala*). This collaborative research project focused on analyzing the extent of natural genetic variation and population structure using 46 populations of *S. eriocephala* sourced throughout its native ranges across Canada (from Atlantic to Prairies). Preliminary findings indicated the presence of two distinct clusters, indicative of an east/west divide. The analysis of molecular variance (AMOVA) revealed that the variability within population was significantly higher (78%) than among populations (14%). Findings from this study provide valuable insight into the levels of natural variation available in the Agriculture and Agri-Food Canada's AgCan*Salix* collection for use in the willow improvement program.

Keywords: biomass, *Salix eriocephala,* AgCan*Salix,* willow, genetic diversity, population structure

SCREENING POPULUS BALSAMIFERA CLONES FOR USE IN RECLAMATION ON CHALLENGING SITES

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ABSTRACT

The largest oil sands deposits in the world are located in the northeastern region of Alberta on an overlapping land base with Alberta-Pacific Forest Industries Inc. In order to bring these areas with large open pit mines and massive settling ponds, which result from the process of bitumen extraction, back into the productive landbase, appropriate plants for revegetation need to be identified. These reclaimed sites are often very high in salts and other compounds, requiring testing to ensure not only survival of the plant material but productivity in the next generation of forest.

Dormant cuttings from one hundred and forty eight native balsam poplar clones selected from Alberta-Pacific Forest Industries Inc. tree improvement program were grown aeroponically for six weeks in a greenhouse in a completely randomized design with three replicates. There were nine tanks in total with three control tanks, containing reverse osmosis (RO) water, three tanks with 25% process water, collected from the Syncrude bitumen extraction facility in Ft. McMurray, mixed with 75% RO water and three tanks with 50% process water and 50% RO water.

Results on clonal performance for growth, biomass and survival will be presented. Clear differences in performance were found indicating that clonal selection for highly saline conditions is possible. In order to meet genetics standards for diversity in Alberta for crown land deployment, a minimum of 18 clones must be selected.

Keywords: balsam poplar, reclamation, salt tolerance

FARMER WILLINGNESS TO PRODUCE SHORT ROTATION WOODY CROPS

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ABSTRACT

This paper presents the findings of a survey of Minnesota agricultural landowners conducted to elicit farmer willingness to supply short rotation woody crops (SRWC) to a hypothetical bioenergy feedstock market. The survey area, in the northern Corn Belt region, is primarily planted with corn and soybean. Using closed-ended dichotomous choice questions, each respondent was asked about their willingness to grow SRWC given a randomly generated relative net income. The survey included questions about farmers' attitudes about the environment and renewable energy, perceived barriers to growing perennial crops, land tenure, preferred financial arrangements and demographic information.

At non-negative (zero and positive) relative net incomes, on average forty-eight percent of farmers were wiling to produce SRWC and were willing to produce SRWC on an average of twenty-five percent of their available land. The data was evaluated using econometric techniques to parameterize a representative farmers' willingness to supply SRWC. The perception of SRWC risk was found to be sustainably higher than the farmer's perception of their current risk. Using enterprise budgets for the survey area, a SRWC supply function for a representative farmer was estimated.

This study illustrates the importance in understanding farmer willingness to produce when estimating aggregate supply in emerging bioenergy markets. Production risk and fixed costs are important components to a farmer's decision to produce SRWC. Supply estimates that ignores these will over-estimate the supply of SRWC.

Keywords: short rotation woody crops, bioenergy, economics

EFFECTS OF PRUNING ON GROWTH AND STEM QUALITY OF THREE HYBRID POPLAR CLONES

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ABSTRACT

Hybrid poplars are usually cultivated under intensive management systems, in order to increase yield in a reduced time period. Pruning stems is also recommended to create knot free wood and increase the value of boles. Although this treatment has been done for ages all over the world, very little scientific data is available on the effects of pruning on growth and quality of boles. The goal of this study was to evaluate the effects of pruning on tree growth, stem taper and on the number and size of knots. Three hybrid poplar clones (*P. balsamifera x trichocarpa*, *P. balsamifera x maximowiczii,* and *P. maximowiczii x balsamifera*) were planted in 2003 at two sites in North Western Quebec at a 3x3 m spacing. Stems were pruned in spring 2006 at three intensities: control, 1/3 and 2/3 of stem height. After five years, light pruning (1/3 stem height) had no effect on tree size, while severe pruning (2/3 stem height) reduced height and diameter at breast height by about 15% from only 1 out of the 3 tested clones. Severe pruning reduced stem taper mostly at the base of stems (ground to breast height), with little effect between breast height and 3 m height. For two of the clones, the number of knots between 0.5 and 2 m was reduced by 33% and 63% with light and severe pruning, respectively, while it was unaffected for the slowest growing clone. Size of knots was however greatly reduced with pruning height (R-squares between 0.72 and 0.93 for the three clones). Practical implications of the results on hybrid poplar wood processing and products value are discussed.

Keywords: hybrid poplar, pruning, wood quality

EVALUATION OF HYBRID POPLAR CLONES UNDER INTENSIVE CULTIVATION FOR BIOMASS PRODUCTION IN QUÉBEC

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ABSTRACT

Three experimental plantations were established in 2012 at three sites in the *Bas-Saint-Laurent* and *Lac-Saint-Jean* regions to promote and demonstrate the short-rotation-intensive-culture (SRIC) hybrid poplar crop concept for biomass production. The general objective of this study was to evaluate already-available material for poplar plantations and new hybrid poplar clones, obtained from breeding at the *Direction de la recherche forestière*, for SRIC. Many performing clones from different hybrids with *Populus maximowiczii*, *P. nigra*, *P. trichocarpa*, *P. deltoides* (MxN, MxT, MxD, etc.) are already available for evaluation of their characteristics under various coppicing regimes. The plantations were established in collaboration with regional organizations involved in energy crops like *Osons l'Osier* and *Nutrinor* to compare coppicing ability and biomass yield among poplar clones. Preliminary growth results obtained after the first growing season are presented for several clones. Significant clone differences are expected in vigour, yield, and coppice regrowth after repeated rotations. Mechanical harvesting of the crop may also have a strong influence on resprouting and sustainability of the stools over repeated growth cycles.

Keywords: biomass production, hybrid poplar, clone selection, coppice, SRIC, *Populus* spp.

INTRODUCTION

After more than 40 years of breeding and testing, the Québec's hybrid poplar improvement program produced superior clonal populations selected for production of timber in plantations with 15 to 20-year rotations and density varying between 600 and 1 100 trees per hectare. Poplars could also be planted at close spacings (over 6 000 trees per ha) under short-rotation-intensive-culture (SRIC) to provision feedstock for energy industry (Geyer 2006, Di Matteo *et al.* 2012). Already-in-use varieties of hybrid poplars and new MT and MN clones, obtained through recent breeding operations, have to be evaluated for repeated coppice growth with short-rotation harvests. In Italy, new cultivars selected for SRIC regimes were more successful than traditional timber clones (Paris et al. 2011). Capacity to tolerate high stand density, high survival rates of sprouts and high yield over frequent and repeated coppicing, and suitability for mechanical harvesting were some of the important poplar characteristics to select for.

MATERIALS AND METHODS

Three tests and one regular plantation were established in May 2012 in Saint-Bruno d'Alma (*Lac-Saint-Jean* region), Saint-Paul-de-la-Croix and Cacouna (*Bas-Saint-Laurent* region) with 14 different clones cultivated under a SRIC cultural regime (Table 1). We used 25-cm long cuttings provided by the DGPSP (MRN) and produced in stoolbeds in Saint-Modeste and Normandin forest nurseries. Cuttings were mechanically planted at a density of 10 000 plants per ha (55 cm × 180 cm) for two tests in the *Bas-Saint-Laurent* region. At Saint-Bruno, plant density of the contiguous plantation, bordering the test on the same site, was 15 000 plants per ha (manual planting), except for the replicated test where four clones were planted at two densities (9 000 and 15 000 plants per ha) (Fig. 1). Pre-emergent herbicide (Suregard) was sprayed after planting; then manual weeding was done during summer. Trees were measured in November 2012, after one-season growth, according to a systematic sampling plan (24 plants per treatment): number of sprouts per plant, height and diameter at the base of all shoots, individual shoot fresh weight, and dry weight for all shoots gathered per treatment. Border trees were excluded from sampling for each plot or sector. All trees were pruned down after the first-year growth in November at 10 cm from the base, except for the Agrinova test in St-Bruno where the trees were not coppiced and kept full height. Hence, trees from the test were not sampled for fresh and dry weight, only data for height, diameter at the base, and the number of shoots per tree were recorded.

RESULTS

At the St-Bruno site, data vary according to clone and to microsite (Table 2). After one growing season, it is interesting to note large differences among clones for all variables. The number of sprouts per plant varied from 1,1 to 2,3, mean height and diameter of the largest sprout from 103 to 175 cm and 10 to 18 mm, respectively. The dendromass dry weight varied from 440 to 1475 kg/ha. For the replicated test with four clones, where no destructive sampling was performed, we could compare the diameter at the base of the largest sprout with the data from the same clones in the adjacent plantation (Table 3). On that basis, we could predict the biomass yield produced in the test. Growth did not differ for the two densities after the first growing season. For all clones, tree growth in block 2 was slightly inferior than the two other blocks. Dendromass data from test B at Saint-Paul (Fig. 2) are shown in Table 4, as a example of the first-season growth results obtained on a less fertile site than Saint-Bruno.

DISCUSSION AND CONCLUSION

As expected, poplar growth is largely reliable to site conditions but clonal characteristics varied sufficiently to select for traits suitable for SRIC crops. Survival at high density with repeated coppicing, as well as resprouting and sustainability of the stools over recurrent growth cycles are key factors to ensure high production over time. Large populations of superior hybrids are already available for evaluation and testing over different coppicing regimes.

Table 1. Clone frequency, block number, and plant density by location and plantation.

		OLO		Agrinova	
		Bas-Saint-Laurent		Lac-Saint-Jean	
		Cacouna	Cacouna & St-Paul	St-Bruno	
Clone	Hybrid	Test A	Test B	Test	Plantation
3478	NxM				
3729	NxM				
750301	MxT				
915308	MxB				
915311	MxB				
915318	MxB				
916401	DNxM				
102380	MxN				
102605	MxDB				
102890	MxN				
103177	MxN				
103712	MxN				
103854	MxN				
104090	MxN				
	Blocks	3	4	3	---
		Cacouna	(2)		
		St-Paul	(2)		
	Density plts/ha	10 000	10 000	9 000	
				15 000	15 000

Table 2. Mean Data per clone for two sectors of the poplar plantation in St-Bruno

Plantation	Sector A*					Sector B*				
Clone	Mean nb of sprouts /plt	Mean height of largest sprout/plt (cm)	Mean diameter largest sh (mm)	Mean dry weight/plt (g)	Dendromass dry weight (kg/ha)	Mean nb of sprouts /plt	Mean height of largest sprout/plt (cm)	Mean diameter largest sh (mm)	Mean dry weight/plt (g)	Dendromass dry weight (kg/ha)
3729	1,6	134,9	13,3	49,4	741					
102380	1,5	175,0	18,3	98,2	1475					
102890	1,9	141,1	14,1	56,3	845					
103177	2,3	134,1	14,4	77,5	1163					
103712	1,9	118,3	12,7	50,1	752					
103854	1,8	96,2	12,0	42,3	635					
104090	1,3	151,2	17,1	71,6	1076					
750301	1,3	147,3	14,7	65,7	987	1,5	114,4	10,5	29,3	440
915308	1,7	112,7	13,4	47,0	705	1,4	103,1	11,8	32,9	494
915318	1,5	119,7	13,2	48,5	729	1,1	130,0	14,1	52,8	792
915311						1,4	109,5	11,4	34,7	521

* Appr. 22 to 31 sample trees per clone per sector

Table 3. Mean diameter (mm) of the largest sprout at the St-Bruno test* in comparison with the contiguous plantation. Data expressed by clone, block and density**

Block (St-Bruno test)	B1		B2		B3				Mean Diam./cl.	Plantation	
Density**	D1	D2	D1	D2	D1	D2	D1	D2		Sector A	Sector B
750301	16,0	17,6	15,4	16,2	19,4	19,6	17,0	17,8	17,4	14,7	10,5
915311	17,1	17,3	15,9	15,5	16,6	13,7	16,5	15,5	16,0		11,4
915318	15,8	15,6	13,3	10,7	17,8	16,9	15,7	14,4	15,0	13,2	14,1
915308	16,6	16,5	15,6	11,5	12,7	16,9	15,0	15,0	15,0	13,4	11,8
Mean Diam./tr./bl.	16,4	16,7	15,0	13,5	16,6	16,8	16,0	15,7			

* Mean of 24 sample trees per plot
** D1: 9 000, D2: 15 000 plants/ha

Table 4. Mean dendromass per clone from the poplar test in St-Paul after one year

	Dendromass dry weight (kg/ha)		
Clone	Block 1	Block 2	Mean
3478	402	315	359
3729	264	444	354
750301	388	365	377
915308	269	339	304
915311	431	435	433
916401	234	295	265

Figure 1. Saint-Bruno poplar test (left) and adjacent-coppiced plantation (right) in spring 2013.

Figure 2. Cacouna poplar test A (left) and Saint-Paul poplar test B (right) in late October 2012.

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Economic, Policy and Outreach

HIGHLIGHTS FROM THE FIRST-EVER USDA REPORT OF AGROFORESTRY ACCOMPLISHMENTS, OUTCOMES, FINANCIAL COMMITMENTS, AND PLANNED NEXT STEPS (REPORT RELEASE)

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ABSTRACT

Agroforestry was identified as an area for increased collaboration in February 2011, in Ottawa, by officials from the United States Department of Agriculture (USDA) and Agriculture and Agri-Food Canada (AAFC) at the "Collaboration on Agri-Environmental Issues Dialogue". The USDA National Agroforestry Center (NAC) and AAFC Agroforestry Development Centre (ADC) have common missions and goals that focus on accelerating the application of temperate agroforestry systems in agricultural landscapes. At the Ottawa meeting, NAC and ADC leaders made a joint presentation and proposed 11 opportunities for action, which were agreed to by their officials. NAC and ADC have collaborated successfully to accomplish many of the actions, including: 1) translation of NAC's *Conservation Buffers Guide* into French for use in Canada; 2) authoring "Branching out: Agroforestry as a climate change mitigation and adaptation tool for agriculture", a featured paper in the *Journal of Soil and Water Conservation* (Sept/Oct 2012); and 3) jointly planning and hosting the very successful Great Plains Windbreak Renovation and Innovation Conference (July 24-26, 2012) at the International Peace Garden on the US-Canada border between Manitoba and North Dakota. USDA and AAFC strengthened their commitments further with the signing of a Memorandum of Understanding (MOU) in April 2012 by USDA Deputy Secretary Kathleen Merrigan and AAFC Deputy Minister John Knubley. The MOU emphasizes collaboration on agroforestry science and tools for climate change mitigation and adaptation in support of the goals of the Global Research Alliance on Agricultural Greenhouse Gases, of which both countries are members.

Keywords: Canada, United States, climate change

AN INTERNATIONAL SUCCESS: GREAT PLAINS WINDBREAK RENOVATION & INNOVATION CONFERENCE, 2012

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ABSTRACT

In March of 2011 discussions began among conservation agencies and organizations in Canada and the U.S. about the need for a region-wide conference or training session on windbreak renovation. Representatives from three Provinces, eight States, numerous local agencies and two federal agroforestry centers met to plan such a conference. That was the beginning of the Great Plains Windbreak Renovation and Innovation Conference that was held in July of 2012 at the International Peace Garden on the border of the U.S. and Canada. The end result after a year of planning was a conference attended by 82 people in-person from 11 states and 3 provinces and about 35 people remotely via the internet. The key components of the planning process that led to a successful conference included: region-wide representation from local, provincial, state and federal conservation partners; a survey of agencies on the likelihood of the number of people they would support to participate in the conference; and a commitment to create learning opportunities apart from the primary conference site. Participant evaluations of the conference indicated that the mix of science, real-world experiences and new techniques and equipment helped make the conference a success. Results from the initial Great Plains conference include: Provincial windbreak renovation meetings, a Southern Great Plains Windbreak Renovation Conference and an online lecture series utilizing ten speakers from the original conference.

Keywords: science delivery, technology transfer, outreach

INTRODUCTION

Windbreaks have been a part of the Great Plains agricultural landscape for over a hundred years. The Prairie States Forestry Project (1935-1942) funded the planting of more than 222 million trees on farmlands from the Dakotas to Texas to combat the severe soil erosion of the Dust Bowl years and to protect the crops from the drying winds. In the Canadian prairies the Government of Canada began distributing seedlings for windbreak establishment as early as 1901. Like any infrastructure, windbreaks age, deteriorate and require maintenance, refurbishing and even removal when they cease to function as desired. The last regional windbreak renovation workshop/training was held over a decade ago. For many years conservation partners in the Great Plains have developed and delivered science-based windbreak tools, technical notes, and training sessions. In spring of 2011, the USDA National Agroforestry Center (NAC) and Agriculture and Agri-Food Canada's Agroforestry Development Centre agreed to work together with other federal, state, provincial and local partners to sponsor a conference focused on windbreak renovation and innovation.

METHODS

In April of 2011 NAC asked the representatives of the Great Plains Forestry Initiative, GPFI, about their interest and perceived value of a region-wide meeting on the subject of windbreak renovation. The GPFI consists of state forestry agencies in the northern Great Plains. At the same time the leadership of the Plains and Prairie Forestry Association, the Agroforestry Development Centre at Indian Head, Saskatchewan and the state foresters with the USDA Natural Resources Conservation Service (NRCS) in the region were similarly approached. In each case the response was a definite desire and perceived need for such a meeting or symposium. By July of 2011 a region-wide planning team was assembled and began the process of planning a windbreak renovation meeting.

The agencies and organizations that were active on the planning team were:

- Agroforestry Development Centre, Agriculture & Agri-Food Canada
- Alberta Agriculture and Rural Development
- Colorado State Forest Service
- Kansas State Forest Service
- Kansas State University Extension
- Montana NRCS
- Nebraska Association of Resources Districts
- North Dakota NRCS
- South Dakota Division of Resource Conservation & Forestry
- USDA National Agroforestry Center

The planning team began with a series of monthly conference calls with four main objectives. First, determine the priority subjects to be included in the agenda and format of the event. Second, select the date and location or multiple locations of the event. Third, identify and acquire funding to offset participant registration costs. And fourth, identify individuals in the team to lead the development of specific aspects of the conference such as publicity, finances, field tour and internal information coordination.

DISCUSSION

Unexpectedly, the objective that required the most time, effort and deliberation was selecting the location of the event. The factor that was identified as the greatest barrier to participation was not the international boundary, but rather the ability to travel on company or agency time and expense for both participants and presenters. An alternative that garnered much support within the team was to support satellite locations throughout the Great Plains where remote participants could participate through live and interactive internet connections. As a part of this scenario the satellite locations would also host a local field tour to coincide with the timing of the field tour at the primary event location. Although this scenario was desired by nearly everyone on the planning team it was ultimately abandoned because of the great amount of time, energy, expense and staff time necessary to support the logistics of multiple event locations. The chosen alternative was a single event location with an option for live and interactive internet connections for individuals at their local computer.

The planning team acquired the services of Digital Visions Enterprise Unit of the U.S. Forest Service, DV, to support the live internet connection and recording of the presentations for future access. Digital Visions provided the host connection, technical support in advance of the event, as well as during the event, and processed the recorded presentations for posting on the web and analysis of online participation of the event. The decision to contract the services of a knowledgeable organization such as Digital Visions turned out to be very beneficial. Several unforeseen technical difficulties arose that may have proven insurmountable if the decision were made to simply use an unsupported internet meeting system.

The primary event location universally was desired to be near the Canada and U.S. border. As a part of the process to determine the event venue, an online survey was created to determine the likelihood of agencies to support their staff people to attend a meeting on the subject of windbreak renovation. The survey was distributed to staff managers in local, state and federal agencies throughout the Great Plains. Results of the survey suggested that travel restrictions would restrict participation for many agency field staff to attend a multiple day meeting regardless of the travel distance. After considering the various agency restrictions on international travel, potential field tour sites and host facilities it was decided to hold the event at the International Peace Garden, situated directly on the international boundary between Boissevain, Manitoba and Dunseith, North Dakota. The International Peace Garden reflects the cooperative nature of the planning team and the common issues affecting windbreaks and conservation in both countries.

Also unexpectedly, the least complicated objective to achieve was the funding support for the event. Both of the federal agroforestry centers were able to dedicate funding for the conference facilities and services. Two other associations that also supported the event with substantial funding were the Plains and Prairie Forestry Association in the U.S. and the Agroforestry and Woodlot Extension Society in Alberta. As a result of the combined financial support there was not a participant registration fee. The planning team expected that the absence of a registration fee would increase participation in the event.

Conceptually, the content of the agenda was agreed upon with limited discussion. The agenda topics should fall into one of two issues, renovation technology and innovative windbreak technology and research. More specifically the planning team desired to provide information on applied renovation techniques, equipment and results from both agency and landowner perspectives, and innovative designs, planning tools, and uses for windbreaks. The other major component of the event that was universally agreed upon was the inclusion of a full day field tour for participants to watch equipment in action, to discuss windbreak renovation planning for a real windbreak, gain experience in windbreak evaluation and to network with other professionals in a less structured environment.

Figure 1- New ideas that possess some ‘gee-whiz’ factor, like this BioBaler, help encourage field-tour participants to interact and share experiences and other ideas. Photo credit: USDA National Agroforestry Center

The field tour, if well done, can be the highlight of any meeting and the converse is also true. The planning team was fortunate to have two members who work near the event location on both sides of the border. Their combined knowledge of local agency contacts, facilities and their availability to evaluate potential field sites and deliver demonstration equipment were a key in creating a field experience that was rated highly by participants. These two team members and the local field staff helped ensure success because they invested time in early reconnaissance, tracking down details and a final walk through of the field tour prior to the actual event.

It is difficult to estimate how much staff time will go into planning and implementing a regional event. Consequently, supervisor commitment to allow staff time for working on a project such as this event throughout the planning process is critical to success. Each member of the planning team was afforded significant supervisor and agency support to serve on the planning team.

When it came time to accept leadership and assignments related to the development of the windbreak renovation event each team member was able to make commitments without hesitation. It was commonly said among the team members that other team member’s willingness to do the necessary hard work was an encouragement to do likewise. Subsequently, individuals quickly volunteered to take leadership of communications and promotion, finances, field tour coordination, facilities arrangements and recruitment of speakers.

Promotion of the event began with a save-the-date announcement in early February of 2012. At that time only the dates, location and title of the *Great Plains Windbreak Renovation and Innovation Conference* had been confirmed. However, the team decided that promotion needed to begin early to allow potential participants to pursue the support they needed for travel and to get the date on agency calendars. It was also decided to follow up the initial promotion with event updates whenever they occurred to keep the event in front of people as frequently as possible. The diverse audience for the conference meant that there was no one email list, web site or agency newsletter that would provide broad enough visibility for the conference. The planning team relied on the willingness of the federal, state and provincial conservation agencies, university extension departments to distribute the promotional materials and registration information as it was created. The USDA National Agroforestry Center web site was selected as the point of contact for all information on the Renovation Conference, http://nac.unl.edu/multimedia/conferences/Great_Plains/windbreakrenovation20120724.htm. This site also hosts all of the recorded presentations from the conference as well as PDF versions of the presentations.

As with any event there were many unexpected problems, and unforeseen barriers that arose. In each case the sense of team work prevailed and solutions were always found. The team work and individual sense of responsibility for a successful conference created an atmosphere where participants were able to focus upon the presentations, networking and discussion of ideas, problems and mutual experiences.

RESULTS

The end result of over a year of planning was a conference attended in-person by 82 people from 11 states and 3 provinces and about 35 people remotely via the internet. Post conference activities included numerous communications among participants and presenters, the sharing of information and purchasing of new equipment featured at the conference.

Figure 2 – Conference participants at the International Peace Garden, July 26, 2012. Photo credit: Agroforestry Development Centre, Canada.

There have been nine related workshops in Alberta with over 200 participants. In each of these workshops Renovation Conference presentations were utilized.

In May of 2013 a Southern Great Plains Windbreak Renovation Conference was held in Dodge City, KS. In addition, the Canadian Institute of Forestry, which hosts "The Forest On Your Desktop National Electronic Lecture Series" every Wednesday, aired a Windbreak

Renovation series from April 10, 2013 until May 29, 2013. All of the series presenters were from the Renovation Conference. The windbreak renovation webinar series averaged over 300 participants each week.

When travel is limited by agencies and organizations, when budgets are tight and people are regularly asked to do more with less, meetings such as the Great Plains Windbreak Renovation and Innovation conference are still supported and attended. The willingness to overcome barriers, such as those above, in order to develop and attend face-to-face conferences reflects the value that people place on such conferences, symposia and meetings.

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The Great Plains Windbreak Renovation and Innovation Conference received high marks in the participant conference evaluations in large part because of the commitment and hard work of the Conference Planning Team and many local conservation partners.

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PRESENTING THE EUROPEAN AGROFORESTRY FEDERATION

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ABSTRACT

The European Agroforestry Federation (EURAF) was founded in Paris in December 2011 by almost 250 people coming from 17 European countries. EURAF aims at promoting the adoption of all agroforestry practices across Europe (new and traditional). www.agroforestry.eu

Dissemination and Technology transfer: reaching general public and farmers is a key aspect developed by EURAF members through the creation of a newsletter, coordination of national courses and leaflets, but also through the dissemination of the general activities developed by EURAF at policy level. EURAF is composed of several farmer associations, technicians and stakeholders who benefited from advice and help of EURAF. There are several regions of Europe with networks of demonstration farms to spread agroforestry practices.

Education: a lot of EURAF members belong to the academic sector, mainly Universities which spread agroforestry in environment and technical degrees, masters and doctorate studies. International, national and regional summer intensive courses, such as specific stakeholder courses are also delivered by the national associations that are members of EURAF.

Research: most EURAF members are linked to universities and research centres involved in different interlinked disciplines (modelling, biodiversity, nutrient cycling) needed for the development of agroforestry practices in Europe. Better agroforestry practices adapted to different environments are evaluated taking into account productive, environment and socio-economic aspects. International research projects linking stakeholders and researchers are also being presented as well as COST actions.

Policy: The federation has been in contact with several political entities from the European Commission and European Parliament trying to promote the definition of tools that promote

agroforestry practices in Europe. As a result the agroforesty definition proposed by EURAF was already included in the Common Agrarian Policy (CAP) that will last from 2015 to 2020. EURAF efforts have also been successfully recognized, as budget provisions have been allocated to agroforestry in different measures of the future CAP. EURAF has also become part of the Forestry and Cork Advisory Group of the European Union.

FOREST PEST FIRST DETECTOR: A VOLUNTARY EARLY DETECTION INVASIVE SPECIES PROGRAM IN MINNESOTA, USA

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The Forest Pest First Detector program is a volunteer program designed to identify the first incidences of key invasive species including, insects, diseases and plants of special concern in Minnesota. Volunteers are trained to identify pests in urban and rural landscapes including Agroforestry plantings. Forest Pest First Detector volunteers are one of the first lines of defense against the establishment of forest/tree pests by helping to identify their infestation quickly. First Detectors also help disseminate information to the public about forest or tree invasive species and preventing their introduction. This first-in-the-United-States program is a joint project between the Minnesota Department of Agriculture (MDA), University of Minnesota Extension, the Minnesota Department of Natural Resources and the National Plant Diagnostic Network. Since the program's inception in 2008, over 970 participants have been trained and over 500 individuals have committed to volunteering for the program. First Detectors utilize a step-by-step process to identify the signs and symptoms of identified pests. If a pest is suspected they notify the MDA. Confidentiality must be maintained for all suspected incidences. First Detectors may visit properties. They are taught to properly collect, photograph and safely deliver samples to the MDA. They also educate and inform the public about immerging forest/tree pests. The program worked as intended in identifying the first find of Emerald Ash Borer, and several other pests, in Minnesota. First Detectors also offer $80,000 USD in public value annually. This successful volunteer program is being replicated by other states to identify new pests quickly.

Keywords: invasive species, forest pests, tree pests, early detection, volunteer program

AGROFORESTRY IN GERMANY – FROM TRADITIONAL TO MODERN APPLICATIONS

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Soil Science of Temperate Ecosystems, Büsgen-Institute, University of Göttingen, Büsgenweg 2, D-37077 Göttingen, Germany

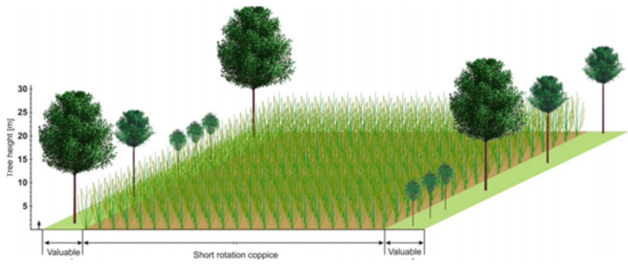
ABSTRACT

Agroforestry (AF) has a long history also in temperate climatic zones (e.g. grassland fruit orchards / "Streuobstwiesen" in southern Germany or wind brakes in northern Germany). However, due to the immense industrialization of the agricultural sector during the last decades those traditional land use systems were pushed to the fringes and were often not further promoted. On the other hand, modern agriculture also in most parts of Germany is progressively facing major ecological problems: i) loss of biodiversity, ii) soil erosion, and iii) eutrophication, including nitrate leaching. Furthermore, as all European member states should strive to a 20% share of renewable energy by 2020 (i.e., an equivalent of ca. 17.5 million ha of land dedicated to only produce energy crops), an additional pressure on farmland biodiversity as well as on soil and water resources can be expected.

Within this context, information on most important and actual running AF activities in Germany, including contact addresses for further details are presented. All German´s AF activities were recently gathered in a newly formed AF working group (www.agroforst.org) to further promote AF on a national but also within the European AF association EURAF on the EU member state level (www.agroforestry.eu).

Keywords: German agroforestry working group, high quality timber, short rotation coppice, alley cropping, bioenergy production, biodiversity, grassland, silvopasture, riparian buffer

AgroCop -
Combining **Agro**forestry with Short Rotation **Cop**pice
www.agrocop.com



1. What is new in AgroCop ?

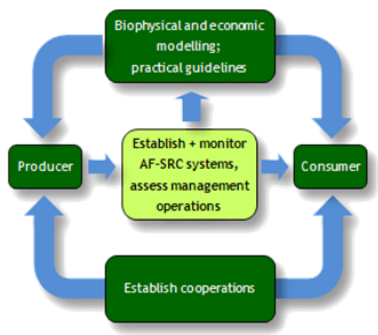
AgroCop utilizes two innovative strategies for wood production on agricultural land. Both have generated increasing interest as potential solutions for timber and feedstock production in Europe.

1) **Agro**forestry Systems (AFS), and
2) Short Rotation **Cop**pice (SRC)

2. The approach of AgroCop

AgroCop will examine how these two systems can be combined, by researching the use of SRC as an intercrop between rows of **high value timber trees**. We will assess the potential of such Agroforestry-SRC (AF-SRC) systems in two ways:

a) by establishing and monitoring experimental AF-SRC systems **across a gradient of environmental conditions throughout Europe**,
b) by modelling the biophysical and economic behaviour of such systems.



3. The expected outcome of AgroCop

By identifying relevant key parameters, we will provide practical knowledge that will help to **optimise the production of high quality timber and feedstock wood for energy** use in AF-SRC systems, for a variety of different environmental conditions in Europe.

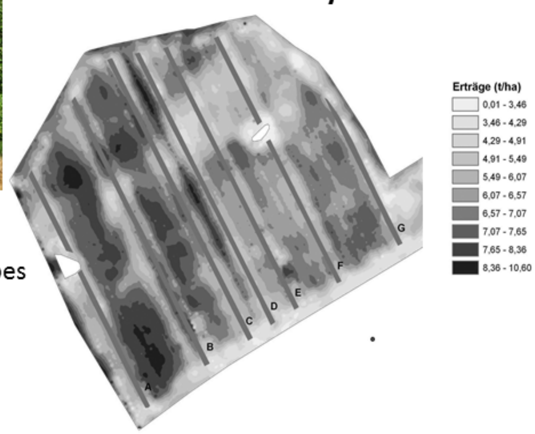
Our research team consists of partners in **five European countries.**

For more information: Chair of Forest Growth, University of Freiburg, Germany
www.iww.uni-freiburg.de & www.agroforestry.de

Studies on an alley cropping agroforestry system with stripes of short rotation coppices in Thuringia, Germany

Jung, Bärwolff, Vetter, 2013, Renewable Resources Department, Thuringian State Research Centre for Agriculture
Contact: linda.jungll.thueringen.de

Yield of Barley 2011



Key study aspects

- Influence of Short-rotation-coppice-stripes on field crop yield, quality, diseases
- Economical evaluation
- Microclimate
- Soil nutrients
- Biodiversity

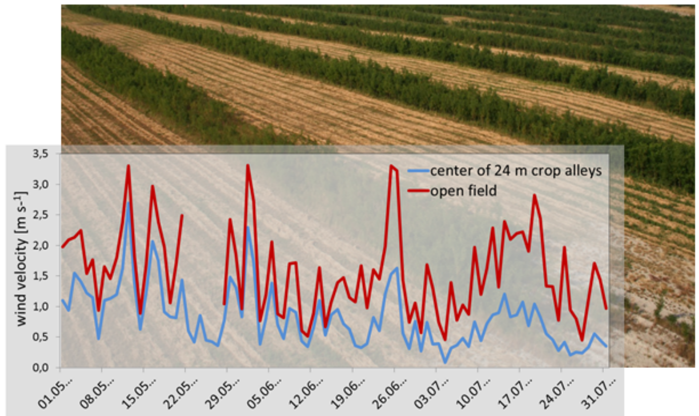
AgroForstEnergie

Studies on short rotation agroforestry system consisting of crops and fast-growing trees for bioenergy production in Brandenburg, Germany

Christian Böhm, Dirk Freese
Brandenburg University of Technology, Chair of Soil Protection and Recultivation,
Konrad-Wachsmann-Allee 6, D-03046 Cottbus, Germany
Contact : boehmc@tu-cottbus.de; http://www.tu-cottbus.de/projekte/de/multiland/

Research focuses

- Carbon sequestration
- Nutrient cycle
- Seepage quality
- Microclimate
- Biodiversitity
- Yields from trees/crops
- Ecosystem services
- Reclamation options



center crop alleys: Ø 0.8 m s^{-1} (53 %); open field: Ø 1.6 m s^{-1} (100 %)

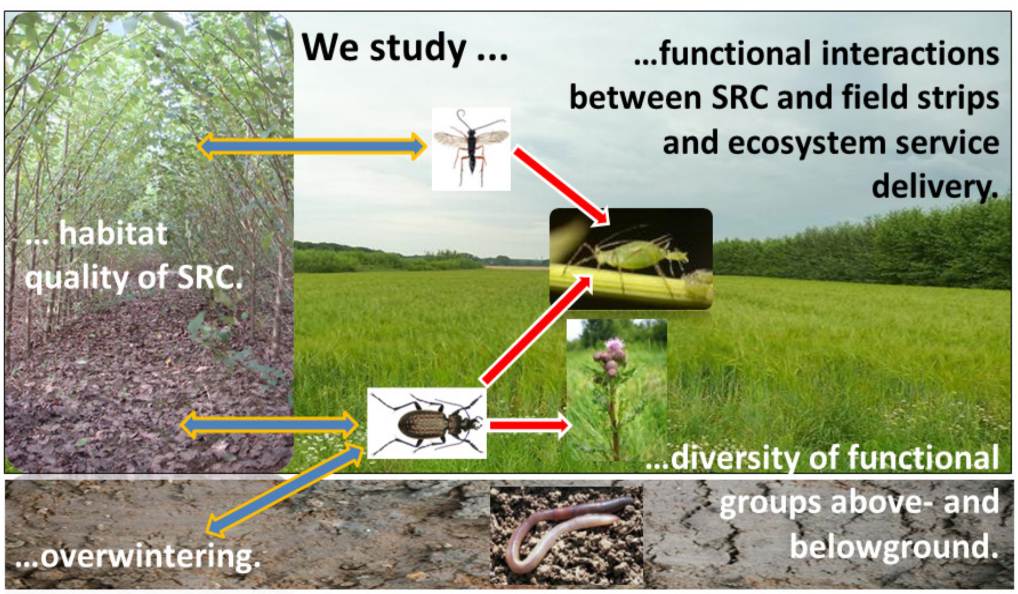
Brandenburg University of Technology Cottbus

AgroForstEnergie

Functional biodiversity in alley cropping with poplar short rotation coppice (SRC) in Lower Saxony, Germany

THÜNEN Institute of Biodiversity

Masur, Dauber 2013; Contact: daniel.masur@ti.bund.de



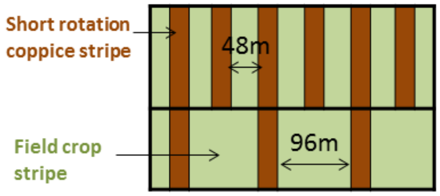
AgroForstEnergie II

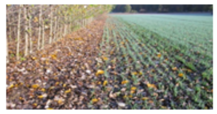
Federal Ministry of Food, Agriculture and Consumer Protection

Structural diversity of an alley cropping agroforestry system with short rotation coppice stripes in Lower Saxony, Germany

Lamerre Justine, Schwarz Kai-Uwe, Langhof Maren, Greef Jörg-Michael
Julius Kühn-Institute, Institute for Crop and Soil Science, Braunschweig, Germany
Contact: justine.lamerre@jki.bund.de

Study of: - **Yield structure modification of trees and crops, especially in the transition area**





Tree diameter, Tree height.

Number of plants, Grain number and weight, Ear size.

- modification of abiotic conditions next to the trees

Leaves coverage,
Light reduction,
Wind speed reduction,
Microclimate modification,
Soil moisture evolution.

JKI Julius Kühn-Institut Federal Research Centre for Cultivated Plants

Fachagentur Nachwachsende Rohstoffe e.V.

AgroForstEnergie

Studies on a young agroforestry system consisting of grassland vegetation and willows for sustainable bioenergy production in Lower Saxony, Germany

Ökologische Agrarwissenschaften UNI KASSEL

Part of the BEST - Project

BEST Bioenergie-Regionen stärken

*Dep. of **Grassland Science** and Renewable Plant Resources*
*University of **Kassel***

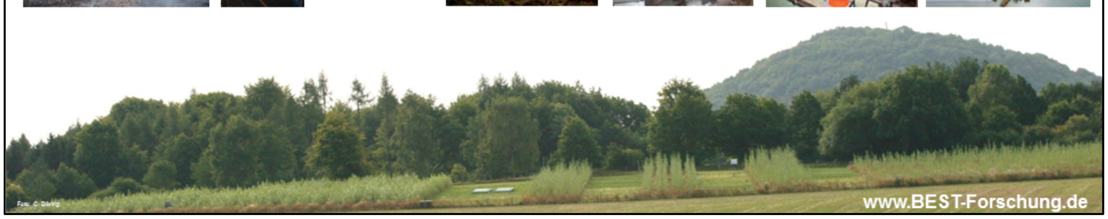
*Dep. **Soil Science** of Temperate Ecosystems*
*University of **Göttingen***

From **SRC** to **Heat**


+

From **Grassland** to **Biogas + Briquettes/Pellets**



Lehrstuhl für Waldbau — Technische Universität München

Oak hard mast for Swabian-Hall swine:
Rediscovering a traditional silvopastoral system

- Institution: Institute of Silviculture, Technische Universität München
  Dr. Bernd Stimm (stimm@forst.wzw.tum.de), Hans-H. Huss
- Partner: Eichelschwein GmbH www.eichelschwein.de
- Approach:
  - Pig herding in coppice and coppice-with-standards (CWS) forests in northern Bavaria
  - Conservation of an endagered race and CWS forests
  - Marketing of premium meat products
  - Monitoring of acorn production
  - Evaluation of foraging effects on composition of ground vegetation, tree regeneration and soil fauna
- *Funding: Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) via the Federal Agency for Agriculture and Food (BLE) (until 2010)*

Pictures taken by B. Stimm and Hans-H. Huss

Livestock Farming & SRC

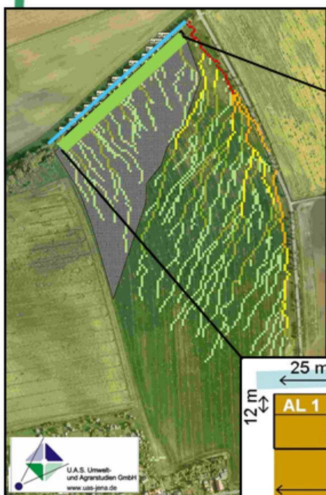
hein@hs-rottenburg.de

Spangenberg, G.; Hein, S. (2012): Hühner und Energieholz als Agroforstsystem. *Allgemeine Forstzeitschrift / Der Wald* 21/2012: 31-33.

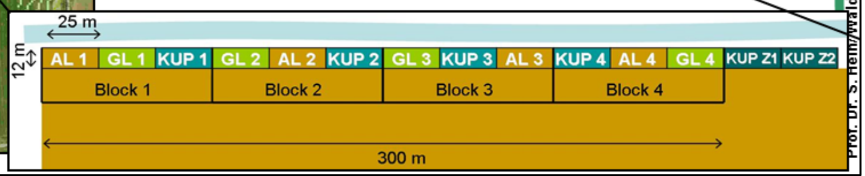
Prof. Dr. S. Hein/ Waldbau

Short rotation coppices along watercourses – water protection by erosion control and nutrient runoff reduction

Dr. Cornelia Fürstenau et al. 2013, (cornelia.fuerstenau@tll.thueringen.de)
Thuringia Regional Institute for Agriculture, Dep. of Renewable Resources, Dornburg



- study site set up in spring 2011 in the north of Thuringia
- three management options: cropland (AL), grassland (GL), and SRC (willow, Tordis) (KUP)
- two additional sites to test other tree species
  - KUP Z1 poplar (Max), KUP Z2 alder
- key aspects:
  - erosion modeling
  - soil analysis
  - water and suspended solids analysis
  - yield measurements of crops, grassland and trees



AGROFORESTRY, ANYONE?
OPPORTUNITIES, BARRIERS AND ATTITUDE TO AGROFORESTRY SYSTEMS IN FLEMISH AGRICULTURE

Bert Reubens[1] Bert Van Gils[1], Dorien Baeyens[1], Celine Vandevelde[1] and Erwin Wauters[2]

[1]Institute for Agricultural and Fisheries Research (ILVO), Plant Sciences Unit, Crop Husbandry and Environment, Burg. van Gansberghelaan 109, 9820 Merelbeke, Belgium, bert.reubens@ilvo.vlaanderen.be
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ABSTRACT

Many of the (traditional) silvo-arable and silvopastoral agroforestry systems in Flanders have been abandoned because they are considered to be incompatible with today's agro-economy and intensive farming practices. Nevertheless, modernized agroforestry could respond to a set of socio-economic and environmental challenges in Flemish agriculture, through diversifying production and supplying a wide range of ecosystem services such as increased carbon sequestration, improved soil fertility and organic carbon content, increased biodiversity or reduced nutrient leaching and erosion. This production system could furthermore enhance farm resilience and turn out to be a shock-proof investment through diversified production, broadening of farm activities and differentiation from other farm enterprises. Whereas these opportunities are increasingly recognized by policy makers, consultants, researchers and educators, the response to the new agroforestry subsidy program (for alley cropping) is low and genuine agroforestry remains sparse.

In our study, we try to reveal the underlying obstacles so as to determine what is needed (in terms of knowledge, policy or logistics) to tackle the current discrepancy between theoretical opportunities and practical implementation. Thereto, an assessment was made of some typical characteristics of Flanders' agriculture, the current appearance, range and characteristics of (older as well as recently established) agroforestry parcels, the present subsidy program and the response to it. Last but not least, farmers' experience with and intention, attitudes and perceptions towards agroforestry were assessed. As for the latter, two target farmer groups were approached. First, a questionnaire was sent out to randomly selected farmers throughout Flanders. Second, 26 semi-structured interviews were performed with early adopters, recent starters and farmers interested in agroforestry. The aim was also to learn about their motivations and perceived obstacles. The questionnaire results were analyzed using the Theory of Planned Behavior (Ajzen & Fishbein, 1980), stating that the intention to perform a certain behavior (in this case applying agroforestry) is guided by three main variables: attitude (being an individual's positive or negative evaluation of performing the behavior), subjective norms (being an individual's beliefs about what significant others think she/he should do) and perceived behavioral control (reflecting perceptions of ease or difficulty to perform the behavior).

Though the original objective of the Flemish government was to establish 250 ha of modern agroforestry through the new subsidy program by the end of 2013, only 16 ha has been realized

so far. Critics state that the subsidy doesn't compensate for the actual costs – particularly for maintenance- or the crop production losses and uncertainty given the long term investment. However, probably most important is that the subsidy by itself does not solve the most pressing obstacles to planting trees on agricultural plots. Some of the biggest problems are of legal or administrative nature and have to do with conflicts between regulations or uncertainty regarding ownership, tree-planting or tree-felling permit. Furthermore, there is a lack of practical experience in Flanders, resulting in a range of economical, technical and organizational questions still to be answered. Also the averagely small agricultural plot size (1.4 ha), the fact that only 35% of the cultivated area is owned by the land users, high land prices and the relatively moist weather conditions are part of the explanation.

The questionnaire pointed out that 55 % of the farmer respondents are not familiar with the concept of agroforestry. The attitude towards agroforestry scored low (2.95 on a scale of 1 to 7) and the perceived difficulty was high (2.24 on a scale of 1 to 7). Conversely, several mainly socio-ecological advantages were recognized. Furthermore, also the perceived pressure from the social environment or a certain group (not) to apply agroforestry appeared to have a high influence on the intention, as well as on attitude or perceived (dis)advantages. As a result, the intention to engage in agroforestry now or in the future was rather low, with a score of 1.42 on a scale of 1 to 7, and 16 % of all respondents expressing a positive intention. As the current concerns are frequently linked with the lack of experience in Flanders, one could hypothesize that the true potentials of agroforestry systems might be insufficiently acknowledged.

Among adopters, tree species preference and motivations varied strongly, as did their farm and agroforestry characteristics. Nevertheless, some clear trends could be assessed. Common Walnut, Poplar and different fruit trees species are most frequently planted. They are combined mainly with grassland (e.g. on 70% of the agroforestry plots in 2013) or occasionally arable crops such as winter wheat, barley or maize. Alley cropping is rarely applied with e.g. potatoes, fodder beet or vegetables, and this choice is generally driven by concerns for diseases, crop productivity and quality.

Since farmers' low intention and attitude were mainly associated with negative perceptions related to compatibility and profitability, future research and extension efforts should target these aspects. For those who already engaged themselves in agroforestry, some frequently asked technical or logistical questions, related to plantation design, establishment, management, damage avoidance and harvest, need to be addressed. At policy level, modern agroforestry clearly still needs to find its place in the legal landscape. Conflicting regulations and different opinions within the different policy domains need to be resolved. The subsidy program might become more effective when based on a more in-depth cost-benefit analysis, taking into account the uncertainty, long term investment, crop production losses and maintenance costs related to agroforestry.

Keywords: temperate agroforestry, alley cropping, attitude, adopters, profitability, compatibility, crop yield

THE LANDSCAPE OF AGROFORESTRY SCIENCE – WHO IS DOING IT? WHERE? WHAT ARE KEY GAPS? HOW DOES USDA SUPPORT IT?

Colleen Rossier

USDA Office of the Chief Scientist, Washington, DC

ABSTRACT

Let's dive into Agroforestry Science! This session will be based on the Science section of the first-ever report on USDA's role in agroforestry (more on this below). It will include:

1) An overview of the agroforestry science (research & extension) being undertaken with USDA support – by whom & where;
2) Agroforestry demonstration sites across the U.S.;
3) Key gaps;
4) How to find science-doing and science-using collaborators from USDA agencies;
5) USDA programs that fund agroforestry science; &
6) A discussion around the question: "What is USDA missing?" Is USDA missing key areas of agroforestry science in their report? What other funding programs support agroforestry science? Are there any challenges accessing USDA programs for agroforestry? How should the future USDA Agroforestry Science Working Group best engage the international agroforestry community?

Background: The *USDA Strategic Framework for Agroforestry* was released by the USDA Secretary in June 2011. It provided a roadmap for advancing agroforestry, and directed USDA to report annually on agroforestry. Responding to that direction, USDA plans to release the first-ever report of USDA's role in agroforestry in June 2013 (in both brief and comprehensive versions). These reports discuss how enterprising people advanced agroforestry in fiscal years 2011-12, how USDA supported those efforts, and planned next steps. The report is organized around the *Framework's* three simple goals: (1) Adoption, (2) Science, and (3) Integration, and includes a final section on Next Steps. This session will focus mostly on the Science section. Colleen Rossier co-authored both reports.

SUMMARY

Agroforestry Science – Who is doing it? Where? What are key gaps? How is it funded? USDA will provide its perspective on these questions with a dive into the science section of the first-ever USDA report of agroforestry accomplishments, outcomes, financial commitments, and planned next steps (report - *Agroforestry: USDA Reports to America; Fiscal Years 2011-2012-* expected in June 2012), and will open the questions up for discussion with the audience – What is USDA missing?

Keywords**:** agroforestry, science, demonstration

THE USDA'S NATIONAL AGROFORESTRY CENTER AND AAFC'S AGROFORESTRY DEVELOPMENT CENTRE ARE SUCCESSFULLY COLLABORATING TO ADVANCE THE APPLICATION OF TEMPERATE AGROFORESTRY SYSTEMS

Andrew Mason[1], and Henry de Gooijer[2]

[1]USDA National Agroforestry Center
[2]AAFC Agroforestry Development Centre

ABSTRACT

Agroforestry was identified as an area for increased collaboration in February 2011, in Ottawa, by officials from the United States Department of Agriculture (USDA) and Agriculture and Agri-Food Canada (AAFC) at the "Collaboration on Agri-Environmental Issues Dialogue". The USDA National Agroforestry Center (NAC) and AAFC Agroforestry Development Centre (ADC) have common missions and goals that focus on accelerating the application of temperate agroforestry systems in agricultural landscapes. At the Ottawa meeting, NAC and ADC leaders made a joint presentation and proposed 11 opportunities for action, which were agreed to by their officials. NAC and ADC have collaborated successfully to accomplish many of the actions, including: 1) translation of NAC's *Conservation Buffers Guide* into French for use in Canada; 2) authoring "Branching out: Agroforestry as a climate change mitigation and adaptation tool for agriculture", a featured paper in the *Journal of Soil and Water Conservation* (Sept/Oct 2012); and 3) jointly planning and hosting the very successful Great Plains Windbreak Renovation and Innovation Conference (July 24-26, 2012) at the International Peace Garden on the US-Canada border between Manitoba and North Dakota. USDA and AAFC strengthened their commitments further with the signing of a Memorandum of Understanding (MOU) in April 2012 by USDA Deputy Secretary Kathleen Merrigan and AAFC Deputy Minister John Knubley. The MOU emphasizes collaboration on agroforestry science and tools for climate change mitigation and adaptation in support of the goals of the Global Research Alliance on Agricultural Greenhouse Gases, of which both countries are members.

Keywords: Canada, United States, climate change

THE ECONOMICS OF ECOSYSTEM SERVICES OF TREE-BASED INTERCROPPING SYSTEMS

Mahbubul Alam[1], Alain Olivier[1], Alain Paquette[2], Jérôme Dupras[3], Jean-Pierre Revéret[4] and Christian Messier[5]

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[2] Département des sciences biologiques, Université du Québec à Montréal, Case postale 8888, Succursale Centre-ville, Montréal, H3C 3P8, Canada
[3] Département de géographie, Université de Montréal, Montréal, Canada
[4] Département stratégie, responsabilité sociale et environnementale, Université du Québec à Montréal, Montréal, Canada
[5] Institut des Sciences de la Forêt tempérée (ISFORT), Université du Québec en Outaouais, Ripon, JOV 1V0, QC, Canada

ABSTRACT

The paper aims to determine the potential environmental benefits of multifunctional tree-based intercropping (TBI) systems. Here we evaluate ten ecosystem services using a mix of mathematical models for quantification and economic valuation. The results reveal a total annual margin of 2 558 CAN\$ $ha^{-1}y^{-1}$. The economic value of combined non-market services is 1 634 CAN\$ $ha^{-1}y^{-1}$, which is higher than the value of marketable products (i.e. timber and agricultural products). The present value of the services for a rotation of 40 years is 54 782 CAN\$ ha^{-1}, about a third of which is contributed by agricultural products. Water quality regulation ranked highest among the non-market benefits followed by air quality maintenance, soil quality regulation, biological control, and pollination.

Keywords: tree-based intercropping systems, economic valuation, ecosystem services, benefit transfer.

INTRODUCTION

It is increasingly recognized that tree planting on agricultural land through agroforestry systems provides diverse ecological services and can mitigate the adverse impacts of extreme weather events (Limoges 2009; Eco Resources 2009). It helps fight against wind erosion, reduce the thermal amplitude, increase water infiltration and encourage pollinator and predator abundance (Griffin et al. 2008) compared to conventional farming systems. Various studies have shown that diversified agricultural and forestry systems provide more services, including higher productivity, than those with less diversity (Paquette and Messier 2011, Duffy 2009), especially in the most intensive human systems (Bennett and Balvanera 2007).

Although little known in Canada, tree-based intercropping systems (TBI) are well established in Europe, the United States and China, where various simulations have shown that they compare favorably, both in terms of productivity and economic profitability, to monoculture and conventional plantations (Graves et al. 2007). The intercropping systems indeed respond to many environmental issues. They increase microbial biomass and earthworm populations (Price et al. 1999), thereby improving soil fertility. The presence of roots can reduce surface runoff and soil erosion. The deep roots of trees can also recover certain nutrient leaching beyond cultures, as has been revealed in studies in Saint-Rémi, Québec (Lacombe 2009).

The intercropping systems may also play a major role in carbon sequestration and reducing atmospheric concentrations of other greenhouse gases, such as nitrous oxide (N_2O). The use of some fast-growing species such as the hybrid poplar can increase the potential of fixing atmospheric carbon (Peichl et al. 2006). Some studies in eastern North America have shown that the diversity and abundance of predator populations were higher in these systems than in agricultural monocultures, which may limit the use pesticides (Howell 2001). The same is true of avian diversity, as has been observed in Ontario (Thevathasan and Gordon 2004).

In this article we evaluate several important ecosystem services provided by tree-based intercropping systems. The overall goal is to calculate the monetary value of those services and evaluate economic performance of the system when non-market benefits are included in benefit-cost equation.

ANALYTICAL FRAMEWORK

The overall objectives of this paper include a marginal analysis of economic value of ecosystem services as well as an evaluation of the present value of future provision of the services for a period of 40 years. We made use of a 4-step analytical framework in this study. In the first step, we identified the full suits of ecosystem services, which are meaningful in the context of our study. In doing so we made an inventory of all possible Ecosystem Goods and Services (EGS) from agroforestry; then based on consultation with expert colleagues and literature reviews we short-listed 10 services for analysis. In the second step, we quantified the service providing units and their relationships with the provision of services. In the third step, we attempted economic valuation of each of the ecosystem services. The final step involved extrapolation of results and examining trade-offs.

We used a variety of mathematical models for quantification of various ecosystem services and their economic valuation. In some instances we used already existing models and equations (e.g. for soil quality maintenance), but in most instances we modified those to fit into our needs. There are several TBI experimental sites established in different parts of Canada. We heavily depended on the data published from the experiments in various TBI sites in Québec and Guelph. In some cases, however, we also transferred data from other study sites situated elsewhere. Details of experimental set up, species composition, management regime and results on TBI systems in Canada can be found in Rivest et al. (2010), Thevathasan and Gordon (2004), Peichl et al. (2006) and Oelbermann et al. (2006).

The final list of ten ecosystem services includes: soil quality regulation (ES_1), water quality regulation (ES_2), climate regulation (ES_3), air quality maintenance (ES_4), pollination (ES_5), nutrient mineralization (ES_6), windbreak (ES_7), biological control (ES_8) and provision of agriculture (ES_9) and timber products (ES_{10}). We use the following sets of general equations for economic analysis:

$$ES_{TEV} = \sum ES_{n} = \sum ES_{non\text{-}market} + \sum ES_{market} \quad (1)$$

Where, n=1, 2, 3… 10
TEV= Total economic value
$\sum ES_{non\text{-}market} = \sum ES_{1\text{-}8}$ and
$\sum ES_{market} = \sum ES_{9\text{-}10}$

A summary of various indicators can be found in Table 1. In the following we provide an overview of the method used for the quantification and valuation of the carbon sequestration service in a climate regulation context, along with economic data, assumptions and results. This is for the purpose of this conference proceedings; the methodology and results associated with the other services will be available in more detail in conference presentation and in future publications.

Table 1: Indicators of ecosystem services of tree-based intercropping systems

TBI Ecosystem services	Indicators	Indicator quantity
Soil quality	Earthworms	2.5 ton ha^{-1} y^{-1}
	Invertebrates	1 ton ha^{-1} y^{-1}
Water quality	N decontamination	11 kg $ha^{-1}y^{-1}$
	P decontamination	7.5 kg $ha^{-1}y^{-1}$
	Sediment dredging	-
Biological control	Pest infestation levels	-
Air quality	Pollutant removal	1.67 kg/tree
Wind break	Productivity change	1.47 ton ha^{-1}
Nutrient Mineralization	N input	7 kg $ha^{-1}y^{-1}$
	P input	11.42 kg $ha^{-1}y^{-1}$
	K input	21.22 kg $ha^{-1}y^{-1}$
	Change in yield (timber)	0.162 m^3 $ha^{-1}y^{-1}$
Climate regulation	Carbon sequestration	8.3 Mg CO_{2e} $ha^{-1}y^{-1}$
Pollination	Yield changes (crop)	1.47 ton ha^{-1} yr^{-1}
Timber provisioning	Annual yield	3.5 m^3 $ha^{-1}y^{-1}$
Agriculture provisioning	Annual yield	1.47 t $ha^{-1}y^{-1}$

The Economics of Carbon Sequestration

From an agroforestry perspective, carbon sequestration is made possible through the removal of atmospheric CO_2 and its transfer to both above and below ground biomass. While above ground components include various tree parts (stems, leaves) as well as the alley crops, below ground biomass includes roots, soil organisms and soil organic carbon.

The following is one of the equations employed for the estimation of the carbon sequestration potential of agroforestry trees (a 0.5 ratio of C per unit biomass is used here) (Hernandez et al. 2008):

CO_2 (kg/ha) = [(total biomass (m^3/ha) x bone dry density of wood (kg dry/m^3)) x Carbon/dry matter (kg/kg)] x CO_2/Carbon (kg/kg)] + C contained in the litter and dead wood (kg/ha) (2)

Another way of estimating C content *in situ* is to use remote sensing data. In this case species-specific allometric equations which were developed using biophysical properties of trees for a given environment are used for estimation of C stocks. Although this method is fairly common for large scale estimation in forests, it has had limited use in agroforestry (Nair 2011).

In agroforestry systems a considerable portion of C which is added to soil through litter falls goes back to the atmosphere through soil respiration. Further, an amount of C, along with other nutrients, is leached out through soil profiles (Peichl *et al*. 2006). Therefore, a simple representation of an estimation of net carbon sequestration from an agroforestry plot can be stated as:

Net carbon sequestration = Above ground C sequestration + Below ground C sequestration – Carbon liberation (3)

For operational purpose a more detailed breakdown of above equation can be written as:

$$NCS = (B_t + B_r + B_l + CR + SOC) – (C_r + C_l) + C_{N2O} \quad (4)$$

where, NCS, Net Carbon Sequestered; B_t, and B_r, Carbon stored in tree trunk biomass (including branches and leaves) and roots respectively; B_l, Carbon stored in litter fall; CR, Carbon stored in crop residues; SOC, Carbon pool in soil; C_r, Carbon returned back through soil respiration; C_l, Carbon lost through leaching into soil profiles; C_{N2O}, CO_2 equivalent avoided emission of N_2O.

Several valuation methods exist to estimate the economic value of carbon sequestration. Most relevant methods would be the social cost of carbon, carbon tax, emission trading, investments in alternative technologies, but only the social cost of C sequestration is presented here.

Elevated greenhouse gas concentrations in the atmosphere will cause societal damage in a number of ways including property damage due to elevated sea-levels, increased occurrence of extreme weather events, decrease in crop yields, damage in fisheries and increased health hazards. The Social Cost of Carbon (SCC) represents the marginal cost of emitting an additional unit of CO_2 into the atmosphere, i.e. the estimate of monetary value of damage resulting from CO_2 emissions. Thus SCC can also be referred to as Damage Cost Avoided. The societal value of carbon sequestration can be mathematically represented by the following function (Conte et al. 2011):

$$VAD_{xtT} = \sum_{z=t}^{T-1} \frac{\Delta C_{x,z,z+1}\, SCC_{z+1}}{(1+r)^{z-1}} \tag{5}$$

Where, VAD_{xtT} is the present value of all damage avoided (or additional damage when negative), due to carbon sequestration on x land parcel from time t to T. In the right hand side $\Delta C_{x,z,z+1}$ is the carbon sequestered over the rotation period (between time z and z+1), SCC_{z+1} is the SCC in year z+1 and r is the discount rate. In our analysis the duration of the rotation of TBI is 40 years and SCC is assumed to increase with time as additional carbon will be emitted in the future and as societal willingness to pay should increase due to income increase (Pearce, 2003). If δ is the rate of increase then $SCC_t = SCC_0\ (1+\delta)^t$; we use δ=0.04 assuming an increase of SCC at a rate of 4% (Yohe et al 2007; Johnson et al 2012). Thus the function can be re-written as:

$$VAD_s = \sum_{t=0}^{t=39} \{SCC_0\ (1+\delta)^t\} \frac{\Delta C_t}{(1+r)^t} \tag{6}$$

Where: VAD_s is the value of damage avoided for scenario s, t is the rotation period, r is the discount rate, ΔC_t is the change in carbon sequestration during time t, SCC_0 is the initial SCC.

Choosing a SCC can be challenging since we cannot sensibly calculate an SCC without assuming that future emissions and stocks following a specified path. Different specified paths will present different SCC (Stern, 2007). As a result, Conte et al. (2011) suggested the use of an average or median value. There are several estimates of SCC in the literature. Yohe et al. (2007) estimates SCC to be ranging from as low as $10 to as high as $350 with a mean of $43 and a standard deviation of $83 per ton of carbon sequestered. This mean value of $43 was used in our analysis. Any observed differences between SCC and the price of carbon in markets would not be surprising. Conte et al. (2011) argued that there is no 'functional relationship' between these two values given that in a regulated market, the price of carbon reflects producers' cost of sequestration and buyers' willingness to pay, while SCC reflects the damage cost that is avoided through carbon sequestration. Similarly, SCC should differ from the price of other measures such as carbon taxes imposed in various jurisdictions since the tax rates are designed to meet local or regional needs.

RESULTS

The total annual margin of TBI ecosystem services has been estimated to be $2 558 $ha^{-1}y^{-1}$. The economic value of combined non-market services is $1 634 $ha^{-1}y^{-1}$, which is higher than the value of marketable products (i.e. timber and agricultural products). The economic return from agriculture in monoculture is $1 110 $ha^{-1}y^{-1}$, whereas the return from agriculture in TBI is $784 $ha^{-1}y^{-1}$. Table 3 presents breakdown of the marginal value of ecosystem services stemming from TBI.

An analysis of the present value of future benefits of ecosystem services for a rotation of 40 years was also carried out and the results suggest that provision of agricultural products ranked highest ($16 287 ha^{-1}) among the ecosystem services followed by water quality ($11 581 ha^{-1}), air quality ($9 510 ha^{-1}), soil quality ($3 631 ha^{-1}), biological control (1 556 ha^{-1}) and pollination ($500 ha^{-1}) (Table 3). Total economic value (TEV) of all the ecosystem services for the rotation period was $54 782 ha^{-1}, only a third of which is contributed by agricultural products. Total non-market benefits constitute two-thirds of the TEV i.e. twice as high as the provisioning services combined (i.e. timber and agriculture) (Table 4).

Table 3: Marginal and present values of TBI ecosystem services

Ecosystem services	Marginal values ($ ha^{-1}y^{-1})	NPVs ($ ha^{-1})
Soil quality maintenance	175	3 631
Air quality regulation	462	9 510
Water quality regulation	558	11 581
Carbon sequestration	356	7 346
Pollination services	24	500
Windbreak	39	813
Nutrient mineralization	31	652
Biological control	75	1 556
Ag provisioning	784	16 287
Timber provisioning	140	2 905

We do not have precise estimates on the number of available farms that can be converted into agroforestry in Québec. Oelbermann et al. (2006) stated that 40% of Canada's approximate 7M ha marginal lands are eligible to be converted into agroforestry, whereas spatial analysis done by Hernandez et al (2008) showed that a 34% increase in wooded area in the L'Ormière River watershed in Québec is possible through agroforestry practices. If we assume in a conservative manner that 20% of Québec's 1.93 M ha croplands can be converted to TBI, then the potential marginal benefits of TBI ecosystem services equivalents to about $5 billion per year. This land area excludes summer fallow land (4 288 ha), tame or seed pasture (147 387 ha), natural land for pasture (158 602 ha) and other land areas including Christmas tree area, woodlands and wetlands (>1.2 M ha) (Statistics Canada 2006).

Table 4: Ecosystem Services in Various Bundles

Bundles	Marginal values ($ $ha^{-1}y^{-1}$)	NPVs ($ ha^{-1})
Agriculture in Monoculture	1 110	23 046
Agriculture in TBI	784	16 287
TBI Provisioning	924	19 192
TBI Non-market	1 634	35 590
Total Economic Value (TEV)	2 558	54 782

DISCUSSION AND CONCLUSIONS

There are several limitations to the biophysical and economic estimates used in our study. We suffered from the lack of sufficient quantitative data in the existing literature. Certain relevant studies, such as in tropical agroforestry systems, have limited use in this study because of a completely different environmental setting. In contrast to the limitations associated with the transfer of economic data from other studies, one of the strengths of our approcah is that we depended heavily on the biophysical data from 'local' experimental sites in Canada during quantification process. Secondly, it takes for an ecosystem many years to develop interactions among its various components, and therefore it may take years to start realizing benefits after establishing a system. The same is true for an agroforestry system. In this study we assume a uniform distribution of the provision of the ecosystem services throughout the rotation period, which is certainly not the case in reality. However, addressing such complex issues is out of the scope of this study.

Despite the inherent caveats and uncertainties in quantification and valuation of goods and services this study provides a reasonable estimate of the economic contribution of tree-based intercropping systems to society's welfare. The benefits are substantial, however, are realized at the cost of farmers' private benefits due to reduced provisioning services and the expected cost of adoption and maintenance of this new technology for a longer time frame. While it is impractical to suggest that all agricultural lands should be converted to agroforestry, a land inventory can determine the areas suitable for TBI based on environmental and technical feasibility and the willingness of the farmers in doing so. Therefore, adoption and expansion of TBI in Québec as well as in other parts of Canada is certainly worthy of discussion in policy forums.

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AGROFORESTRY CASE STUDIES: PUTTING TREES TO WORK FROM SEA TO SHINING SEA

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ABSTRACT

Innovators are putting trees to work in diverse ways from coast to coast! We will visit people using different agroforestry systems to learn how and why they are implementing agroforestry and which USDA resources can help others do the same. Our case studies will profile:

1) Farmers growing edible hedgerows and riparian vegetation in Washington state;
2) Silvopasture producers in the Southeast;
3) A cooperative of woodland owners trying out alley cropping and forest farming to increase their income from their natural resources in Oregon; and
4) Entrepreneurs harvesting and processing nuts from hedgerows and silvopasture in the Midwest.

These case studies will be published in the first-ever comprehensive report of USDA's role in agroforestry (expected June 2013). The report is organized around the *USDA Agroforestry Strategic Framework's* three simple goals: (1) Adoption, (2) Science, and (3) Integration. Because one of the barriers to agroforestry adoption is that people do not have a clear vision of it in their minds, we included fifteen case studies in the report to show how people are advancing agroforestry with USDA's assistance. Relevant case studies are referenced in each section and included all together in appendix D. There is also a companion *Brief version* of the report that weaves many of these stories – and more – into a narrative to introduce new audiences to agroforestry. Colleen Rossier was lead author on both reports with assistance from a cross-USDA team and many others.

SUMMARY

We'll visit agroforestry entrepreneurs across the United States: from the Pacific Northwest, the Southeast, and the Midwest. To increase agroforestry adoption, it seems that the trick is often finding people willing to take the risk, and assisting them to move theory into practice. We will learn what these innovators are doing, why they adopted agroforestry, how USDA helped them along the way, and how others can do the same.

Keywords**:** agroforestry, entrepreneur, USDA

CREATING THE KNOWLEDGE INFRASTRUCTURE TO ENHANCE LANDOWNER ADOPTION OF AGROFORESTRY THROUGH AN AGROFORESTRY ACADEMY

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ABSTRACT

Agroforestry offers a novel approach to land management that provides opportunities to combine productivity and profitability with environmental stewardship, resulting in healthy and sustainable agricultural systems that can be passed on to future generations. In spite of significant advances in both the science and practice of US agroforestry over the past 20 years, adoption has been limited. In the US, natural resource professionals and other educators are currently not equipped to help landowners adopt agroforestry. To advance adoption of agroforestry as a cornerstone of productive land use, a week-long agroforestry academy is being developed by a regional consortium of experts from Missouri, Iowa, Nebraska, Minnesota and Wisconsin. The academy is designed to train natural resource professionals, extension agents, and other agricultural educators who work with landowners. Advanced training will be provided on the five recognized temperate zone agroforestry practices integrated with options for bioenergy, marketing, economic, social dimensions, and environmental services. The cornerstone of the academy will be an applied planning and design exercise. Academy trainees will work in small groups to gain hands on practice in agroforestry design based on the needs of a working farm. Academy trainers and graduates will form the core of the knowledge infrastructure needed to enhance landowner adoption of agroforestry, resulting in increased sustainability of rural communities and the food and agricultural system.

Keywords: train-the-trainers, learning communities, agroforestry education

INTRODUCTION

US agricultural and rural communities face ongoing challenges including profitability and environmental stresses (e.g., floods and drought), that threaten the livelihoods and well-being of many who work the land and/or live in rural areas. Agroforestry offers opportunities to help address many of these challenges and introduce environmentally, economically and socially sustainable agricultural systems that create new opportunities for farmers, ranchers, forest landowners, and families in rural communities (Jose et al., 2012).

Agroforestry is the intentional mixing of trees and shrubs with crop and/or animal production systems to create economic, environmental, and social benefits. Agroforestry land use practices are intentional, intensive, integrated, and interactive. There are five widely recognized agroforestry US practices: 1) windbreaks -living fences that protect field, farmstead, and livestock; 2) riparian and upland buffers that act as sponges and filters to protect water quality; 3) silvopastoral systems with trees, livestock, and forages growing together; 4) alley cropping which integrates annual or perennial crops with high-value trees and shrubs; and 5) forest farming where food, herbal (botanicals), and decorative products are grown under the protection of a managed forest canopy.

The benefits of agroforestry include opportunities to enhance our local-regional-national food, income, environment and energy security. When properly designed and integrated, agroforestry protects crops, improves crop yields, creates resilient production systems that adapt to climatic extremes (e.g., droughts and floods), shelters livestock, reduces animal stress while improving weight gain; improves water and air quality; and enhances biodiversity and landscape diversity. On smaller farms (e.g., as small as 10 acres) unable to compete in large commodity markets, agroforestry provides opportunities to produce specialty crops and integrated intensively managed tree/livestock systems that help make these operations profitable while providing jobs and increasing wealth in rural communities (Gold et al., 2009).

The public is demanding more food from local and regional systems, as evidenced by the rapid increase in farmers markets, i.e., from 2,863 in 2000 to 7,864 in 2012 (Agriculture Marketing Service, 2012). Agroforestry is part of the solution for our rural lands to sustainably produce the food, fuel (e.g., biomass/biofuels) and other products in demand in local, regional, national and international markets. Enhancing and diversifying the production capabilities of rural lands, agroforestry practices will help revitalize rural communities by providing opportunities for small farms to be profitable and enable all categories of aspiring young farmers to view agriculture as a viable career.

EXISTING AGROFORESTRY INFRASTRUCTURE

Significant advances have been made in the science and practice of agroforestry over the past 20 years, yet on-the-ground application of agroforestry practices has lagged with the exception of government subsidized windbreaks and riparian buffers. Creating greater awareness of agroforestry's benefits will lead to increased acceptance and adoption of agroforestry, resulting in increased financial security and environmental protection for all classes of farmers, ranchers, forest owners, and communities. Over the past decade, numerous actions have been taken at the local, regional and national level to advance agroforestry research and increase agroforestry adoption.

Locally, in Missouri, the MU Center for Agroforestry (UMCA) supports the largest US university agroforestry program and maintains a comprehensive set of agroforestry research, education (Gold and Jose, 2012) and outreach programs. UMCA and numerous collaborators actively conduct research to discover, integrate and apply new knowledge and technologies to promote economic, environmental, and social vitality while also educating and training students, professionals, scientists, leaders, and the general public who are empowered to make a difference locally, regionally, and globally.

The Mid-American Agroforestry Working Group (MAAWG) was established in 2009 to advance the science, practice and adoption of agroforestry by landowners and natural resource managers in the US Midwest (MO, IA, NE, MN, WI). MAAWG's goals include the identification of the core issues (gaps, barriers, conflicts, opportunities) needed to advance adoption of agroforestry as a cornerstone of productive land use in the Midwest; and to initiate actions to address and resolve these core issues (MAAWG, 2013). UMCA is an active member of MAAWG.

Working at the national level, the USDA National Agroforestry Center (NAC) accelerates agroforestry application through a national network of partners who conduct research, develop technologies and tools, coordinate demonstrations and trainings, and provide useful information to natural resource professionals (NAC, 2013). In June, 2011, with prior input from a diverse group of 90 stakeholders, the USDA released an Agroforestry Strategic Framework, a roadmap for advancing the science, practice, and application of agroforestry as a means of enhancing America's agricultural landscapes, watersheds, and rural communities (USDA, 2011). The Framework's first goal is to increase agroforestry adoption by landowners and communities by expanding learning partnerships with stakeholders and educating professionals. A major concern is the fact that professionals, including USDA NRCS and state agency conservation staff, are currently not sufficiently equipped to provide technical, financial, and marketing assistance needed to plan and apply agroforestry systems.

THE APPROACH

To achieve on-the-ground adoption of agroforestry, it is essential to train a core group of individuals within State and Federal Government Agencies, University Extension, Non-Profit, and Professional Organizations who deal with land management issues and/or interact with farmers and landowners. It is also of utmost importance to facilitate collaboration among researchers, extension personnel, and practitioners, diverse disciplines, departments and colleges, and different agencies and organizations.

To help create the knowledge infrastructure leading to enhanced landowner adoption of agroforestry as a cornerstone of productive land use, a week-long agroforestry academy is being developed by a regional consortium of experts from Missouri, Iowa, Nebraska, Minnesota and Wisconsin. The agroforestry academy will provide "train-the-trainer" professional development to agriculture and natural resource professionals and extension personnel agriculture as recommended by both MAAWG and USDA Strategic Framework goals. Increasing the knowledge of professionals in agroforestry will allow them to transfer these strategies and principles to an even broader audience that reaches into rural communities across five Midwestern states. Importantly, the agroforestry academy will help to create a learning community of researchers, professionals and practitioners with a range of expertise in agroforestry that will facilitate education, idea exchange, and adoption.

THE AGROFORESTRY ACADEMY

Planning for the Academy: A number of actions and activities need to take place prior to the offering of the agroforestry academy.

First: Agroforestry academy partners will meet monthly prior to the launch of the first academy to review and finalize logistics, topics, schedule, content, etc.

Second: The agroforestry academy training manual to be used in 2013 will be updated from the 2006 UMCA agroforestry training manual (UMCA, 2006) containing the latest scientific knowledge and outreach materials developed since 2006. For academy participants, the manual will be provided in hard copy and as an online resource which will include videos, all livestreamed agroforestry academy presentations and hotlinks to additional resources). The online manual will be cross-linked to all partners in the five-state area. The manual will incorporate and benefit from input and active collaboration with MAAWG, and NAC.

Third: An online agroforestry academy portal will be created. A key element of the academy design is creation of both an online forum for academy participants and graduates, and a web home for an online learning community. The learning community site will house both the forum and agroforestry resources such as the recorded academy workshops, and the 2013 training manual. It will provide a means to link researchers, professionals and practitioners and facilitate education and idea exchange. The learning community will be hosted on UMCA website, and cross-linked with partner organizations across all the states.

Target audience: The target audience includes Agriculture and Natural Resource professionals; Univ. Extension personnel; Certified Crop Advisors; USDA NRCS, and FSA field staff; Soil and Water Conservation District personnel; Farm Bureau, Farmers Union, conservation groups (especially those with tree and forest missions such as Trees For Ever and American Forest Foundation) and similar organizations. At least two individuals from each agency within each state will be recruited as trainees so that they will be able to network together post academy (along with all of their new agroforestry learning community members) to affect change in the state. By enrolling in the academy, participants will, with technical assistance from academy organizers, commit to organizing spin-off trainings within one year of completion and to report results. They will also participate in the online learning community forum.

Academy design: With an initial two-year funding commitment from the USDA NCR-SARE PDP competitive grant program, the academy will consist of a week-long “train-the-trainer” program containing classroom presentations and visits to practitioners’ farms culminating with a “hands-on case study” exercise in agroforestry design. The first two days of the academy will include workshops (comprehensive classroom presentations) on the latest science and practice in support of agroforestry practices plus information intended to assist landowners develop financial budgets for agroforestry practices and market the products they grow. Days three and four will consist of visits to practitioners’ farms with established agroforestry sites along with a “hands-on case study” farm that does not yet contain agroforestry. The academy will conclude with an agroforestry design exercise which will sum up all the knowledge and experience received during the week and apply it to the “hands-on case study” farm. The case study design exercise (with small group presentations and follow-up discussions) will facilitate experience in the implementation of agroforestry design and will encourage collaborative learning community efforts. The planning process will help participants envision how agroforestry practices can be successfully integrated on a farm. Lunch and dinner will also include presentations from a number of agroforestry practitioners, partner agencies and group discussions. Workshops will be recorded and made available for later use. The curriculum will be targeted to specific audiences of natural resource and agricultural professionals with national application. The one-week academy will be repeated the second year in a new location.

CREATING THE KNOWLEDGE INFRASTRUCTURE

The agroforestry academy and associated activities are designed to help create the knowledge infrastructure to enhance landowner adoption of agroforestry. As a result of the academy, it is expected that knowledge about agroforestry and communication within and between core agencies and organizations will be strengthened. The number of key individuals with a working knowledge of agroforestry practices will be increased. As participants of the academy, attendees will realize new opportunities to interact across agency and organizational boundaries, and to creating or enhancing knowledge networks. There will be an increased incidence of extension and natural resource professionals recommending agroforestry to landowners. Academy graduates offering spin-off trainings to farmers and landowners will result in increased adoption of agroforestry.

Based on their new knowledge and relationships, academy graduates will help to identify necessary and innovative policy changes that facilitate agency support for agroforestry. Any subsequent policy changes within agencies and organizations will reflect knowledge gained and an appreciation for the benefits of agroforestry practices applied to the farm. Such changes, if implemented, will result in greater cooperation and collaboration between agencies, organizations, and natural resource professionals when recommending agroforestry and other sustainable forest and farm management practices.

The long-term goal of the agroforestry academy is to increase landowner adoption of agroforestry practices resulting in a greater diversification on farm landscapes, enhanced farm sustainability through product diversification and enhanced stewardship of farm resources.

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FAST GROWING TREE SPECIES IN ALLEY CROPPING SYSTEMS AND THEIR INFLUENCE ON MICROCLIMATE IN GERMANY

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ABSTRACT

The production of energy wood on arable land has been increased in Germany during the last years. In this context, agroforestry systems keep a prominent position in agriculture, since they allow the simultaneous production of energy wood and food or feed on the same field. Fast growing trees arranged in hedge structures (alley cropping) can have positive effects on microclimate.

Results of different research studies carried out in several alley cropping sites located in eastern Germany show that wind velocity can be reduced by more than 50 percent, even though tree hedgerows were not higher than four meters. The observed reduction of wind speed was depending on the distance to trees, on the orientation of tree hedges as well as on the width of the crop alleys. Potentially negative effects on crop yield were expected due to the shading the peripheries of crop alleys by trees. However, first results indicate that the reduction of the global radiation by short rotation trees did no show any negative effect on crop yield. As an exception, the crop yield on a post-mining site was evenly higher near trees compared to the center of crop alleys. In summary, the establishment of alley cropping with fast growing trees have positive effects on microclimate and hence on the yield stability of crops cultivated in between the tree hedgerows without any significantly negative impact on the recent practice of land management.

Keywords: bioenergy, black locust, crop yield, hedgerows, poplar, shadowing, short rotation, soil erosion, wind break, wind velocity

INTRODUCTION

Cultivation of energy crops is increasingly gaining importance against a background of the stronger focusing on renewable energy sources in Germany (Fachagentur Nachwachsende Rohstoffe 2013a). In this context, bioenergy provided by woody biomass is still the most important form of renewable energy (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2010). Because of the increasing demand for energy wood during the last years, cultivation of fast-growing trees on agricultural sites was expanded perceptibly in Germany (Fachagentur Nachwachsende Rohstoffe 2013b). Mostly, cultivation of fast-growing trees takes place in the form of short rotation coppices. Alley cropping systems, however, represent a promising possibility to cultivate woody crops as well. This type of agroforestry is currently progressing in Germany, due to the fact that conventional crops and trees for bioenergy can be produced simultaneously on the same field without to restrict established management practices or existing technical equipment.

Generally, microclimate of arable land is influenced by tree rows planted in close distance to crop fields. Such modifications of microclimatic parameters can be mainly assessed as beneficial for the growth performance as well as the yield of crops cultivated on adjacent fields (e.g. Pretzschel *et al.* 1991). Especially in terms of shelterbelts there is a quite large amount of research studies that dealt with tree rows and their effect on the wind velocity (e.g. Nuberg 1998). Significantly less investigated is the question of how such changes may be transferred to short rotation hedgerows of alley cropping systems. Due to the usually short rotation periods of three to six years average height of these tree hedges is comparatively low and varies commonly between three and eight meters. Furthermore, tree hedgerows are harvested periodically, and hence, lose temporarily their protective effect. Shadowing effects of trees and their influence on crop yield represent another important issue that should be investigated in more detail for short rotation alley cropping systems.

The primary objective of this study was to quantify the influence of relatively small tree hedgerows within short rotation alley cropping systems in the temperate region on selected microclimatic parameters including wind velocity and global radiation on the basis of multiannual high temporal resolution measurement series. In addition the influence of the arrangement of tree hedges (e.g. distance between hedgerows, orientation of stripes) on microclimate was also part of this study and finally the meteorological data were related to the crop yield depending on the varied distance from hedgerows.

MATERIALS AND METHODS

Study sites

Investigations were carried out at two sites that are situated in Southern Brandenburg State, Germany, about 150 km southeast of Berlin. The study area is characterised by an average annual precipitation sum of 560 mm and a mean annual temperature of 9.3 °C (1951-2003, meteorological station Cottbus). Both sites are part of a broad, mainly flat and less structured landscape.

Site I is located in the post-mining area of the lignite opencast mining “Welzow-Süd” and encompasses an area of almost 18 ha. This site is characterized by humus- and nutrient-poor sand-dominated dump substrates. The establishment of the alley cropping system occurred in spring 2007 using one-year-old, bare-rooted seedlings of black locust (*Robinia pseudoacacia*). Trees were planted in hedgerows consisting each of four double rows, which 1.8 m away from each other (plant density: 9200 trees per hectare wood area). The distance between hedgerows is 12 and 24 m, respectively. Hedgerows are oriented in north-south direction on about 50 % of the area, whereas the other half was planted in east-west direction. After five years of growth (mean tree height: 3.75 m) each second hedgerow was harvested completely. Alfalfa (*Medicago sativa*) was cultivated on crop alleys during the first four years. The crop rotation has been continued with spring barley (*Hordeum vulgare*), oat (*Avena sativa*) and winter rye (*Secale cereale*).

Site II is farm land at a naturally formed area of land close to the river “Neiße” and was used for agriculture for several decades. The alley cropping system was established on 40 ha in spring 2010. Hedgerows are composed of four double rows of black locust and poplar clones “Max”

(*Populus maximowiczii x Populus nigra*) and "Fritzi Pauley" (*Populus trichocarpa*) that were planted as one-year-old, bare-rooted seedlings and cuttings, respectively. The plant density was around 8700 trees per hectare woodland. Trees were not harvested before. Hedgerows are oriented in north-south direction. The distance between hedgerows varies between 24, 48 and 96 m. Crop alleys were cultivated with lupine (*Lupinus* spec.) and potatoes (*Solanum tuberosum*) during the period of measurement.

Microclimatic parameters

Meteorological data were collected by means of weather stations that were placed in different distances to the tree stripes. Data were measured every 10 minutes in 1 m above soil surface and recorded using data loggers (Delta-T devices). To guarantee comparability, temporary data losses occurred due to technical problems at one weather station were assumed for all stations within the same site.

At site I climate data were recorded from June 2008 until spring 2013, while at site II weather data were measured from April 2012 on. Altogether four weather stations were installed a site. Following meteorological parameters were measured at these stations: wind velocity, air temperature, relative air humidity, global radiation, precipitation. Furthermore, soil moisture and soil temperature were measured continuously in different soil depths.

At each site, one of these stations was installed on an adjacent open field (Site I REF and Site II REF), which each acts as reference area for the alley cropping systems. The remaining three weather stations at site I were built up on a north-south oriented, 24 m wide crop alley. One was installed at the center of this alley (Site I CENTER 24m), one 2 m away from trees at the western (Site I 2m-WEST 24m) and the last station 2 m away from trees at the eastern (Site I 2m-EAST 24m) edge area. Additionally, one anemometer was installed at the center of an east-west oriented, 24 m wide crop alley in January 2012 (Site I CENTER 24m EW). At site II three meteorological stations were built up on a 96 m wide crop alley. Analogous to site I, one station was placed at the center (Site II CENTER 96m) and one 3 m away from trees at the western side (Site II 3m-WEST 96m). The fourth station here was installed at the western edge area as well, about 23 m away from the hedgerow (Site II 23m-WEST 96m). In addition to these stations three further anemometers were installed at site II in June 2012. One of that was placed 3 m away from trees at the eastern side of a 96 m wide crop alley (Site II 3m-EAST 96m). The others were built up at the center of a 24 m and a 48 m wide crop alley, respectively (Site II CENTER 24m and site II CENTER 48m).

Crop yield

Determination of crop yields was carried out using the partial harvest method on the 24 m wide, north-south oriented crop alleys at site I depending on the distance to hedgerows. For that, the complete aboveground biomass was sampled at squares of 1x1 m. Three of such sampling points were established at each of eight crop alleys. One was placed at the center and the others 3 m away from tree hedges at the western and eastern edge areas, respectively. Samplings were carried out in summer 2010 (alfalfa) and 2012 (oat) before the harvest.

RESULTS

Meteorological data

In the following, only the meteorological parameters wind velocity and global radiation are considered. For site I climate data are given as annual averages for the years 2009 to 2012, while for site II the average has been calculated for the measurement period from July 2012 until the end of April 2013. The data from the alley cropping systems were compared to measured values of the reference stations, which were set to 100 %.

On crop alleys at site I the mean wind velocity from 2009 to 2012 amounted to 1.1 m s^{-1}, while in the same time period this was nearly twice as high at the adjacent open field (Table 1). Generally, the windbreak effect increased with increasing tree height until the end of 2011. A moderate increase of wind velocity was observed after the harvest of each second hedgerow in winter 2011/2012. The highest windbreak impact was observed in the western edge area (leeward side) of the north-south oriented crop alleys, where the wind velocity was reduced by almost 60 %. In the center of the crop alleys at site I the reduction of wind velocity still amounted to 54 % compared to the reference field, although the average high of the five years old trees was only 3.75 m before the harvest in winter 2011 (Table 1). The wind reducing effect was considerably lower when tree hedges were planted not towards the prevailing wind direction. In 2012, the wind velocity was only 25 % lower in the center of the east-west oriented crop alleys, while in the center of the north-south oriented alleys the velocity of the west dominant winds was reduced by almost 44 % compared to the open field (Table 1).

Table 1: Annual averages of wind velocity for the years 2009 to 2012 and their relations to the reference values (open field) expressed as percentage at site I

Weather station	2009		2010		2011		2012	
	[m s^{-1}]	[%]	[m s^{-1}]	[%]	[m s^{-1}]	[%]	[m s^{-1}]	[%]
Site I CENTER 24m EW	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.4	74.6
Site I 2m-WEST 24m	1.3	65.5	0.9	50.3	0.9	40.1	0.9	48.4
Site I CENTER 24m	1.5	77.4	1.2	61.8	1.0	45.9	1.0	56.3
Site I 2m-EAST 24m	1.5	76.0	1.1	60.6	1.1	53.0	n.d.	n.d.
Site I REF	1.9	100.0	1.9	100.0	2.2	100.0	1.8	100.0

n.d. = not determined

On the reference field without trees of site II the average wind velocity amounted to 1.8 m s^{-1} at site II, whereas the mean wind velocity of the 96 m wide crop alley three years after planting of the tree hedgerows varied between 1.0 and 1.7 m s^{-1}. Here, the highest windbreak effect was also observed at the western edge area (Table 3). Despite the relatively low average tree height of 3.15 m, the wind reducing effect still amounted to 6 % at the center of the 96 m wide crop alleys. Generally, the windbreak effect increased significantly with decreasing width of crop alleys. Thus, the wind velocity has been reduced by 49 % compared to the open field at the center of the 24 m wide crop alleys (Table 3).

At site I, no reduction of global radiation occurred during the whole period of investigation at the center of crop alleys. However, an increasing shadowing leading to a decrease of the global radiation has been ascertained at their peripheries (Table 2). In 2011, the average decline of the global radiation amounted to more than 10 % at the eastern edge area and even almost 30 % at the western side that included an area at a distance of up to 3 to 4 m from tree stripes. After the harvest of the hedgerows adjacent to the western periphery of crop alleys the re-sprouted trees caused a reduction of the global radiation, on an annual average, of about 7 % compared to the open field (Table 2).

Table 2: Annual averages of global radiation for the years 2009 to 2012 and their relations to the reference values (open field) expressed as percentage at site I

Weather station	2009		2010		2011		2012	
	[W m²]	[%]	[W m²]	[%]	[W m²]	[%]	[W m²]	[%]
Site I 2m-WEST 24m	116.2	93.1	105.7	81.4	91.9	70.5	117.9	93.3
Site I CENTER 24m	123.3	98.8	129.3	99.5	131.2	100.8	126.8	100.4
Site I 2m-EAST 24m	117.4	94.1	117.1	90.1	116.3	89.3	103.2	81.7
Site I REF	124.8	100.0	129.9	100.0	130.3	100.0	126.3	100.0

At site II there was a similar trend in global radiation compared with site I. No interference was observed on the radiation intensity at the center of the 96 m wide crop alleys as well as at 13 m away from tree hedges. A radiation deficiency has been shown only directly adjacent to the hedgerows (Table 3). The comparatively lower shadowing effect at site II could be explained by the fact that the weather station placed on the western edge area was installed about 1 m further away from the hedgerow than at site I.

Table 3: Annual averages of wind velocity and global radiation for the measurement period July 2012 until the end of April 2013 and their relations to the reference values (open field) expressed as percentage at site II

Weather station	Wind velocity		Global radiation	
	[m s^{-1}]	[%]	[W m²]	[%]
Site II 3m-WEST 96m	1.0	58.6	94.5	95.2
Site II 23m-WEST 96m	1.5	81.7	108.2	109.0
Site II CENTER 96m	1.7	94.3	104.2	105.0
Site II 3m-EAST 96m	1.4	76.0	n.d.	n.d.
Site II CENTER 24m	0.9	51.0	n.d.	n.d.
Site II CENTER 48m	1.2	70.2	n.d.	n.d.
Site II REF	1.8	100.0	99.2	100.0

n.d. = not determined

Crop yield

Yield differences depending on the distance from hedgerows were determined for alfalfa as well as for oat. Generally, higher yields were observed at the periphery of the 24 m wide crop alleys at site I. The surplus at edge areas related to the center of crop alleys amounted to between 12 % (west side) and 19 % (east side) for alfalfa and between 15 % (grain, west side) and 39 % (grain, east side) for oat (Table 4).

Table 4: Yields of alfalfa (*Medicago sativa*) and oat (*Avena sativa*) depending on the distance to the tree hedgerows at site I in 2010 and 2012, respectively (n = 8)

Location at 24 m wide crop alley	Alfalfa (harvested 2010)	Oat (harvested 2012)	
		Straw	Grain
	[t ha^{-1}]		
West side, 3 m away from hedgerows	4.2	2.8	2.7
Center of crop alley	3.8	2.3	2.3
East side, 3 m away from hedgerows	4.5	3.0	3.3

DISCUSSION

Due to the reduction of wind velocity direct, physical damages to crops (Cleugh *et al.* 1998) as well as indirect negative effects such as soil erosion (Kort 1988) or an increased soil drying by wind (Unger *et al.* 1991) can be depleted considerably. Generally, there are several recent studies which focus on windbreak effects by shelterbelts. In this context, the influence of factors such as tree height or porosity was investigated in model approaches as well (Cleugh 1998). In most cases, however, shelterbelts are tree hedges higher than 5 m. Thus, results of these studies are only of limited suitability for the description of shelterbelt effects at low hedgerows which are typical for short rotation alley cropping systems. As the findings from this study show, such land use systems with tree heights of usually less than 5 m can lead to a significant decrease of wind velocity as well. Furthermore, the fact that tree stripes arranged one after another may result in a large-scale reduction of wind velocity (Kurz *et al.* 2001) indicates to the possibility to decline the wind erosion potential in extensive agricultural landscapes due to the establishment of short rotation alley cropping systems.

According to Nuberg (1998) the area of maximum shelter is usually between four and twelve times the height of trees, while the wind velocity is less reduced directly adjacent to the hedgerows. If this, for example, is assumed for site II, then only the center of the 48 m wide crop alley would be located in the maximum sheltered zone. However, this is contrary to the results presented in this study, which show for short rotation alley cropping systems that the wind velocity is lowest at the edge areas of crop alleys and that the wind reduction increases with decreasing distances between hedgerows. Although the average reduction of wind velocity was lower, wind peaks were attenuated significantly also at the center of the 96 m wide alleys (data not shown). This fact is particularly important in terms of the avoidance of wind erosion. Additionally to the width of crop alleys the orientation of the hedgerows had a significant influence on the wind velocity. This is consistent with statements by (Brandle *et al.* 2004). In order to guarantee the maximum shelter effect short rotation hedgerows should be orientated against the prevailing wind direction.

Wind-related soil drying can play a central role especially at extensive, unstructured landscapes. In such areas to which also belongs the study region, the drying-out potential of agriculturally used soils can be decreased and thus the water availability for crops enhanced due to the reduction of wind velocity (Böhm *et al.* 2011). At site I, which can be assessed as susceptible to drought stress, highest crop yields were determined at the edge areas of crop alleys. This is contrary to investigations by Varella *et al.* (2011) or Ding and Su (2010). According to these authors crop yields are often lower near trees (mostly between once and twice the height of trees) due to competition effects. However, water availability is one of the most important yield limiting factors at site I. Therefore, it can be assumed that the water availability was higher at edge areas compared to the centers of crop alleys. This is still supported by the fact that yields were higher at edge areas despite the lower radiation intensity. The comparison of yields (Table 4) and global radiation (Table 2) shows that the reduced global radiation had no negative effect on the crop yield. Rather, highest oat yields, for example, were determined at most shadowed areas in 2012. Thus, the decrease of radiation intensity due to the interspecific competition appears to be less important than the potentially lower evapotranspiration rate caused by the shadowing. This is consistent with findings by Surböck *et al.* (2005) or Seiter *et al.* (1999), who determined higher yields at edge areas as well. Hence, the attenuation of radiation cannot be seen as negative at site I. However, especially for sites with sufficient water supply during the vegetation period, a certain depression of crop yield due to competition with trees cannot be excluded. Additionally, crop species respond differently to the competition with tree hedgerows (Kort 1988). Intensity as well as quality of changes in microclimate caused by short rotation tree hedgerows depends considerably on site conditions. Therefore, a generalization of microclimate effects in short rotation alley cropping systems seems to be hardly possible.

CONCLUSIONS

Short rotation alley cropping systems result in changes of microclimatic parameters compared to open fields without trees, leading to more favorable conditions for crops. Especially, tree hedges consisted of short rotated fast growing tree species represent an effective windbreak referring to their comparatively low height. Consequently, short rotation alley cropping systems serve for the supply of woody biomass for bioenergy and contribute simultaneously to an enhancement of the microclimate. Furthermore, there is an indirect positive impact on soil fertility and partly on the average crop yield. This fact appears to be particularly relevant for extensive agricultural landscapes at the temperate region.

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Riparian and Silvopasture

WILLOW RIPARIAN BUFFERS FOR BIOMASS FEEDSTOCK AND NUTRIENT EXPORT

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ABSTRACT

We tested the hypothesis that a riparian buffer BMP that uses *Salix* as the primary species and includes systematic removal of willow vegetation substantially increases capture and export of nutrients from sedimentation and shallow sub-surface runoff into riparian zones. The Prince Edward Island study site consisted of a willow buffer planted between an agriculture field and the Wilmot River. Cropping at the site followed a rotation of cereal, forage and potatoes. The buffer was planted in June, 2006, half the plots with willow were harvested in November 2009 and half were left to grow with all plots harvested in November 2012. The experiment included two willow cultivar (*Salix viminalis* '5027' and *S. dasyclados* 'SV1') and two harvest cycle (three and six years) treatments.

Above and below ground biomass growth influenced total nutrient accumulation and export. Superior biomass growth of *Salix viminalis* lead to higher N accumulation whereas phosphorous accumulation showed no difference between *S. viminalis* and *S. dasyclados*. Highest concentration of N was in the root fraction followed by fine stems and the wood (main stems or trunk). *S. viminalis* had a higher total N concentration than *S. dasyclados* mainly due to higher concentrations in the stem and wood fractions. Total concentration for SV1 was 17 gN/kg wood whereas *S. viminalis* is 21 gN/kg wood. Over a four year period a one kilometer long *Salix* buffer intercepted and accumulated 584 kg N and 45kg phosphorous. The majority of the N was removed through the biomass harvest whereas the phosphorous was sequestered in the willow root system.

Keywords: *Salix*, riparian buffer, biomass, nutrient export

PROJECT SUMMARY

This project is testing the hypothesis that a riparian buffer BMP that uses willow as the primary species and includes systematic removal of willow vegetation substantially increases capture and export of nutrients from sedimentation and shallow sub-surface runoff into riparian zones. The study site was located adjacent to the Wilmot River in Prince Edward Island, Canada in close proximity of the town of Summerside, PEI. Land use in the watersheds is dominated by row crop agriculture with fields in potato rotation. The study site consisted of a planted willow buffer that was planted between the agriculture field and the south shore of the Wilmot River. Cropping at the site followed a rotation of cereal, forage and potatoes.

The buffer included four single rows with 1.0 m spacing within the row and 2.0 m between the rows for a buffer plant density of 6666 trees/ha. Half of the plots with willow were harvested in November 2009 and half were left to grow with all plots harvested in November 2012. The experiment included three vegetation treatments; grass and two willow cultivars: *Salix viminalis* ('5027') and *S. dasyclados* ('SV1') and two harvest cycle treatments.

During each growing season from 2007 to 2012 soil samples were taken at the 0-30 cm depth in each plot and two trees per plot were sampled, Plant tissue samples were taken from two trees per cultivar per plot in June, July, August and September. These samples were analyzed for nitrogen and phosphorous concentrations. Destructive yield measurements were taken in November of 2009 and 2012. Harvested trees were cut leaving a 20 cm stump. Belowground root mass was determined by using 5cm diameter root cores sampled to a depth of 80cm. To determine the export of nutrients from the buffer site harvested chips from each plot were analyzed for nitrogen and phosphorous concentration. Using this data the total nitrogen and phosphorous exported from the site was calculated as kg/ha of N or P.

The study has developed a new agricultural Beneficial Management Practice (BMP) that serves dual purpose of riparian protection providing a significant amount of technically available feedstock for bio-energy production with no land conversion from agricultural production. The co-management of willow riparian buffers for water quality protection and biomass production is an effective strategy facilitating effective nutrient removal from the site while producing large quantities of biomass. Research results have demonstrated that very high willow biomass yields are attainable at low cost on nutrient rich riparian sites. High biomass accumulation leads to enhanced nitrogen and phosphorous accumulation in above and belowground portions of willows. Total nitrogen removed during harvest of the 0.10 ha buffer site after seven years was 165 kg. A total of 14.8 green tonnes of wood chips were harvested from the buffer which is equivalent to 178 GJ energy or 4500L heating oil.

Figure 1**:** Willow riparian buffer project along Wilmot River in Prince Edward Island

CONCENTRATED RUNOFF FLOW: IMPLICATIONS FOR BUFFER DESIGN AND WATER QUALITY BENEFITS

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ABSTRACT

Non-uniform or concentrated flow of surface runoff from agricultural fields can reduce the pollutant trapping effectiveness of buffer strips having constant width along a riparian zone or field margin. Effectiveness and cost-effectiveness might be improved by reconfiguring the buffer to be larger where more runoff flows and smaller where runoff is less. A GIS tool has been developed that accounts for non-uniform patterns of runoff flow which can be used for assessing performance of buffers and for designing them. This tool was used to assess the effect of non-uniform runoff on sediment trapping efficiency of constant-width buffer designs and to compare performance of constant-width and variable-size configurations.

The tool is an ArcGIS extension based on the design model of Dosskey *et al.* (2011). It employs a digital elevation model (DEM) to divide the riparian area or field margin into many segments, determine contributing area and slope to each one and, then, design for a buffer area ratio that provides a specified level of trapping efficiency. The assessment procedure employs these same algorithms, but in a different order; first, determining the existing buffer area ratio and, then, calculating it's trapping efficiency.

Results using this tool on a sample of fields in the Midwestern U.S. suggest that variable-size designs can be more than twice as effective per unit buffer area as conventional constant-width designs. Producing cost-effective designs and accurate performance assessments of buffers requires accounting for detailed spatial patterns of runoff flow from agricultural fields.

Keywords: design, GIS, nonpoint pollution, precision conservation, riparian, terrain analysis

INTRODUCTION

Vegetative buffers reduce the load of sediment, nutrients, and other pollutants in runoff from fields to waterways. Typically, they are designed to have a constant width along an entire field margin. Several methods have been developed for determining an appropriate width for a buffer where runoff is uniformly distributed along the field margin (e.g., Dillaha and Hayes 1991; Suwandono *et al.* 1999; NRCS 2007; Dosskey *et al.* 2008).

In many situations, however, runoff is not uniformly distributed and moves as concentrated flow across only portions of a field margin (Dillaha *et al.* 1986, 1989; Dosskey *et al.* 2002; Pankau *et* *al.* 2012). One study of farms in eastern Nebraska estimated sediment trapping efficiency under observed non-uniform runoff flow to be less than half of what would be expected if runoff flow was uniform (Dosskey *et al.* 2002). Trapping efficiency was reduced by elevated loads to segments receiving concentrated flows. Other segments of buffer received little or no runoff and contributed little to reducing sediment from these farms. Runoff could be spread more evenly by grading the field or constructing spreaders, but these actions would add substantial cost. A more cost-effective design would simply vary the width of filter strip according to the amount of runoff received; larger where runoff is greater and smaller where runoff is less (Dosskey *et al.* 2005).

A design method was developed recently for sizing buffers that can account for non-uniform overland runoff (Dosskey *et al.* 2011). This method, however, is time-consuming to apply manually because it requires precise mapping of runoff flow paths from fields. To make it easier to use, the design method was automated by adapting it to terrain analysis in a GIS. Its utility was further enhanced by modifying these procedures to enable estimation of performance of existing and hypothetical buffers. The automated tool, called *BufferBuilder*, was used to (1) assess the impact of concentrated or non-uniform flow on sediment trapping by constant-width buffers, and (2) determine if performance can be improved by reconfiguring buffer area to match non-uniform patterns of runoff flow.

MATERIALS AND METHODS

The *BufferBuilder* program, an extension of ArcGIS v.10.0 and v.10.1 (ESRI, Redlands, CA, USA), was used to design variable-size buffers having a specified sediment trapping efficiency and to assess the corresponding trapping efficiency of constant-width buffers having identical total area. Several sample farm fields across the Midwestern U.S. were designed and assessed in this way, and the results compared.

The key feature of *BufferBuilder v.1.0* is that it sizes buffer in segments along a field margin in proportion to the size of field area that drains to each segment, i.e., buffer area ratio. This approach can account for varying sizes and irregular shapes of contributing areas that produce non-uniform runoff. The appropriate buffer area ratio is determined by additional information on slope, soil texture, tillage conditions, and the level of trapping efficiency that is desired for a design storm of 61 mm in 1 hr (Dosskey et al. 2011). In the GIS, a digital elevation model (DEM) is used to divide the field margin into segments, determine contributing area and slope to each segment, and to provide a grid structure for calculating and mapping buffer area for many segments around a field margin.

For this study, digital aerial orthophotos of the fields were obtained from the USDA-NRCS Geospatial Data Gateway website (http://datagateway.nrcs.usda.gov). Digital elevation models having approximately 10-m grid spacing were obtained from the USGS National Elevation Database website at http://seamless.usgs.gov/ and were resampled to a 5 m grid.

RESULTS

An example of a *BufferBuilder*-designed buffer is shown in figure 1 (in red). The sinuous contours suggest that runoff does not distribute uniformly to the field margin around this field. Consequently, the designed filter strip has a highly variable configuration. Despite the variable configuration, this design is expected to provide a constant 72% sediment trapping efficiency along the entire field margin.

Figure 1. Aerial photo of a 59.3 ha field in Madison Co., IL showing 1-m contours and a constant-width (20-25 m) buffer (in yellow) having the same total area as the *BufferBuilder* design (in red). The sediment trapping efficiency of the constant-width configuration on a whole-field basis was estimated to be 35% while that of the *BufferBuilder* design was estimated to be 72%.

An example of an assessment using *BufferBuilder* is also shown in figure 1. In this scenario, a 20-25 m-wide buffer was drawn along the margin (in yellow) where the design procedure indicates that most runoff would leave the field. It was drawn to have the same total area (4.0 ha) as the *BufferBuilder*-designed buffer. This constant-width buffer was estimated to have 35% sediment trapping efficiency or about 35% of the sediment delivered to the field margin from this field would be trapped by this buffer.

Several additional fields were analyzed using both the design and the assessment procedures in the same manner as the example in figure 1. In every scenario the design produced by *BufferBuilder* performed better than the constant-width configuration having the same total area (table 1). On average the variable-size configuration would trap 67% of the sediment in field runoff compared to only 30% by the constant-width configuration.

Table 1. Comparison of whole-field average sediment trapping efficiency of *BufferBuilder*-designed and constant-width buffers having equivalent total area for selected fields in the Midwestern U.S.

Field Location	**Field area (ha)**	**Buffer area (ha)**	**Sediment Trapping Efficiency (%)**	
			***BufferBuilder* design**	**Constant-width design**
Madison Co., IL	59.3	4.0	72	35
Shelby Co., KY	25.1	3.4	67	40
Cedar Co., IA	14.9	0.9	69	62
Clinton Co., MO	30.1	0.8	66	24
Clinton Co., MO	4.0	0.1	64	16
Dekalb Co. MO	15.2	0.8	64	33
		Average	67	30

DISCUSSION

Results from this study are consistent with an earlier study in Nebraska which estimated that observed patterns of non-uniform runoff limited the sediment trapping efficiency to less than half of what would be expected if runoff was distributed uniformly through the existing buffers (Dosskey et al. 2002). Although the field scenarios in table 1 were not intended to be statistically representative of the Midwestern U.S., the results of this sample invariably point toward better performance by variable-size buffers, often by very large margins.

Since installation costs and program incentives (e.g. USDA Conservation Reserve Enhancement Program) for buffers are proportional to the total area of the buffer installation, these results translate directly into greater water quality improvement per dollar spent for *BufferBuilder*-designed variable-size buffers than for constant-width configurations. Alternatively, additional structural practices could be installed that distribute runoff uniformly through the constant-width filter strips and bring the trapping efficiency up to the level determined for *BufferBuilder*-designed buffers, but that approach would add substantially to the total cost of the buffer. Both effectiveness and cost-effectiveness of buffers could be enhanced simply by configuring the buffer area to match detailed spatial patterns of field runoff.

The results of this study suggest that producing cost-effective designs and accurate performance assessments of buffers requires accounting for detailed spatial patterns of runoff flow from agricultural fields. Failure to do so could result in substantial underperformance of buffer installations and overestimation of water quality benefits.

CONCLUSIONS

Pollutant trapping effectiveness of constant-width buffers can be greatly limited by concentrated or non-uniform runoff flow. Better designs would match size of buffer to the runoff load along riparian zones and field margins. The design model of Dosskey et al. (2011), which can account for non-uniform runoff, was programmed into a GIS tool for designing and assessing performance of water quality buffers. Variable-size designs developed for sample fields with this tool were estimated to trap substantially greater amounts of sediments than constant-width configurations having the same total area. This result translates directly into greater cost-effectiveness of variable-size designs compared to constant-width configurations where runoff is non-uniform. Producing cost-effective designs and accurate performance assessments of buffers requires accounting for detailed spatial patterns of runoff flow from agricultural fields.

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RESPONSE OF AVIAN COMMUNITY TO WILLOW RING MANGEMENT IN PRAIRIE POTHOLE WETLANDS

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ABSTRACT

Wetlands surrounded by willow vegetation (willow rings) within the Prairie Pothole Region (PPR) are an important part of the prairie landscape. They provide habitat for wildlife, remove agricultural runoff, and reduce soil salinity. However, willow rings in the PPR are continually destroyed to increase crop production. Recently willow rings have been targeted as a renewable source of biomass for bioenergy operations because it is adapted for quick growth following harvest. Management of willow vegetation from wetlands will increase the economic incentive to retain wetlands intact on the prairie landscape. However, there is currently, little known about the avian species inhabiting willow rings or the impact that harvesting natural willow vegetation will have on these species. My research will look at the natural variation in willow ring coverage and age to simulate harvest treatments of willow rings. Point counts will provide information on the bird species that use each wetland as well as how birds react to changes in willow vegetation structure. Comparisons of high and low density wetland areas across different land cover types will be used to demonstrate any habitat preferences bird species may have. The results of this research will determine the impact that willow harvest will have on avian populations inhabiting these wetlands. This research can then be used to create guidelines for sustainable willow ring management practice in the future.

Keywords: wetlands, willow vegetation, birds

INTRODUCTION

Millions of highly productive wetlands were created during the last glacial retreat, creating the Prairie Pothole Region. These depressional wetlands perform important ecological functions within the prairie ecosystem; including the removal of agricultural runoff from soils and reduction of slough ring salinity (Kuzovkina and Quigley 2005). This matrix of wetlands also provides habitat and necessary resources for wildlife and is especially important to avian species. This region is known as an important stopover for migratory birds, supporting over 50% of North Americas waterfowl migrants alone (Leon and Smith 1999). During the breeding season this region hosts over 100 different bird species (Haig *et al.* 1998).

However, the processes that created the Prairie Pothole Region also created exceptionally fertile soils with high potential for agricultural production. Consequently, 50% of historical wetland area in the United States and 71% in Canada has been drained for agricultural use (Rashford *et al.* 2011). Between 1985 and 2001 over 500,000 acres of Canadian Prairie Pothole Region was lost with 62% of it converted for agricultural activities (Rashford *et al.* 2011). In addition agricultural and urban activities have altered upland pasture and grassland, lowering the habitat suitability of the wetlands for biota (Naugle *et al.* 2000).

The development of bioenergy has put pressure on wetlands with willow (*Salix sp.)* vegetation growing around them (willow rings). Willow biomass has been found to be an efficient and renewable feedstock for bioenergy (Schroeder et al 2009). The harvest of natural willow biomass will increase the economic value of willow rings, influencing land owners to maintain these wetlands on their land rather than the common alternative of draining them. However, little is known about the avian communities that make use of willow rings or how willow ring management will affect avian species.

To understand how willow ring management will affect avian community structure one must understand what influences birds to use a specific habitat. Characteristics important to habitat selection include the size of the habitat patch available. Some species use large territories that include foraging and breeding habitat while other species forage outside of their nesting territory and defend a smaller territory (Lowther *et al.* 1999, Grant and Knapton 2012, Yasukawa and Searcy 1995). Differences in nesting preferences (shrub, ground, cavity, and reed nesters, for example) will also influence what site a bird chooses. Food and feeding preferences can also influences how species choose their territory; whether they forage by gleaning shrubs, ground or aquatic vegetation or feed on grains or berries (Lowther *et al.* 1999, Grant and Knapton 2012, Yasukawa and Searcy 1995).

A single willow ring may contain several different resources. Wetland vegetation zones develop in concentric rings from the centre point. Each zone is characterized by a different type of vegetation based on moisture levels (Steward and Kantrud 1971). This creates a wetland system that has diverse vegetation structure and multiple niches for many species to inhabit, creating a diverse avian community within willow rings.

The objectives of my research include:
1. To determine what species make up the avian community of a willow ring.
2. To determine species' preferences to landscape (wetland density, land cover) and local (wetland vegetation) habitat characteristics.
3. To determine the impacts of periodic willow biomass harvest on the avian community.

This information can be used to inform industry on sustainable willow ring management practice and to create best practice guidelines for future management of willow rings to maintain healthy wetlands for numerous breeding bird species, and millions of spring and fall migrants using the willow rings in the Prairie Pothole Region.

METHODS

FlySask aerial photos along with a water body inventory layer were used to randomly select 116 willow ring sites. The selected sites were then ground truthed to determine they were willow rings. If the wetland lacked willow vegetation or was dominated by another tree or shrub species the nearest willow ring is then used. All sites were divided into two land cover categories; Cropland and grassland. Cropland cover includes various annual crops; flax, wheat, canola and legumes. Grassland cover includes perennial forage crop and tame grass. The sites were then further divided into low and high wetland density classes. Between 27 May and 7 July 2012 point count surveys were conducted at each willow ring beginning at sunrise and ending at 08:00. Point counts were then conducted again the following breeding season. From July to October 2012 vegetation measurements were taken including willow height and willow stem density. Wetland and willow area was measured using a geographic information system (ArcMap).

Using this collected data I will analyze changes in avian richness and abundance along a gradient of varying vegetation structures. This will determine which willow ring characteristics contribute the most to habitat selection in different bird species. Analysis of avian communities along a gradient of percent willow cover will simulate how willow harvest will affect bird populations using these wetlands.

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MODELING INTEREST IN PLANTING NATIVE FRUIT AND NUT TREE RIPARIAN BUFFERS

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ABSTRACT

Agroforestry riparian buffers help protect water quality, conserve soil, benefit aquatic health, and provide terrestrial habitat. However, conservation buffers often displace land that could be effectively used for production. Agroforestry riparian buffers comprised of native fruit and nut trees could help landowners manage for both conservation and production in creeksides. This agroforestry strategy provides beneficial environmental services, while enhancing opportunities for revenue, subsistence, wildlife, and aesthetics.

We used technology and agroforestry adoption theory to study potential adoption of native fruit and nut trees in 3 Virginia watersheds. Our intent was to develop and test an exploratory model of landowner interest in planting native fruit and nut tree riparian buffer systems. We used illustration and a questionnaire to collect data from a sample of 469 creekside owners in 3 Virginia watersheds.

The Universal Theory of Acceptance and Use of Technology (UTAUT; Venkatesh *et al*. 2003) and Pattanayak *et al.'s* (2003) agroforestry adoption model were used to develop testable models. Confirmatory factor analysis (CFA) was used to verify underlying latent measures and multiple linear regression was used to model interest. A combination of constructs from both theories proved to be the best predictor of creekside owner interest.

Keywords: agroforestry, riparian forest buffer, native fruit and nut trees, adoption, universal theory of acceptance and use of technology

SELECTED CARBON FLUXES IN *PINUS PONDEROSA*-BASED SILVOPASTORAL SYSTEMS, EXOTIC PLANTATIONS AND PASTURES ON ANDISOLS IN THE CHILEAN PATAGONIA

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ABSTRACT

This study was undertaken to measure certain carbon (C) fluxes in a *Pinus ponderosa* - based silvopastoral systems (SPS) in Patagonia, Chile. Results are compared to those from adjacent 18-year-old managed pine plantations (PPP) and natural prairie (PST). Litter decomposition was determined using the litterbag method. Leached soil solution was collected with tension lysimeters at 80 cm depth, and soil respiration evaluated *in situ* with the soda lime technique. Wind direction influenced the litterfall distribution in SPS, with 94% falling in the tree strips and within 3 m on the east side. In the first six months the initial needle decomposition was low and less than 5% of the initial mass. The overall soil organic carbon (SOC) and N contents (0-40 cm depth) decreased significantly in the order SPS>PST>PPP, and within SPS were greater in the alleys, starting at 2.5 m from the tree strip, with the highest values always eastward of the strip, suggesting influence by the wind direction. Total soil respiration decreased in the order PST>SPS>PPP and leached C decreased in the order PPP>PST>SPS. In general, the mean annual soil moisture in the pasture alleys of SPS was twice that of PST. The air/soil temperatures decreased significantly in the second year only in PST and at 2 m and beyond from the tree strip in SPS. Soil moisture varied significantly among treatments, but showed the strong influence exerted by trees in the creation of a favorable microclimate within the pasture alleys of SPS.

Keywords: C sequestration, decomposition, soil respiration

SHEEP VEGETATION MANAGEMENT IN YOUNG CONIFER PLANTATIONS OF BRITISH COLUMBIA, CANADA

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ABSTRACT

Over the last few years, there has been a willingness to reduce the use of herbicides and mechanical practices in forest operations. as a result, the interest in using sheep grazing as a sylvopastoral system, is increasing. In British Columbia, Sheep Vegetation Management (SVM) is a relatively new technique; thus, limited data are available for examining its benefits on conifer growth.

We collected field data from grazed and ungrazed blocks established in young mixed-conifer plantations of lodgepole pine (*pinus contorta*) and hybrid spruce (*picea glauca* x *p. engelmannii*). Our main objective was to determine if sheep grazing had a significant effect on the growth of hybrid spruce. We measured total height (TH), stem diameter at 15 cm height (ø15cm), and cumulative internodal length (IL). The height: diameter ratio (HDR) was calculated to determine if seedlings prioritised growth in terms of height or diameter. Cumulative IL was calculated from the node corresponding to the year 2002 to 2010 for every node (positions 2 to 10). Results indicated that grazing treatment did not significantly affect diameter, TH or HDR; however, IL was significantly affected following the 2006 grazing treatment for internode positions 6 to 10.

Grazing as a form of vegetation management will undoubtedly increase in the future, especially on public lands as the use of herbicides and fire are restricted due to environmental concerns. This presentation will discuss results of the study and demonstrate how SVM can be an effective biological method to control vegetative competition in young conifer plantations.

Keywords: silvopastoralism, sheep vegetation management, growth response, conifer plantations, hybrid spruce

Windbreaks and Alleycropping

QUANTIFYING NITROGEN FIXATION OF AGROFORESTRY SHRUB SPECIES BY THE NATURAL ABUNDANCE AND ^{15}N DILUTION TECHNIQUES UNDER GREENHOUSE CONDITIONS

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ABSTRACT

Some land-use systems in the province of Saskatchewan include agroforestry trees/shrub species such as sea buckthorn (*Hippophae rhamnoides* L.), caragana (*Caragana arborescens* Lam.) and buffaloberry (*Shepherdia argentea* Nutt.) as important components. These species provide various ecological functions such as ameliorating soil moisture, light and temperature through reduction in wind speed and trapping snow which have been widely studied. However, the nutrient supply function of most of the agroforestry trees/shrubs in Saskatchewan, especially N_2-fixation, has not been determined. A greenhouse experiment was conducted in the at the University of Saskatchewan, Saskatoon, SK, Canada from January 2012 to April 2012. The objective of the study was to quantify N_2-fixation in caragana, sea buckthorn and buffaloberry using isotope-based techniques in two separate but concurrent experiments. Shoot percentage of nitrogen derived from atmosphere (% Ndfa) ranged from 20-59 % for caragana, 21-70 % for sea buckthorn and 3-15 % for buffaloberry. The whole plant % Ndfa in the species ranged from 18-47 % in caragana, 49-54 % in sea buckthorn and 38-41 % in buffaloberry in both experiments. Total amounts of N_2 fixed ranged from 73-91 kg N ha^{-1} in caragana, 25-261 kg N ha^{-1} in sea buckthorn and 15-110 kg N ha^{-1} in buffaloberry, for both experiments. The amount of N_2 fixed by the species gives clue to their potentials in alley cropping systems to provide sufficient N to meet the requirements of most of the forage and grass species grown in Saskatchewan. The tested shrub species, may therefore, hold high promise to improve on-farm N management by providing N for sustaining forage crop production. This would minimize the reliance on synthetic fertilizers and thus reduces the risk of agrarian-derived soil and water pollution from excessive use of inorganic nutrient sources.

Keywords: alley cropping, agroforestry, forage crops, isotopic techniques, nutrient management, N_2 fixation

EFFECT OF A ROADSIDE SHELTERBELT ON SUSPENDED ROAD DUST PARTICLES

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ABSTRACT

Intuition suggests that a moderately dense shelterbelt, which is known to greatly reduce the wind speed in its wake, should likewise exert a filtering effect on whatever the wind may carry. Here we report field measurements of suspended road dust particles in the lee of a uniform, two-row (green ash and Scots pine) shelterbelt that ran parallel to the road and was centred 60 m eastward (downwind). We then compared the field results with numerical simulations. Taken together, the field and modeled results indicate that a shelterbelt of the type studied offers little if any benefit, in regard to the filtration of the fine (PM10) fraction of rural road dust. Although the reduction of wind speed by the shelterbelt delayed the arrival of dust clouds at the point of measurement, the duration of the dust cloud was greater behind the shelterbelt and the overall dust load suspended in the air was not diminished. We will discuss both the field results and the aerodynamic theory and calculations that resulted in these conclusions.

Keywords: windbreak, aerodynamics, particulates

THE INFLUENCE OF THE HEDGEROW AND ADJACENT CROP ON CARABID SPECIES DIVERSITY AND MOVEMENT IN AGRICULTURAL FIELDS IN PEI

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ABSTRACT

The influence of the hedgerow and adjacent crop type on the diversity and movement of Carabid beetle species over a three year crop rotation cycle, was studied at Harrington farms in PEI under the Green Cover Canada - Agroforestry project initiative. Five transects were established within three fields. Using the edge of the hedgerow as the starting point, each transect was divided into six 5 x 1m sections (1m into the hedgerow and 1, 3, 10, 30, and 60 m into the adjacent crop field). Two pitfall traps in each section were used to collect beetles every two weeks. Beetle diversity was monitored for three years in the same field; two years in the rotation crop and the third year in the main crop (potatoes). Rotation crops were either, barley, clover, or soybeans. A total of 46 Carabids species were identified. Results showed a higher diversity of species at the 1m distance in the field. The lowest diversity was found within the hedgerow into all three years and crops. The abundance of the nine most dominant species at each distance varied with the crop. As expected some species were more dominant early in the season while others at the end of the season. Certain species were lower in numbers in the potato crop when compared to the clover and barley crops. Two introduced species *Harpauls rufipes* and *Pterostichus melanarius* dominated the catch in all three years.

Keywords: carabid beetles, hedgerows, movement

TRANSPORTATION AGENCY TOOL TO ANALYZE BENEFITS OF LIVING SNOW FENCES

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ABSTRACT

A benefit and cost analysis tool was developed for the Minnesota Department of Transportation's (MnDOT) living snow fence (LSF) program. This transportation agency tool calculates global and site-specific economic, transportation and environmental benefits and the opportunity costs to landowners. This aids in prioritizing snow problem areas and developing landowner payment programs. Results from the application of the tool on Minnesota highway snow problem areas suggests, expansion of the program to other states with snow precipitation is justified. LSF are plantings of trees and/or shrubs set back from the right of way along the upwind roadside to minimize drifting and blowing snow problems on the roadway. This tool will also analyze the benefit and cost of leaving standing corn rows to protect roadways. Blowing and drifting snow are costly realities for transportation agencies in regions with significant snow precipitation. Blowing snow can require extra trips by standard plows, use of additional equipment and increased usage of sand and salt. From1995 to 2005 Minnesota found over 9,000 snow related accidents, 64 fatal and 131 incapacitating accidents. Snow fences can decrease travel time and reduce the severity and number of snow related accidents. LSF also provide environmental services such as wildlife conservation, hunting opportunities, and carbon storage and sequestration. Collaborating with USDA programs provides additional resources that can reduce the transportation agency's share of landowner payments. This lowers financial barriers to offer incentives to more sites and expand the program with substantial economic net benefits. This tool will be offered on-line in 2014.

Keywords: benefit cost tool, blowing, environment, fence, drifting, snow

WINDBREAK REMOVAL IN EASTERN NEBRASKA

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ABSTRACT

Higher prices for commodities (maize, soybean and wheat) have meant more tree removal in Eastern Nebraska. Casual window surveys each spring have shown new piles of woody vegetation pushed out to make room for an additional few acres of crop ground. During the summer of 2012 in an effort to document the removal, we undertook a more definite survey of windbreak removal for the period 2003 to 2010. Using digital imagery from the Nebraska Spatial GIS Database, we compared 12, one mile wide transects across the eastern third of Nebraska. Each section along each transect was observed manually and compared between the two study years. A total of 1,514 square miles (968,987 acres) were examined. The total number of field windbreaks dropped from 1,994 in 2003 to 1,852 in 2010, a loss of 142 windbreaks or a net loss of 7.12% of the windbreaks in the study area. The total length of the field windbreaks removed was 34.8 miles.

INTRODUCTION

Windbreaks, also known as shelterbelts, are defined as plantings of single or multiple rows of trees or shrubs established for environmental purposes (USDA-NRCS, 1997). Windbreaks in North America came into early prominence primarily as a filter/barrier tool to combat the Dust Bowl in the North American-Great Plains (Mize et al, 2008). Field windbreaks provide a wide variety of benefits in agriculture, ecology, society and economics. While benefits of field windbreaks have been documented for a long time (Brandle et al, 2009), less attention has been paid to changes in the distribution and abundance of windbreaks (Baltensperger, 1987). Casual observations have seen many instances of woody vegetation being removed to facilitate conversion to crop production. Recent increases in commodity prices are one possible reason for this conversion of non-crop acres to row-crop production. In the case of field windbreaks the question remains, how extensive is the removal? This study was initialed to investigate windbreak removal trends in eastern Nebraska.

MATERIAL AND METHODS

The Study Area

Based on the 1:24,000 scale quadrangle boundary data from the U.S. Geological Survey, a quadrangle was selected on the south state boundary as a benchmark (98°33'30.76"W 40°3'5.943"N). Additional quadrangles were selected south to north from this benchmark to the northern state border, skipping every two quadrangles. After reaching the last one, which is located at 98°34'19.946"W 42°55'43.191"N, 12 quadrangles were selected. In each of these 12 quadrangles, a 1-mile (1.61 kilometers) wide transect from the north quadrangle boundary to south was selected. These transects extend from longitudes between 98°32'15.954"W and 98°37'45.064"W on the west, and extend east to the state boundary. These areas were designated from Section A to Section L as shown in Figure 1, with a total of 262 quadrangles, and an area of 3921.4 square kilometers (968,987.6 acres).

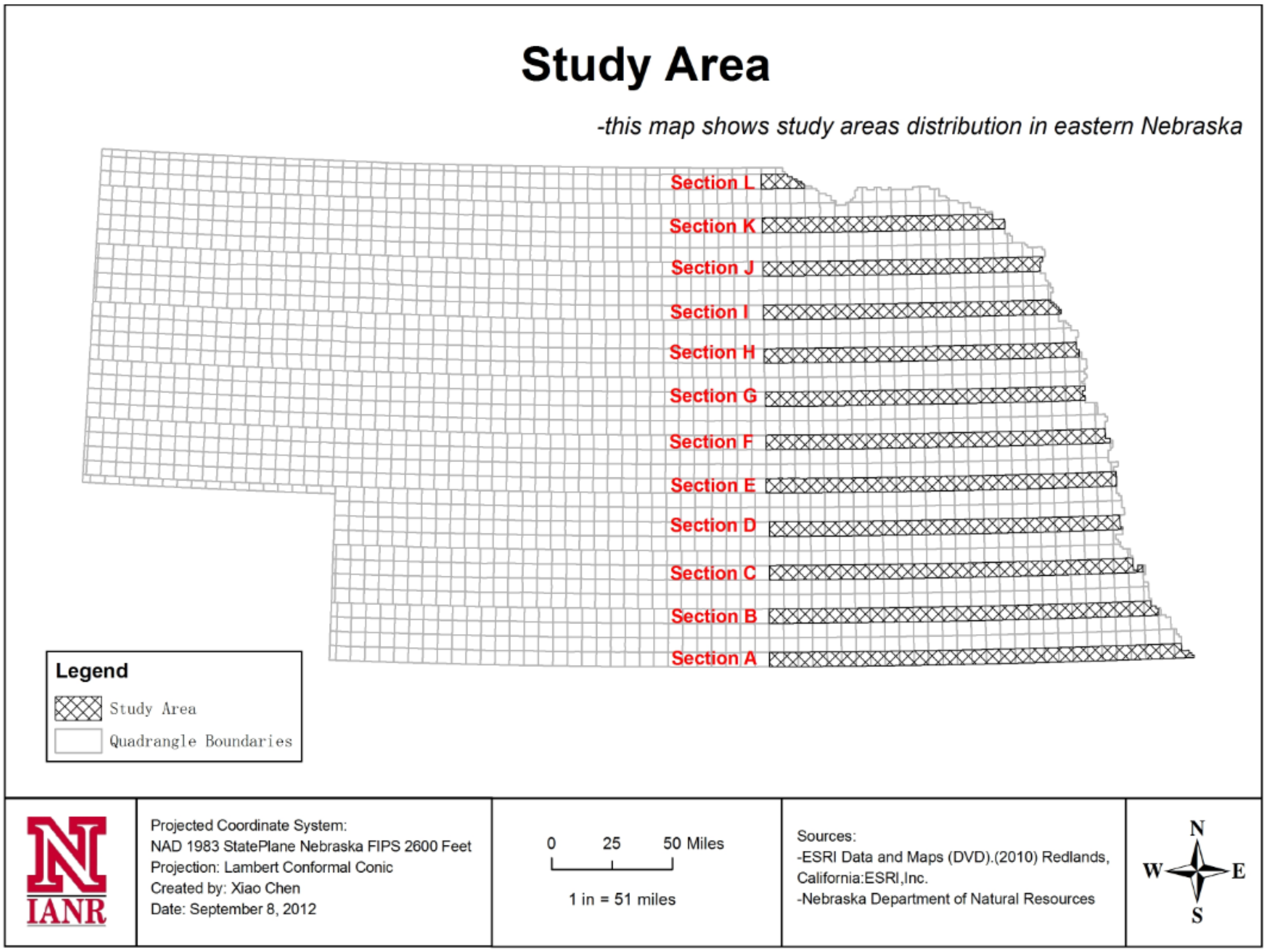

Figure 1. Windbreak removal study area in eastern Nebraska.

Data Processing

Using Geographical Information System (GIS) technology, a geodatabase was built to analyze changes in windbreak distributions in eastern Nebraska between 2003 and 2010. Digital 2003, 2010 imagery, and quadrangle vector data were all acquired from The Nebraska Department of Natural Resources Data Bank. The Nebraska Farm Service Agency (FSA) 2003 digital orthophoto was published by USDA FSA Aerial Photography Field Office (APFO) on 15 March 2004. The Nebraska FSA 2010 imagery was also published by APFO on 13 August 2010. Both 2003 and 2010 imagery are in 1 m ground sample distance (GSD) and are products of the National Agriculture Imagery Program, which acquires ortho imagery during the agricultural growing seasons in the continental U.S. The vector digital data by quadrangle were published by Nebraska Department of Natural Resources in January 1997. The quadrangle coverage was mathematically generated from latitude/longitude. It reflects the standard 7.5 minute USGS quadrangle.

Processing of 2003 images and 2010 images, and windbreak digitization, were completed in ArcMap 10.0 (ESRI, 2011). Data analysis was conducted in Microsoft Office Excel 2010.

There were thousands of separate images for each quadrangle in Nebraska that were combined into a single contiguous form. File geodatabase was utilized to accomplish this task. Under this geodatabase, a mosaic dataset was created and images were then loaded to merge into a single map. At last, this mosaic dataset was added to ArcMap as a layer for next step.

For 2010 images, each county has a separate file of satellite imagery with the same coordinate system in MrSID format, which is supported in ArcGIS. Therefore, images of counties in the study areas were added into ArcMap, and a group was created to manage their display.

After data preparation, windbreak digitization for 2003 image was necessary. The first step was to identify and extract windbreak features. The feature extraction step was conducted in ArcMap 10.0 manually using the Draw tool in Editor. Following extraction, data were converted to feature class and added to the 2010 imagery. Visual comparison of the 2003 and 2010 data sets allowed the determination of the change in the number and area of windbreaks removed during the period. Geometric calculation provided the length of each windbreak and, all data were imported to Excel spreadsheet for analysis.

RESULTS

Between the years 2003 and 2010 losses in both the number of windbreaks and the area of windbreaks were observed. From 2003 to 2010, the number of windbreaks dropped from 1,994 to 1,852 within the sampled transects, a loss of 142 windbreaks or a 7.1% net loss in the number of field windbreaks. The total length of windbreaks removed was 56.0 km (34.8 miles) or a loss of 7.8% of total windbreak length in the study area (see Figure 2). The sampled area represents approximately one-third of land area within the sampling region. If the sampled transects are representative of the entire area and if the removal rate is extrapolated to the entire sample region, windbreak loss would exceed 400 windbreak removals with a total length of over 150 km.

Windbreak removal rates were not uniform across the area ranging from a net gain in windbreaks in transect K in northeast Nebraska to over 20% loss for transect H in east central Nebraska (see Table 1).

Table 1. Rate of field windbreak loss (%) by transect in eastern Nebraska 2003 to 2010.

Transect	A	B	C	D	E	F	G	H	I	J	K	L
% loss	7.6	6.3	6.0	4.9	2.0	9.4	7.3	20.0	9.2	12.1	-2.4	0.0

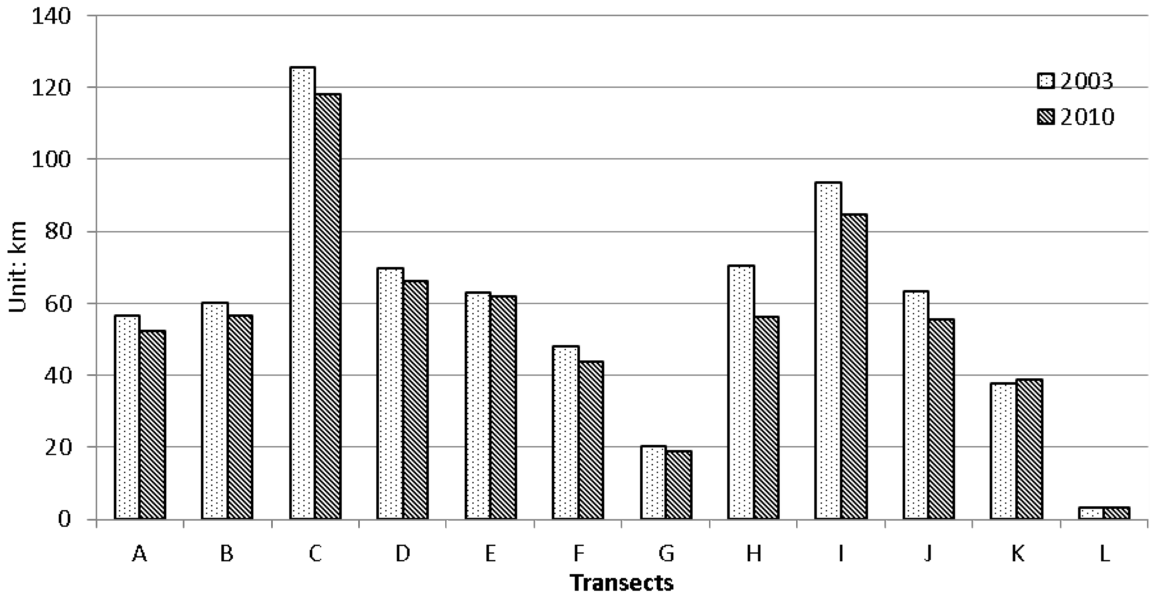

Figure 2. Kilometers of field windbreaks lost between 2003 and 2010 in eastern Nebraska by transect.

Field windbreaks are randomly distributed in the landscape. Using the 2010 inventory data, we calculated that for the sampled transects only 0.032 to 0.237% of the land area per square mile was devoted to field windbreak plantings (see Figure 3).

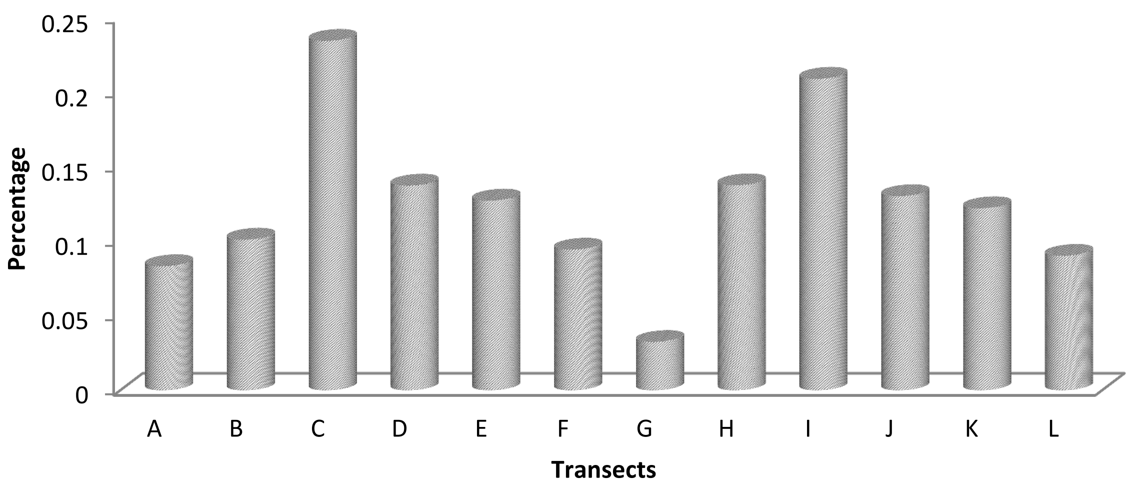

Figure 3. Windbreak density per square mile on sampled agricultural lands in eastern Nebraska, 2010.

Field windbreak protection typically extends for a distance of 10 to 15 times the height of the windbreak (H) to the leeward side and 2 to 5 H to the windward side. Most fields can be totally protected by planting 3 to 5% of the land to field windbreaks. At these densities, the investment in a field system is economically viable and increases the income flow to the producer (Helmers and Brandle 2005). Our analysis indicated that field windbreaks protect less than 1 percent of the cropland found in the study area. Given that adequate protection for a crop field requires that 3 to 5% of the land be planted to windbreaks the potential for additional field windbreak plantings in eastern Nebraska is high (Helmers and Brandle, 2005).

DISCUSSION AND CONCLUSIONS

Speculation as to the reasons for the increase in removal rates leads one to quickly assume that the huge run up in commodity prices (see Figure 4) over the last five years may have encouraged farmers to remove various types of tree plantings, including field windbreaks and riparian forest buffers.

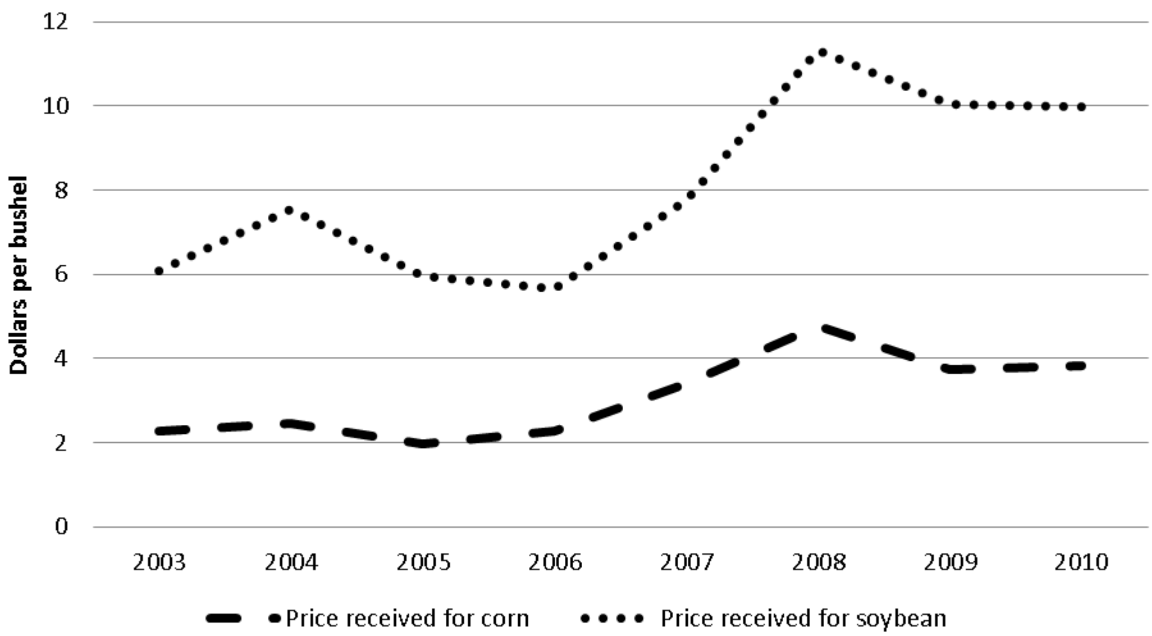

Figure 4. Commodity prices for corn and soybean for the period 2003 to 2010. (http://www.nass.usda.gov/Charts_and_Maps/Agricultural_Prices/pricecn.asp)

Note that prices for both corn and soybean continued to rise in 2011 and 2012 adding additional pressure to land conversion from windbreaks to cropland. Closing prices as of June 4, 2013 in Lincoln, Nebraska were $6.98 for corn and $14.87 for soybeans.

Perhaps of greater concern is the belief that improvements in agricultural practices such as minimum tillage and no tillage have reduced the need for windbreaks for wind erosion control. To the contrary, while these practices are a positive control measure they lose effectiveness in a prolong drought. The introduction of GMO crops resistant to drought has also been cited as a reason to remove windbreaks as the need for water conservation is no longer a critical need. At this point in time the authors are inclined to believe that removal is being driven primarily by commodity price.

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SOIL BIOCHEMICAL PROPERTIES AND MICROBIAL RESILIENCE IN TWO AGROFORESTRY SYSTEMS IN SOUTHERN QUEBEC: EFFECTS ON WHEAT GROWTH UNDER CONTROLLED DROUGHT AND FLOODING CONDITIONS

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ABSTRACT

Agroforestry is increasingly viewed as an effective means of maintaining or even increasing crop and tree productivity under climate change while promoting other ecosystem functions and services. This study focused on soil biochemical properties and resilience following disturbance within agroforestry and conventional agricultural systems and aimed to determine whether soil differences would subsequently affect crop productivity under extreme soil water conditions. Two research sites that had been established on agricultural land in southern Quebec were selected for this study. The Rivière-Ouelle site included an 18 years old windbreak, while the St-Paulin site consisted in an 8 years old tree-based intercropping system. In each site, soil samples were used for the determination of soil nutrient availability, microbial dynamics, microbial resilience to different wetting-drying perturbations and for a greenhouse pot experiment with wheat. Drying and flooding were selected as water stress treatments and compared to a control. These treatments were initiated at the beginning of the wheat anthesis period and maintained over 10 days. Trees contributed to increase soil nutrient pools, as evidenced by the higher extractable-P (both sites), and the higher total N and mineralizable N (St-Paulin) found in the agroforestry compared to the conventional agricultural system. Metabolic quotient (qCO^2) was lower in the agroforestry than in the agricultural system, suggesting higher microbial substrate use efficiency in agroforestry systems. Microbial resilience was higher in the agroforestry soils compared to soils from the conventional agricultural system (Rivière-Ouelle site only). At Rivière-Ouelle, wheat growing in soils from agroforestry systems exhibited higher aboveground biomass and number of grains per spike than in agricultural system soils in the three water stress treatments. At St-Paulin, higher wheat biomass, grain yield and number of grains per spike were observed in agroforestry than in agricultural system soils, but in the drought treatment only. Drought (Rivière-Ouelle) and flooding (both sites) treatments significantly reduced wheat yield and 1000-grain weight in both types of agroecosystem. Relationships between soil biochemical properties and soil microbial resilience or wheat productivity were strongly dependent on site. This study suggests that agroforestry systems may have a positive effect on soil biochemical properties and microbial resilience, which could operate positively on crop productivity and tolerance to severe water stress.

PROMOTING TREE-BASED INTERCROPPING SYSTEMS IN THE POLITICAL ARENA: A COGNITIVE ANALYSIS OF PUBLIC POLICIES IN AGRICULTURE, NATURAL RESOURCES AND RURAL DEVELOPMENT IN QUEBEC

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ABSTRACT

In Quebec, tree-based intercropping (TBI) systems are considered as potential contributors to climate change adaptation as well as ecological goods and services providers. TBI systems are consequently promoted by stakeholders as complex systems accurately addressing issues related to environmental deterioration, landscape degradation and rural devitalization. However, financing the implementation of these systems on farms remains a challenge. In fact, no clear policy on agroforestry or TBI systems has been developed and implemented yet in the province, complicating the work of both receptive farmers and experts. Thus, we could wonder how the arguments put forward by TBI systems promoters are or can be integrated at all in the mainstream ideas now driving three specific public policies (agriculture, natural resources and rural development).

Our research uses qualitative methods and a content analysis based on Muller's notion of referentials to understand how TBI systems can be integrated in the pre-existing referentials of actors in the agriculture, natural resources and rural development public policies. Based on the analysis of formal publications and semi-directed interviews, our preliminary results show that the referentials driving agriculture, natural resources and rural development policies are slowly shifting from strict economic development to multifunctionality and sustainable development. TBI systems may then have the opportunity to be integrated in these policies' referentials, especially when they are promoted as multifunctional and sustainable systems. Nonetheless, the integration of TBI systems is insufficient to produce large-scale policies given the present policies referentials, but may lead to small-scale initiatives support.

Keywords: tree-based intercropping systems, public policies, cognitive referentials.

INTRODUCTION

A promising system…

Tree-based intercropping systems (TBI) associate annual or perennial crops to widely spaced rows of trees (CRAAQ, 2011). In a context where agriculture faces simultaneously crucial environmental, economic and social issues, TBI systems may be an alternative to conventional land-use systems worth considering (Anel 2007; Tessier *et al.* 2009). Providing many ecological goods and services, these systems have proven to be particularly well-suited to help the agricultural sector face many challenges related to environmental, economic and social sustainability. On the one hand, their environmental benefits are numerous: they reduce soil erosion, limit water contamination by nitrates (Bergeron *et al*. 2011), improve soil quality (Chifflot *et al.* 2009, Rivest *et al.* 2010) and protect biodiversity and wildlife habitats (Desrochers *et al*. 2010). Moreover, these systems sequester carbon in the tree biomass (both below and above ground) and the soil (Bambrick *et al.* 2010) and may help create a site-scale microclimate regulating humidity and temperature, thus contributing to climate change mitigation and adaptation. On the other hand, these benefits may be obtained while a relatively high crop productivity is maintained and tree growth rate is enhanced, leading to good high-quality timber market opportunities (Rivest *et al.* 2009; 2010). The implementation of paiement mechanism for ecosystem services provision may also be an opportunity to assure the economic sustainability of TBI systems (EcoRessources 2009). Last but least, TBI systems can significantly contribute to create new dynamism in rural collectivities facing landscape degradation problems related to farmland abandonment or agricultural intensification (Anel 2007; Tessier *et al.* 2009; Domon 2011).

… awaiting public support

Although integrated in almost every agricultural context in the tropics, these agroforestry systems are quite rare in Quebec's agricultural landscape, as in most North American landscapes (Garrett, 2011). In Quebec, TBI systems are estimated to cover approximately only 150 hectares (Rivest, 2013, pers. comm.) of the 3,5 M hectares of cultivated land (Government of Quebec, 2013). Indeed, integrating so closely crops and trees in a productive system is nothing but something like a "UAO" (unidentified agricultural object) in the contemporary agricultural landscape. The concept of planting trees and crops in the same field contrasts with the broadly shared assumption among farmers and specialists that trees and crops grow better separately. Moreover, implementing such a practice in Quebec's agricultural context is clearly going against the historical, political and social driving forces that have led to a clear-cut separation between forested and cultivated land in Quebec's landscape (Paquette and Domon, 1993). It is then not surprising that TBI systems adoption rates stay very low in that specific context. In order to tackle this issue, many specialists have pointed out the importance of implementing coherent public policies to make TBI systems truly attractive to farmers (Marchand et Masse 2008, Place *et al.* 2012, Tartera *et al.* 2012). In fact, studies have shown that current policies, in Quebec as in many others developed countries, are still inadequate and maladapted to bring efficient support to these systems (Place *et al.* 2012, Tartera *et al.* 2012).

This situation calls for tremendous efforts to make TBI systems an alternative to conventional land-use systems, and to promote them in every policy sector having a chance to consider these systems as valuable, such as agricultural, natural resources and rural development policies. The success of such an undertaking will depend, as it has already been demonstrated in other fields, on the capacity of TBI systems promoters to understand the major trends and ideas influencing these policy sectors and to adapt their discursive resources to these trends (Fouilleux 2004, Schmidt and Radaelli 2004, Schmidt 2008). In that context, it may be useful, on the first hand, to answer this preliminary question: what policy sector, if any among agriculture, natural resources and rural development, is the most receptive to TBI systems, and therefore the best positioned to integrate these land-use systems in its policies?

This study shades light on the actors and ideas having an influence on the integration of TBI systems in public policies. Using a conceptual framework based on the "cognitive referentials" in public policies developed by Muller (2008), it aims at 1) identifying the cognitive referential in which TBI systems are situated 2) comparing this referential to the referentials currently driving policies in agriculture, natural resources and rural development and 3) analyse the relationships between these referentials and the TBI systems referential in order to determine the policy sector sharing the ideas closest to the ideas put forward by TBI systems promoters. We hypothesize that policy sectors using referentials close to the referential used to promote TBI systems are the best suited to foster TBI systems support. On the contrary, policy sectors using a referential highly contrasting with TBI systems' referential are unable to integrate these land-use systems in their policies.

METHODOLOGY

Public policy referentials as a conceptual framework

Our study uses a conceptual framework slightly derived from the public policy referential framework designed first by Jobert and Muller (1987). Muller defines the policy referential as a shared conception of the place and role of a specific policy sector in the society (Muller 2008: 60). This referential is nothing but a cognitive structure which dictates and justifies the scope and nature of its actions. The referential is made of various levels of perceptions: values, images, norms and algorithms (Muller, 2008). The policy referential may be decomposed in two interrelated parts: the global referential and the specific referential related to the policy sector. The global referential is composed of a hierarchized set of values and norms influencing the society. If conflicting values and norms may coexist in this global referential, some are indubitably, at one given time, more influent than others on policies. In the same way, the sectorial referential is composed of a plurality of hierarchized values, norms, images and algorithms defining the frontiers of the policy sector and justifying its place and roles in the global system of public policies. The sectorial values, norms, images and algorithms that appear to be the most coherent with the global referential will necessarily be the most influent in the sectorial referential.

Consequently, public policies may be seen as means taken by stakeholders to maintain coherence between pregnant values and norms at the global and the sectorial levels, and at the meantime to construct their own vision of the world. When new land-use practices such as TBI systems are presented by stakeholders (in Quebec, mostly scientists and professionals) as potential solutions to public problems, their integration in different policies depends, among many other factors, on their compatibility with the different sectorial referentials used by policymakers in agriculture, natural resources (recovering forestry) and rural development, these referentials all being modulated by the global referential. The core of this system is made by the relations between the sectorial (or policy) referentials and the TBI system referential. This system is schematized in figure 1.

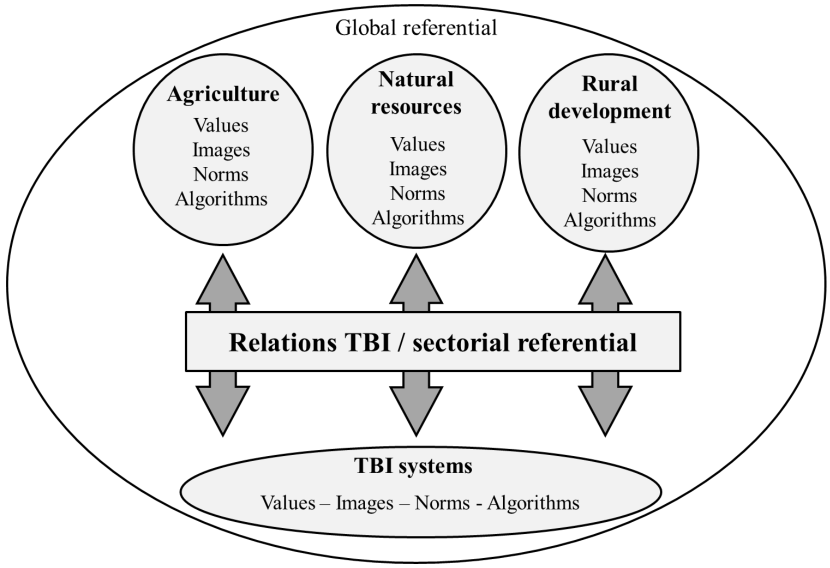

Figure 1. Schematic representation of the relations between referentials.

Data collection and analysis

For the purpose of this preliminary study, data was collected exclusively from written sources. A total of 22 information sources of different kinds (mostly brochures, memoirs presented in parliamentary commissions, web pages and online presentations) produced by scientists, professionals and policymakers to inform or present TBI systems. The documents were codified and analyzed following the content analysis method. QDA Minor (v. 4.0.13) software was used in order to reveal the main values, norms, algorithms and images composing the TBI systems' referential, in order to compare it to the sectorial referentials currently driving policies. Policies in agriculture, natural resources (including forestry) and rural development at the federal, provincial and municipal level were scrutinized and the elements (programs, special funds strategies, etc.) making the integration of TBI systems possible identified, in order to understand the ideas involved in TBI systems' policy integration.

RESULTS AND DISCUSSION

Description and comparison of the referentials

TBI systems' referential is depicted in table 1. TBI systems are promoted as integrated and multifunctional land-use systems in 84,7 % of the documents consulted. They are also presented as land-use systems integrating (or re-integrating) trees in agricultural systems for both productive and environmental purposes, as titles a publication: " hardwood intercropping systems: combining wood and agricultural production while delivering environmental services " (AAFC, 2010). This combination of characteristics creates the image of a complex system fulfilling the need for sustainability and productivity in both agriculture and forestry. TBI systems are also depicted as modern systems (table 1). In more than a third of the documents consulted, promoters underline that TBI systems are not only a reminiscence from the past, but that they have been developed and optimised in the present prevailing conditions, with a strong concern for productivity. TBI systems are therefore presented as systems not only suited for marginalized lands and extensive agricultural management, but also for productive lands.

Table 1: Images, values, norms and algorithms related to TBI systems' referential

Category	Description	% of documents consulted containing this item
Images	Multifunctional/Integrated	84,7
	New/modern	38,5
	Productive	38,5
	Sustainable agroecosystems	38,5
Values	Environment protection	84,7
	Productivity	66,3
	Rural vitality	46,2
Norms (we have to…)	… integrate trees in the agroecosystem	23,1
	… improve agricultural sustainability	15,2
	… intensify hardwood production	7,7
Algorithms (TBI =…)	Environmental goods and services	46,2
	… better crop productivity	30,8
	… social benefits	30,8
	… economic benefits	23,1

Despite the emphasis put on productivity and environmental advantages, promoters make efforts to describe TBI systems as multifunctional. This conclusion can be drawn by taking a look at the algorithms and norms evocated by TBI promoters. The environmental goods and services (EGS) provided by these systems compose the main algorithms, which are coherent with the norm "land-use systems have to improve agricultural sustainability". Social benefits provided by TBI systems are the second most frequent algorithms presented, equal to algorithms related to productivity (table 1). This clearly shows that it is desirable for TBI systems promoters to manage agricultural land for multiple purposes. It consequently explains why TBI systems are presented as multifunctional systems, even if data on social or economic benefits are not as numerous as environmental evidences. The values driving the necessity of promoting TBI systems are mainly environmental protection, productivity and rural vitality, confirming that TBI systems are situated in a referential of "multifunctional land-use systems". The choice to present TBI systems as multifunctional is coherent with the broader context of agroforestry promotion, which emphases on the multiple functions of the systems combining trees and crops for foresters, farmers and rural communities.

Sectorial and global referentials in agriculture, forestry and rural development

On the other hand, driven by economic profitability, scientific advancements, productivity needs, mechanisation and the expansion of a global market that would put local producers in competition with the rest of the world, policies in agriculture, forestry and rural development have supported the specialisation and the separation of land uses and economic activities, in order to lead to a better economic and social development (Morisset 2010; Coulombe *et al.* 2004). Therefore, modern and coherent agricultural and forestry practices excluded each other, and the images, norms and algorithms used in these sectors were coherent with this dichotomous evolution. Even in rural policies, the separation between agriculture and forestry was evident (Jean, 2003). This common sectorial referential of "land use specificity" was expressed differently in the three policy sectors, especially through their specific algorithms, but was driven by the same values, images and norms of productivity, intensification and profitability.

In recent years, sectorial crisis in agriculture, forestry and rural development, along with the emergence of concepts such as sustainable development, multifunctionality, ecosystem management and landscape planning, have slightly shaken this global referential separating agriculture and forestry, thus conducting to new sets of small policies and programs dedicated to experiment new ways to manage our resources and occupy our land (MAMROT 2012; MAPAQ 2012, MRN 2012). Despite the emergence of new concepts, the description of the referentials used in the policy sectors and the promotion of TBI systems indicates that multifunctionality is not the mainstream idea currently driving policies in agriculture and forestry. It leads to conclude that multifunctional land-use system can't be fully supported by the current policy frameworks in these sectors, and will probably stay marginally supported until multifunctionality becomes a real driving force in the global or a sectorial referential.

Multifunctionality: the key for TBI systems policy integration?

Although no policy directly supports agroforestry or TBI systems more specifically in Quebec, TBI systems find support in a few policies or strategies in agriculture, forestry and rural development. Rural policies and agricultural policies are currently the most supportive for TBI systems. Two major programs of the rurality policy offer opportunity and funding for TBI systems. All these programs have in common to promote rural vitality, diversification, land-use innovation and imply a collective approach. The agricultural policies integrate TBI systems in four programs, but only three offer direct funding for TBI systems implementation. Moreover, two of these programs are dedicated to specific regions, thus limiting the support. Nonetheless, the agricultural programs integrating TBI systems share common objectives: diversification, concerted agricultural development, landscape improvement and agricultural multifunctionality. The results demonstrate that for rural and agricultural policies, TBI systems are supported on the basis of their potential to combine the effects of many attributes in order to tackle complex land-use problems and provide a broad range of opportunities for rural and agricultural communities. The place given to multifunctionality in these two policy sectors explains the support given to TBI systems.

The situation is quite different for forestry policies. In fact, only one program of tree distribution gives a real support to TBI systems implementation under some conditions. The strategic plan for the hardwood forest and the recent new forest policy contain a few elements related to intensification and productivity that may lead to a better recognition and support for TBI systems. Interestingly, the main objectives of these policy elements are not related to multifunctionality, but to environment protection or wood production intensification. Public policies that do not consider TBI systems as multifunctional land-use systems are not the most supportive, but they can provide support to these systems on the basis of other characteristics.

CONCLUSION

TBI systems are presented in Quebec as multifunctional land-use systems with a good productivity potential and efficiently providing environmental services. From the partial analysis made of the policy context modulating TBI systems recognition and support, evidence arises that TBI systems are best supported through policies tackling land-use issues using multifunctionality as a key concept such as rural and agricultural policies. The analysis also shows that in absence of this multifunctionality concept in a sectorial policy, TBI systems are not adequately supported, but other characteristics may be used as support drivers. Although partial, these results lead to conclude that integrated land-use systems such as TBI systems may receive a marginal support in the current policies referentials, but can't expect large-scale support given the global cognitive referential still clearly separating trees and crops both in minds and landscapes.

AKNOWLEDGEMENTS

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DETERMINATION OF THE EXTENT AREA OF INTERACTIONS BETWEEN THE OLIVE TREES AND CEREALS IN AN ALLEY CROPPING SYSTEM IN MOROCCO

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ABSTRACT

In an Agroforestry system, interactions between annual crops and perennial ones are complex. In the objective of elucidating the resultant of those interactions on the performances of the system olive tree - cereal crops, barley (*Hordeum vulgare*), durum wheat (*Triticum turgidum*) and soft wheat (*Triticum aestivum*) were cultivated between the rows of olive trees (*Olea europaea*) (10 x 10 m) under rainfed conditions. Cereals were sown according to two orientations: North - South and East –West.

At maturity, assessment of cereals productions (yields and their components) was realized at various distances from olive tree rows. Under the weather conditions of the year (rainfall: 300 mm), the experiment showed that the height of plants (H) of various cereals is the parameter which illustrates the best representation models of its evolution in relation with distance (D) from olive tree row. The cereals with sowing realized according to the orientation East – West were the most successful. The models developed under this orientation were, respectively for barley and durum wheat $H = -5.33D^2 + 56.36D - 110.89$ ($R^2 = 0.74$) and $H = -2.89D^2 + 29.70D - 40.738$ ($R^2 = 0.75$). For cereals sown according to the orientation North – South, the models developed respectively for barley, durum wheat and soft wheat are:
$H = -1.39D^2 + 16.99D - 22.245$ ($R^2 = 0.75$), $H = -2.33D^2 + 27.44D - 56.13$ ($R^2 = 0.73$) and
$H = -2.22D^2 + 25.63D - 47.15$ ($R^2 = 0.76$).

Keywords**:** alley cropping, *Olea europaea, Hordeum vulgare, Triticum turgidum, Triticum aestivum,*. Morocco.

INTRODUCTION

In Morocco, agroforestry exists in oasis and also in mountainous regions where in both situations agricultural lands and water resources are scarce. In order to face climatic change, Moroccan government plans the conversion of 1 million ha of cereals to olive tree. In fact, in a previous study, Daoui *et al*. (2012) showed that 75% of farmers growing olive trees are also producing annual crops between tree rows. Those crops included cereals, legumes, and vegetables. Cereals are dominant in 50% of land occupation. Farmers indicated that technical interventions (ploughing, fertilizing) concerns mainly annual crops and then can promote olive tree production (Daoui *et al*. 2011).

The objective of this study is the optimization of the production of an alley cropping system basis on olive tree and cereals, this by:

- Determination of extent area of interaction between olive tree and cereals in order to make the association (olive tree and cereals) more profitable.
- Evaluation of productivity of different cereals in an alley cropping system with olive tree.

MATERIALS AND METHODS

A field trial was implemented on 2011-2012 in the Experimental Station of Douyet (National Institute for Agricultural Research INRA, Morocco). Tree cereals (barley (*Hordeum vulgare),* durum wheat (*Triticum durum) and* soft wheat (Triticum aestivum) were sown on row separately between olive trees (*Olea europaea*) planted at the density of 10 * 10 m². Cereal sowing rows were oriented East – West and North South.

At maturity of each cereals, from one tree in front of another, one sample of 1 m long has been collected every third row of sowing according to orientations: For rows oriented East – West, we took 6 samples, of 1 m long on the same row of sowing, in front of olive tree (tree 1 up to the tree 6). Then the average of these 6 samples was calculated and it represents the average of the parameter studied for this row of sowing, and the calculations were done following the same pattern for all the rows going from 1 to 7 where row 1 is located under the sunny side and the row 7 under the shaded side. For rows oriented North – South, we took 4 samples of 1 m long on the same row of sowing in front of olive tree (tree 1 to tree 4). Then the average of these 4 samples was calculated and represents the average of the parameter studied for this row of sowing. Same calculation basis was used for all rows (1 to 7), where row 1 is located under the sunny side and row 7 under the shaded side.

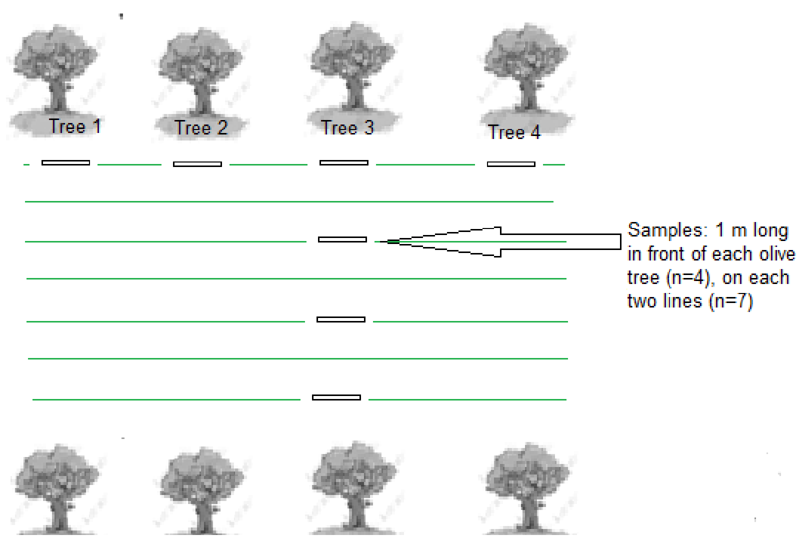

Figure 1. Sampling method

Statistical analysis (ANOVA 1) was performed to evaluate the effect of distance from olive tree on studied parameters. Models of correlation have been proposed according to their significant R^2. Sowing orientations East – West or Norh - South were compared using *S*tudent's t-test.

RESULTS

Climatic condition of the year

The total rainfall recorded during the experiment was 300 mm, while 50% of it was received from October and November. After that, a severe drought was recorded from December to March where only 50 mm of rainfall was received (figure 2).

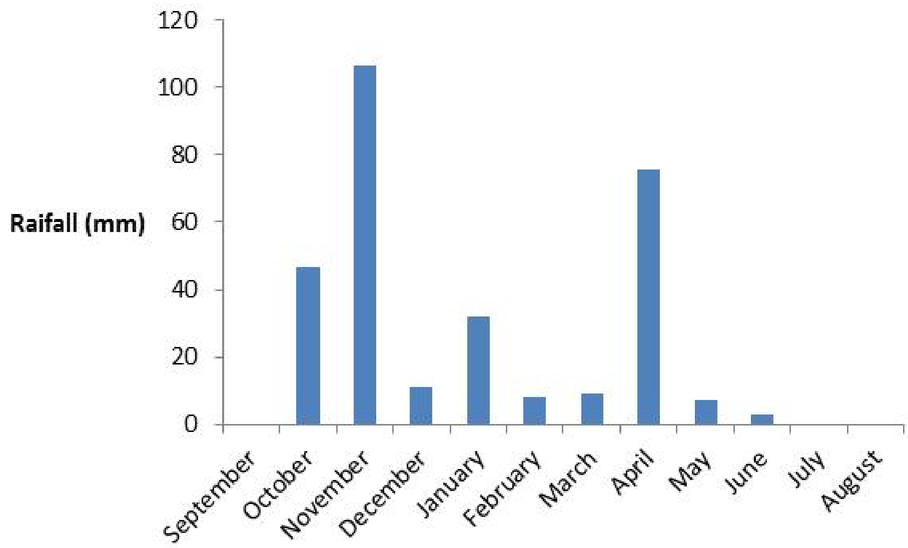

Figure 2. Monthly rainfall (Experimental Station of Douyet, 2011–2012)

All studied parameters present the same tendency than plant height (H) which is discussed in more details in this paper.

Evolution of the height of various cereals by referring to various distances from olive tree and to the orientations of the sowing rows.

Barley

For the NORTH-SOUTH directed rows of sowing, we note that there is a significant effect of the distance between the olive tree and the row of sowing of barley on the variable height of plants. The maximal height about 24 cm is observed at row 4, the minimum of 15 cm is observed for row 2. The evolution plan height of barley, in relation with the distance from olive tree follows a polynomial curve ($y=-1.39x^2 + 16.99x - 22.245$ ($R^2 = 0.75$)).

For rows of sowing directed EAST-WEST, we note that there is a significant effect of the distance between the olive tree and row of sowing of the barley on the variable height of plants. The maximal height about 45 cm is observed at row 7, while for row 1, plants died. The evolution of plant height of barley, in relation with the distance from olive tree, follows a polynomial curve ($y=-5.33x^2 + 56.36x - 110.89$ ($R^2 = 0.74$)).

Durum wheat

For the row of sowing oriented NORTH-SOUTH, plan height of durum wheat was significantly affected by the distance from olive tree. The maximal plan height was about 23 cm observed at row 5 while, the minimum was about 20 cm observed for row 2. The evolution of plant height of durum wheat, in relation with the distance from olive tree follows a polynomial curve (y: =-2.33x ² + 27.77x – 56.13 (R ² = 0.73)).

For the rows of sowing directed EAST-WEST, we note that there is a significant effect of the distance between the olive tree and the row of sowing of the durum wheat on plant height. The maximal height was about 40 cm observed at row 6, the minimum about 20 cm is observed for row 1. The evolution plant height of durum wheat, in relation with the distance from olive tree follows a polynomial curve ($y=-2.89x^2 + 29.70x - 40.738$ ($R^2 = 0.75$)).

Soft wheat

For the NORTH-SOUTH directed rows of sowing, we note that there is a significant effect of the distance from olive tree on plant height of soft wheat. The maximal height was about 30 cm observed at row 7, while the minimum about 15 cm is observed for row 4. The evolution of plant height of soft wheat in relation with the distance from olive tree follows a polynomial curve ($y =-2.22x^2 + 25.63x - 47.15$ ($R^2 = 0.76$)).

For the rows of sowing oriented EAST-WEST, we note that there is a significant effect of the distance from the olive tree on plant height (H) of soft wheat. The maximal height was about 33 cm observed at row 3, while the minimum was about 20 cm observed for rows 5 and 4.

DISCUSSION

As arable land has become scare and length of forest fallow periods has declined, simultaneous associations of trees and annual crops have been investigated as alternatives to shifting cultivation systems (Liebman and Staver 2004). Scientists demonstrate that agroforestry may have many advantages: diversification of ecosystems, C sequestration, and efficient use of inputs. In Moroccan conditions, Chebli *et al.* (2012) and Chryaa and El Mzouri (2004) demonstrate benefits from introducing fodder shrubs in low rainfall area of Morocco, alley cropping (*Atriplex nummularia* and *Hordeum vulgar*e) permit an increase in yield per unit area, diversification of species; a decrease of feeding cost in addition to the increase of economic efficiency of land with low potential; an improvement of animal performance and a rehabilitation marginal land, and fauna and flora (Chryaa and El Mzouri, 2004). The association of olive tree and cereal that dominate in olive tree cultivation by small farmers, should be monitored for a better use of available resources (water, light and nutrient), and also taking advantages from associated crops.

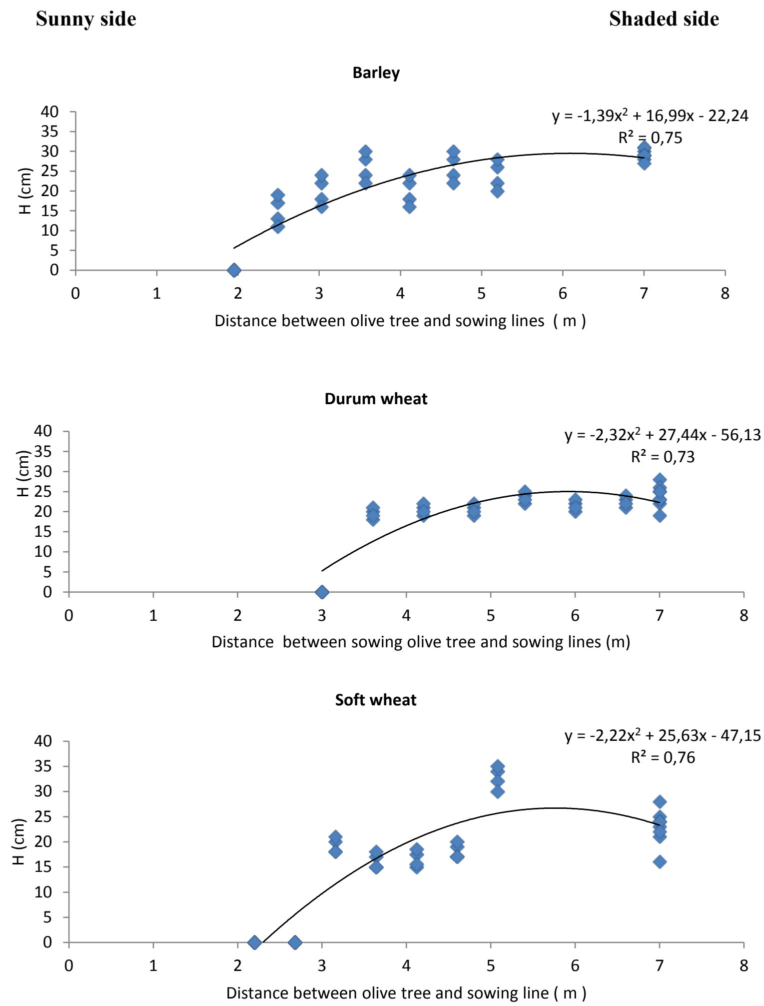

Figure 3. Models of cereals plant height evolution at different distance from olive tree (sowing rows oriented North – South)

So under shaded part, cereal are less affected than the sunny part, probably due to less loss of soil water by evaporation, this indicate that:

1. When water is not limited, alley crop even if under olive trunk, may not suffer from water availability,
2. For olive tree, irrigation could be monitored according to soil water content according to side subjected to more sun light.
3. Soil water under the sunny side could be protected against evaporation by mulching for example.
4. Under rainfed conditions, with limited rainfall, and for a better productivity of the hole system (olive tree and cereals), it should be more profitable to cultivated cereal a part from the olive foliage. Otherwise, both crops may suffer from competition.
5. Sowing rows oriented North South performs more better than sowing rows oriented East - West

CONCLUSIONS

In arid and semi-arid conditions, alley cropping may be a good choice to face climatic change. In fact choosing a better combination of tree and annual crops is necessary. Annual crops should be implemented at least at the limit of tree foliage; otherwise both crops in the association will suffer from competition for water and light.

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Non-Timber Forest Products

UPDATE ON HAZELNUT DEVELOPMENT PROGRAM IN THE LAKE STATES

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ABSTRACT

Hazelnut (*Corylus* spp.) is a potential nut crop for the Lake States. In the past, researchers and hobbyists have hybridized American and European hazelnut in an effort to develop a cold hardy, disease resistant hybrid hazelnut. There are relatively few varieties available and most plantings are currently seed origin. For pure American hazelnut, there are nearly no available varieties (at this point we know of two). Our goals are to: select high productivity wild hazelnuts, successfully pilot one or more propagation protocols and field test the selected genotypes. A group representing a diversity of disciplines and Upper Midwest States has been selecting American hazelnut from wild populations in Northern Wisconsin for use as parents in controlled crosses as well as potential clonal planting stock. To date, we have screened 35 sites across 10 WI Counties and have selected more than 30 individuals that meet 1% selection criteria on kernel yield per square foot. We are currently micropropagating these individuals for evaluation in replicated germplasm trials. We have also successfully tested mound layering protocols. This is an intermediate general report and specific results will be reported as they become available.

Keywords: filbert, breeding, yield component analysis, microsatellites, SSR

INTRODUCTION

Because American hazelnut, *Corylus americana,* is a perennial plant, its cultivation would be expected to result in fewer environmental impacts than annual crops. American hazelnut has had an important cultural history of food use by North American tribes, but has not been commercialized as a domesticated crop. European hazelnut, *Corylus avellana,* by comparison, is an internationally traded commodity crop. Turkey alone exports an annual crop valued at $1.4 billion dollars (Hazelnut and Products Exporters' Association 2010). Production in North America is predominantly in the Pacific Northwest and is only a few percent of world production (USDA FAS 2004). Commercialization of European hazelnuts in the Upper Midwest is restricted by a combination of cold hardiness issues and lack of Eastern Filbert Blight (EFB) tolerance. By contrast, American hazelnut co-evolved with EFB and has higher tolerance for the disease.

Both hobbists and researchers have been interspecifically hybridizing American and European hazelnut. While the goals of these breeders have varied, the inclusion of American hazelnut genetics has been driven by its native tolerance to EFB and its cold hardiness (Weschcke, 1954; Rutter, 1991). As far as we know, only two pure American hazelnuts varieties are commercially available for cultivation. Very few other American hazelnut genotypes are represented in the interspecific hybrid varieties. While interspecific hybrid seedlings are available from several companies, clonal varieties are lacking. Selections from wild American hazelnut populations could provide additional sources of genetics to use both as varieties and as parents in crosses.

Our overall project goals at this point were to:

1. Select wild American hazelnuts
2. Develop propagation tools
3. Assess nut quality parameters (oil, size, flavor, etc.)
4. Provide outreach to growers

METHODS AND RESULTS

Because many of these projects were still on-going at the time of submission of this paper and because the individual studies will be published through peer-reviewed venues, this paper was intended to provide an overview of the project with intermediate results as of early 2013.

Meeting Goal 1: Select wild American hazelnuts

At each site, 100 plants were screened using a visual assessment tool. After collection, drying and cracking all nut clusters, the highest productivity plants were selected. To date, 35 sites were screened across 10 WI Counties and more than 30 individuals were selected that meet 1% selection criteria on kernel yield. Initial results of this project can be found at the website: http://midwesthazelnuts.org/assets/files/Research%20Bulletin%2016_American%20hazelnut%20yields.pdf. Screening using genetics tools (microsatellites) and morphological characteristics were still in process to better target selection efforts.

Meeting Goal 2: Develop propagation tools

Micropropagation presents a potential tool to rapidly expand high-productivity genotypes. At this point, success has varied between genotype. Due to differences in ease of propagation between genotypes, ability to propagate was added as a selection criterion. Additionally, early tests of mound layering has been successful (described at http://midwesthazelnuts.org/assets/files/Research%20Bulletin%2015_stool%20bed%20layering%20American%20hazelnut.pdf); however, new efforts were focused on preparing stock plants for a pilot scale test where the plants would resemble commercially managed beds.

Meeting Goal 3: Assess nut quality parameters (oil, size, flavor, etc.)

In an effort to assess the potential of hazelnut as an oilseed, Lane et al. (2012) found the nut oils to be predominantly oleic acid (a monounsaturated fatty acid). Overall, nut kernels from wild American hazelnut were found to be approximately half the size of the nut kernels from seedling interspecific hybrid hazelnuts and much smaller than Oregon nuts sold in-shell. Flavor assessment was planned for 2014.

Meeting Goal 4: Provide outreach to growers

Through collaboration between Minnesota, Iowa and Wisconsin, an Annual Midwest Hazelnut Growers Conference was held four times. Several extension publications have resulted from this effort (reports available at http://midwesthazelnuts.org/research.html). Multiple field tours have also been offered.

DISCUSSION

With increased interest in North American for hazelnut products, the potential for increased demand for hazelnut seems high. For example, Ferrero recently opened a hazelnut processing plant in Ontario to serve the North American market. Whether American hazelnut could meet a portion of this demand is still an open question. American hazelnut is at a much earlier stage of domestication than the European hazelnut (50 years of formal breeding efforts have been invested into European hazelnut, Mehlenbacher 1991). While much of the knowledge gained from European hazelnut research efforts can be applied to American hazelnut selection, potentially speeding the plant development process, the plant itself has been subject to a very different anthropogenic dispersal patterns when compared to European hazelnut. Historic transportation of propagules in Europe produced wide dispersal of genetics (T. Molnar, personal communication, March 2, 2013), resulting in centuries of human selection for "desirable traits" that can be capitalized on in current breeding efforts. Indeed, until recently, the backbone of the hazelnut industry in North America was the result of the selection of chance seedlings (Mehlenbacher 1991). Whether anthropogenic selection occurred with American hazelnut in North American pre-history is unknown; however, if selection did occur, the resulting genotypes are not currently available. For these reasons, American hazelnut selections will likely not be available until the end of the decade at the earliest.

Propagation does not appear to be a barrier for the species as a whole. While micropropagation has been successful and predictable with one of our initial selections, one other selection has been unsuccessful under the same protocol. At this stage, the technique is still in development. Mound layering has worked in initial tests with both wild plants and interspecific hybrids in production fields. Pilot scale tests on managed beds are planned for 2014. A combination of micropropagation and mound layering would be expected to be able to provide clonal plant materials for use in commercial plantings.

Increasing grower interest in the Lake States may help push this from a cottage industry to a more significant commercial enterprise. Outreach to these potential and current growers is essential to aid in the development of this industry. At this point, one of the main constraints is availability of genetics. Commercial breeders have been supplying seedling hybrids, but have yet to delivery commercial clonal varieties. While there appears to be commercial potential for these seedlings under some conditions (Fischbach and Braun 2012), further genetic improvement would likely be required to improve the financial viability of the operations. With woody crops, this is often a slow process.

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FOREST FARMING OF SHIITAKE MUSHROOMS: BUILDING A NETWORK AND MARKETS IN THE NORTHEAST US

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ABSTRACT

Over the last decade, research and development and Cornell University has paved the way for temperate forest farming of shiitake mushrooms by answering critical questions about its cultivation, such as the appropriate tree species, inoculation strategy, and processes for harvesting and marketing fresh mushrooms.

Shiitake mushrooms are a perfect agroforestry crop. They require low capital input (about $5 per log) for a high commercial output ($50 per log over 4 years). The wood needed for cultivation is easily found in woodlots and can be conducted as a Timber Stand improvement practice. Markets are willing to pay $12-$20 / lb for fresh and dried shiitake.

in 2010, Cornell University and University of Vermont were awarded a grant from Northeast Sustainable Agriculture Research and Education (NE-SARE) to promote shiitake mushroom cultivation and build a network of growers in the Northeastern United States. This effort has educated hundreds of potential growers as well as engaging 27 farms in direct shiitake cultivation and on-farm data collection, which provides valuable "real world" data for growers considering entering mushroom farming.

Researchers, extension agents, and farmers continue to discuss and share information and resources through a facilitated network, the Northeast Forest Mushrooms Growers Network. This organization, run through Cornell extension, offers a grower listserv, online directory, videos, factsheets, and growing guides.

The success of this project has not only been in determining a viable production strategy for log-grown shiitake mushroom, but also in developing a community of growers and tools to help with marketing this specialty crop.

Keywords: mushrooms, forest farming, shiitake

BLACK WALNUT SYRUP PRODUCTION AS AN AGROFORESTRY CROP

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ABSTRACT

There has been a surge of interest in producing syrup from black walnut trees in recent years. Previous research has found that black walnuts produce far less sap than maples, though the sugar concentration of the sap is approximately the same. The flavor of black walnut syrup is very similar to maple syrup and consumers often prefer the taste of black walnut syrup. This presentation will outline the tapping potential for black walnuts in the U.S. and discuss the costs and benefits of using these trees for syrup production. It will highlight the opportunities for incorporating black walnut tapping in an agroforestry setting, either with standard tapping of trunks or pruning cuts of small branches.

LESSONS FROM THE MANAGEMENT AND MEMBERSHIP OF A VIRTUAL FOREST FARMING NETWORK

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ABSTRACT

Landowners are often most interested in forest farming when presented with agroforestry options. Forest farming is the purposive cultivation of non-timber forest products (NTFPs). Instead of collecting NTFPs in the wild, forest farmers establish and sustainably manage them. The practice can improve NTFP consistency and quality for dependent supply-chains. Producers are now able to efficiently reach buyers through online markets and personal direct marketing websites. Forest farming is receiving increased attention as a viable management practice that can add value to forest stewardship.

Forest farming expertise across North America is substantial. Researchers, educators, managers, producers, and organizations have compiled a wealth of knowledge and insight. To strengthen connection between these groups, a virtual forest farming community was established on eXtension (www.extension.org). eXtension is the online information delivery system developed by the United States Department of Agriculture, United States Land Grant Extension System, and other key stakeholders. The initiative is intended to complement the growing forest farming web presence.

The goal of the community is to aggregate forest farming information and initiatives across the United States. Based on membership diversity, and community-related initiatives from year one, we will present an overview of expertise and focus, highlight potential areas for growth, and describe the evolving role of the eXtension network in advancing forest farming and stakeholder collaboration. A second-year strategy in response to findings from year one will be presented and be used to identify next steps in forest farming community development.

EFFECT OF CULTURAL PRACTICES ON LOG CULTIVATION OF SHIITAKE MUSHROOMS

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ABSTRACT

Cultivation of shiitake mushrooms are a gateway to learning about the broader range of non-timber forest products used in Forest Farming. They are a reliable, economically viable crop, and many resources are available to inform the beginner. None the less, much of the information about cultural practices is based on conventional wisdom and does not necessarily take into account regional variation. This research was intended to address some of the uncertainties that pertain to seasonal considerations, laying yard management, and substrate tree species in the Northeastern U.S. Bolts of several tree species were inoculated with shiitake strain WR46, and mushroom yield was evaluated over a four year period with respect to the effects of tree species, season of logging/inoculation, as well as irrigation, and stacking configuration in the laying yard. Yield was significantly affected by tree species and season of logging/inoculation but not by irrigation or stacking configuration. Results will also be presented regarding our research on forest cultivation of lion's mane mushrooms.

Keywords: forest farming, mushroom cultivation

PRODUCTION SYSTEM AND SPECIES SELECTION AFFECTS THE CONCENTRATIONS OF PHENOLICS AND FLAVONOIDS IN LION'S MANE MUSHROOM (HERICIUM SP.)

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ABSTRACT

The mushroom, *Hericium sp*., has received attention for its functional properties. Some of those properties may be related to phenolic and flavonoid compounds, which are believed to promote positive health outcomes. The objective of this study was to determine the effect of production system and species selection on the phenolic and flavonoid content of Lion's Mane mushroom. Mushroom species grown indoors on a fortified sawdust substrate include *H. erinaceus* strain FFP3, *H. americanum* strain He3*,* and *H. americanum* strain He5. Both FFP3 and He5 were also grown in a forest farming system, outdoors, on an American beech log substrate. Concentrations of phenolic compounds were determined using a Folin-Ciocalteu based assay. Flavonoid concentrations were determined through a sodium borohydride/chloronil based assay. Units are expressed, based on the standard, in gallic acid equivalents (GAE) for phenols and catechin equivalents (CE) for flavonoids. All measurements are adjusted for moisture content and based on 100 g samples. FFP3 and He5 harvested in the fall of 2011 contained the greatest concentrations of both phenolics and flavonoids, roughly two times the concentration of FFP3 harvested in the spring of 2011from the same forest farming site. All samples from the Forest Farming sites contained roughly ten-fold the concentrations of phenolics and flavonoids when compared to the same strains grown in a climate controlled site. This evidence suggests that when species of *Hericium* are grown in a Forest Farming site, they may contain greater concentrations of potentially health promoting compounds, than those grown in a climate controlled facility.

Keywords: non-timber forest product, lion's mane mushroom, functional foods, forest farming

FOREST FARMING IN A COMMERCIAL SUGARBUSH IN NORTHWEST NEW BRUNSWICK

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ABSTRACT

Culture of three plants and three fungi was performed under natural cover of *Acer saccharum* from May 2006 to March 2009 in order (1) to diversify sources of income of a commercial sugarbush in Northwest New Brunswick, and (2) to increase the worker retention over a longer period of time. For plants, the specific objectives were (1) to develop techniques for cultivating and propagating *Medeola virginiana*, an edible native plant naturally found in maple stand of Northwest New Brunswick, (2) to identify commercial varieties of *Corylus sp.* that can grow under natural cover of *Acer saccharum*, and (3) to demonstrate cultivation techniques of *Panax quinquefolium* from seeds and seedlings. For fungi, the specific objective was to test mushroom productivity of *Pleurotus ostreatus*, *Lentinula edodes* and *Hericium sp.* inoculated on logs of five species naturally available in maple stand (*Acer saccharum, Betula alleghaniensis, Betula papyrifera*, *Fagus grandifolia* and *Populus tremuloides*). Promotion of forest farming was done via guided tours, showcases, annual meetings, factsheets and conferences with maple syrup associations of Québec and New Brunswick, stakeholders and producers of maple syrup, woodlot owners, teachers and general public. We observed during and after the project that the well-known cultures have generated the most interest. Further investigation is needed to address market access, crop marketing and commercialisation as these are the biggest challenges for adopting this type of agroforestry system.

Keywords: forest farming, edible plants, edible mushrooms

PRACTICES FOR TRACEABILITY, QUALITY, SAFETY AND SUSTAINABILITY FOR AGROFORESTRY AND NON TIMBER FOREST PRODUCTS

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ABSTRACT

The Canadian Herb, Spice and Natural Health Products Coalition (CHSNC or Coalition) is a group of leaders in the herb, spice, botanicals/biomass, wild sourced products and natural health product industry across Canada. The coalition represents the full industry chain from field to shelf, from production, processing and manufacturing, research and regulations through to practitioners, retailers and consumers. The coalition was formed to work together nationally to address national industry issues, including product safety, quality, traceability and sustainability.

Canadian Herb, Spice and Natural Health products coalition is the national lead for non-timber products in Canada. often this area is covered at least in party by agroforestry. With over 4000 botanicals being viable in Canada for commercial use it is essential that both producers/collectors, those processing and those purchasing material, have clear guidelines to ensure that the products are identified correctly, that quality is consistent, that the products are safe and that they are within a traceable system.

Canada, under the Canadian Herb, Spice and Natural Health production coalition, has developed a program to do that. The GACP toolbox gives all participants in the value chain the ability to address risk, ensure good practices are in place and ensure the ability to do an effective recall.

This is an industry lead and owned program that has been validated by the Canadian Food Inspection Agency.

Its strengths are that it fits industry from the smallest to the largest, from field to shelf, from forest or field origins, in an effective useable manner. Over 700 people have been trained on the program in Canada.

Whether you are trying to ensure commercial viability to correct identification to effective cultivation practices to consistent genetics to biodiversity and environmental stability, GACPs are the tools that work.

The GACPs have been benchmarked again the EU GACPs and will be built with support from Health Canada, Ag Canada and the World Health Organization.

POSTERS

YIELD RESPONSE OF COOL-SEASON FORAGES IN LOBLOLLY PINE (PINUS TAEDA L.) SILVOPASTORAL SYSTEMS IN SOUTH EASTERN UNITED STATES

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ABSTRACT

Light is one of the key climatic factors that drive production in agroforestry systems. Understanding resource capture in silvopastoral systems can facilitate appropriate species combinations and management. A mid-rotation pine plantation was thinned into two silvopastoral configurations in North Florida at latitude 30.5°N, longitude 84.6°W, with an elevation of 60 m. The main plot were three tree configurations – paired sets of tree rows 3.1 x 4.6 m and 15.2 m wide alleys between rows (DR), heavy conventional 4th row and selection thinning with scattered tree canopies (HT) and an open pasture, control (OP) with forage combinations sown in each. The sub-plot included three cool-season forage combinations – "Jumbo" ryegrass (*Lolium multiflorium* Lam.) (G); ryegrass+"Dixie' crimson clover (*Trifolium incarnatum* L.) (GC); and GC+"Cherokee" red clovers (*Trifolium pretense* L.) (GCR). Photosynthetic active radiation (PAR), leaf area index (LAI), and dry matter (DM) yield of forages were measured. Tree configurations impacted DM production of forages and the influenced was forage available PAR. Forages in OP produced 20% and 34% higher DM than those in DR and HT, respectively and those in DR produced 18% higher DM than the HT. There was a significant linear relationship between DM and cumulative intercepted PAR. Forages in the silvopastoral treatments differed in yield and LAI, but had similar radiation use efficiency (RUE), and higher RUE compared those of the OP. Forage combinations showed a potential to increase DM yield. The GCR had higher LAI than G, but all combinations had similar RUE and DM yield were generally similar.

Keywords: silvopastoral systems, leaf area index, photosynthetic active radiation, cool-season forages

EMERGING TECHNOLOGY- STOOLING BEDS PROJECT FOR BIOMASS REFORESTATION FOR BOREAL FOREST

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ABSTRACT

The demand for wood biomass for energy is growing rapidly in rural Alaska with the advent of high fuel costs. Woody biomass is a carbon neutral and sustainable resource under the right conditions and can replace oil and diesel used for residential and community buildings. Although some locations can be supported by mill wastes, imported pellets, or driftwood, many locations will rely on local forest harvesting to support biomass facilities. Forest regeneration is an important element of sustainable forest management. Poplar, aspen, and willows stump sprout abundantly after harvest, however, spruces and birch do not and grow very slowly in boreal conditions. Stooling beds are perennial hedgerows that are harvested each year and grow back from stump sprouts. They are commonly used for obtaining stem cuttings in the nursery industry and will be needed for operational applications in rural Alaska in order to restore the forests and regenerate fast growing trees. Recently 8,000 balsam polar whips were collected in the Matsu Valley and Delta areas for cold storage until planting begins in two time windows, early and late June 2013. The whips will be brought out of cold storage 10 days before planting and placed in water to break dormancy and stimulate growth. They will be planted on sites in Palmer and Delta. Soil temperature will be monitored continuously over the summer with the use of data loggers at some sites and utilizing a hand held soil temperature probe on other sites. Planted whips will be monitored for survival condition, and total height at the beginning, middle and end of the growing season for 3 years. We will also experiment with growing local edibles in conjunction with restoration.

FROM WINDBREAKS TO WATERBREAKS: HEDGING YOUR BETS UNDER WEATHER EXTREMES

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ABSTRACT

Extreme weather events are creating environmental problems, accelerating erosion rates, and threatening agricultural production. The implementation of sound conservation practices will be critical for creating climate resilient farms and landscapes. Agroforestry practices are particularly valuable because they can minimize flood and drought impacts while producing other services that landowners' value. Windbreaks are a time-tested strategy for conserving soil moisture and reducing soil erosion during droughts but can be managed to deliver a broader suite of ecosystem services. Through innovative design and plant selection, windbreaks can provide services such as habitat for beneficial insects, biomass feedstock, aesthetic enhancement, and edible food products. Waterbreaks offer a novel approach for addressing the surge in flooding intensity and frequency by providing a series of strategically placed buffers in the floodplain to reduce the impacts of flood events. During nonflooded conditions, waterbreaks can provide wildlife corridors between upland and riparian areas and improve water quality by trapping sediment and filtering runoff, while providing alternative income through hunting fees and harvesting products such as timber, nuts, and other nontimber forest products. In this presentation, we illustrate how these agroforestry practices can be used to create climate resilient landscapes that offer multiple ecosystem services.

Keywords: extreme weather, agroforestry, climate change

VERIFICATION OF SHELTERBELT CROP YIELD IMPROVEMENTS IN THE GREAT PLAINS REGION

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ABSTRACT

In 1962, J. H. Stoeckeler summarized the impacts of windbreaks on agriculture in the Great Plains. This paper has been the standard by which windbreak benefits, particular crop yield benefits have been judge. Over the last 60 years, agricultural practices have changed dramatically. The use of minimum tillage and no-tillage practices has provided significant benefits in the control of wind erosion. Progress in hybrid genetics and the introduction of GMO crops have increased yields dramatically over the last 30 years. Many producers are asking if the benefits of field windbreaks are still economically viable. Can we still afford to divert land from production to field windbreaks? The availability of yield monitors, GPS systems and excellent satellite imagery may provide the technology to verify that the yield responses seen as a result of field windbreaks are still relevant today. Preliminary data will be collected during the summer of 2013 in at least five Great Plains States. Data protocols will be tested and refined during the late summer and funding sought in the fall. Our purpose in coming to the AFTA meeting is to seek additional input and suggestions from agroforestry professionals.

Keywords: crop yield monitors, field windbreaks, economics

Study's purpose and need

Windbreaks have a long history of use in all parts of the world. Their many uses and benefits have been review extensively most recently by Brandle et al (2009). Primarily viewed as a means to control wind erosion, windbreaks have been shown to provide significant economic benefits from increased crop yields. While most studies (Stoeckeler, 1962; Baldwin, 1988; Kort, 1988; Brandle et al. 1992) have reported an overall yield increase, many producers still question whether modern agriculture with its many advances in hybrid genetics and genetically modified varieties still provide the advantages of crop protection from wind. Do field windbreaks still provide the yield advantages and economic benefits seen in the past? The proposed study is designed to answer this question for the Great Plains Regions of the USA.

A different approach

If the study methodology were to involve the establishment of research plots with scientific sampling, it would be too large for any one agency, university, or group to take on. The size of the area, the number of crops grown, and the differences in climate, soils, and farming methods would add so many variables that the number of needed plots would be huge. The intent with this study is to compare multiple years of protected/unprotected field data over a large area and from many farmers. Because we are looking for relative crop yield changes and not absolute numbers, this approach will minimize the variables listed above. In addition, we will not be answering why there is an effect, just whether there is one.

The important part to this study is that the much of the data already exists and is in the hands of many farmers. Yield monitors are a recent development in agricultural machinery that allow producers to assess the effects of factors such as weather, soil properties, management, and in our case, windbreaks, on production. When combined with GPS, they can provide crop yield data for virtually every point in a field. So if this data were joined with knowing if a functioning windbreak was present or not, a comparison of yields between protected and unprotected fields would be possible. Many farmers maintain this data for several years. This could minimize the effects that weather and cropping systems might have on the overall effect.

Working with Extension Educators, NRCS District Conservationists, District Foresters and local Soil and Water Conservation Districts in the seven state region of Minnesota, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, we will seek out individual farmers willing to participate. Their operation must include fields protected by functioning field windbreaks; they must have crop yield monitors on their combines; and they must be willing to share their yield data with the research group.

A minimum of 10 sites per state will be identified (20 or more is desirable) providing at least 70 farm sites for the study. The study will continue for at least two growing seasons providing yield curves for a minimum of 140 fields within the 7 state area. It is anticipated that many of the cooperators will have additional yield data from previous years which will be added to the data file.

Once an individual cooperator has been identified and agreed to participate, an on-site visit will be arranged to assess the location, height, width and condition of any field windbreaks on the farm. Individual crop fields (both protected and unprotected if available) will be selected and a harvest pattern will be agreed upon with the farmer. Field information (crop and soil type) will be collected for each field. Any past year’s crop yield data along with cropping practices information will be identified and included in the study.

What do we expect?

At a minimum we expect to be able to produce yield curves of shelter responses of the major crops (maize, soybean, and wheat) as well as important crops with more localized areas of production. Economic analysis in year 3 will help define the economic value of field windbreaks under today’s modern agricultural practices.

Our purpose for coming to the AFTA meeting is to solicit input from other agroforesters. We welcome any and all suggestions you might have.

Where do you send comments?

Send your comments to:
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Gary Wyatt at wyatt@umn.edu
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OPTIMAL SOIL OCCUPATION OF ANNUAL CROPS AND RAINFED OLIVE ORCHARD IN AN ALLEY CROPPING SYSTEM IN MOROCCO

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ABSTRACT

In Morocco, 75% of rainfed olive orchards are associated with annual crops, with a predominance of faba bean and wheat, generally cultivated near the trees trunks. In order to determine the optimal spacing, in this agroforestry system, at which production of annual crops is not affected and the interaction effects on the trees are low, behavior of faba bean, wheat and olive tree, grown in association, was examined at different distances and exposures in differ farmer's field in the north part of Morocco. Results showed that spatial occupation of intercropping in rainfed adult olive may be optimized depending on species of intercropping, trees height and orchard exposure. Preliminary measurements revealed that intercropping yield was very affected sub the tree foliage and is still affected in the north-eastern side due to the shading of trees, up to a limit whose value (Y) is linearly correlated with the tree height (X): $Y = 0.52 X – 0.63$ ($r^2 = 0.98$). Shading effects on annual crops are manifested by a decrease in all yield components. Especially for faba bean, yield decreases in shaded area under the additional influence of the etiolation phenomenon.

Keywords: Morocco, rainfed olive, faba bean, wheat, spatial occupation

OPTIMIZING STEM CULTURE EXPANSION FOR AMERICAN HAZELNUT

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ABSTRACT

Due to the smaller size of the nuts and the lack of improved varieties, the American hazelnut (*Corylus americana*) is not currently traded on the world market, while the European hazelnut is the basis for a sizable industry. The main barriers to cultivation of European hazelnut in the Lake States are its lack of winter hardiness and lack of resistance to the main disease, Eastern Filbert Blight, to which the American hazelnut has coevolved. This project aims at successfully optimizing the transfer intervals for micropropagated stem cultures of American hazelnut. We are assessing transfer intervals of 2-weeks, 3-weeks, and 4-weeks. We started with 3-4 cultures per transfer interval with a total of 2-3 stems per culture. It was found that cycle times of 2 weeks significantly increase the rate of expansion of the stem cultures over 3 or 4 weeks while 3 and 4 weeks were found to not be significantly different from one another.

Keywords: micropropagation, filbert, oilseed

THE EFFECT OF INTERCROPPING HYBRID POPLARS AND RED OAKS ON SOIL ORIBATID DIVERSITY DISTRIBUTION

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ABSTRACT

The benefits of Tree Based Intercropping (TBI) in North American agro-ecosystems could include climate change mitigation and adaptation, although enhancing resilience through increasing soil diversity remain poorly explored. Diversity of soil microarthropods supports a series of ecological services that may be altered through soil desiccation due to climate change. Here we study the effect of red oak and hybrid poplar TBI on soil oribatid mite species assemblages associated to Timothy-grass and red clover crops. TBI increased oribatid diversity only in the case of red oaks, and such effect was equally important from superficial to deeper soil levels. The distribution of oribatids was highly associated to root biomass. Results are very important considering that oribatid fauna depend on organics resources to perform their ecological roles. If increasing drought associated to climate change will desiccate superficial levels of agro-ecosystem soils, deeper sources of food should result crucial in the maintenance of microarthropod communities.

BUFFERBUILDER: A BUFFER DESIGN TOOL FOR GIS

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ABSTRACT

A GIS-based design tool has been developed that sizes a buffer according to detailed spatial patterns of overland runoff from agricultural fields–placing more buffer where runoff is greater and less buffer where runoff is less. A digital elevation model (DEM) is used to divide the field margin into many segments and to determine the size and slope of contributing area to each segment. Buffer is sized independently for each segment utilizing a relationship between trapping efficiency and buffer area ratio, rather than width, so it can account for irregular-shaped contributing areas resulting from uneven topography. The tool, called BufferBuilder, can design for either sediment or sediment-bound pollutants.

BufferBuilder runs as an extension of ArcGIS versions 10.1 and 10.0 with SP5. To run it, inputs include an aerial photograph and a DEM of the delineated field area, an estimate of its soil texture and its tillage/residue condition, and a desired level of trapping efficiency for the selected pollutant type. BufferBuilder produces an image showing the locations for buffer on the aerial photo and an output table showing, among other data, the total area of buffer and its trapping efficiency.

An additional module enables the user to assess the trapping efficiency of existing buffers and other user-defined buffers of various size and configuration. By accounting for uneven patterns of field runoff, BufferBuilder-produced designs can be more than twice as effective per unit buffer area as conventional constant-width designs.

Keywords: riparian buffers, water quality, design tool

COMPARATIVE WATER USE BY RIPARIAN FOREST, GRASS AND CROPS IN THE U.S. GREAT PLAINS

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ABSTRACT

In arid regions, riparian vegetation consumes water that would otherwise support critical in-stream flows. Average annual evapotranspiration (ET) was estimated for different types of riparian vegetation in Nebraska. The Penman-Montieth dual crop coefficient model (Allen et al 1998) was used for estimating ET which included adjustments for capillary rise from ground water and for clothesline and oasis effects. Modeled scenarios included forest, grass, and common cropping systems over different groundwater depths in three climate regions across Nebraska. Annual rainfall averages from 425 mm in the western region to 695 mm in the eastern region. Estimates of ET ranged from 251 to 1343 mm across all scenarios. The lowest values were obtained for crop-fallow rotations which were less than annual precipitation. All non-fallow, non-irrigated, vegetation types where groundwater was far below the root zone had ET values that were similar to annual precipitation. The highest ET values were obtained for vegetation having access to ground water and/or irrigation in the order of trees > alfalfa > grass > row crops and values for tall phreatophyte trees were 1.4 to 1.6 times greater than for row crops. Annual ET for vegetation having access to groundwater or irrigation was only 5-18% higher in western Nebraska than in eastern Nebraska because a shorter growing season partially offsets the drier climate conditions. These results provide insight on potential in-stream effects of different riparian management options in the central U.S. Great Plains.

Keywords: consumptive use; Penman-Monteith; riparian vegetation; water supply.

USING GOATS IN AGROFORESTRY SYSTEMS TO ENHANCE FOOD SECURITY FOR SUBSISTENCE FARMERS

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ABSTRACT

For thousands of years, goats have played a significant role in the agroforestry systems of people around the world. Their small size, robust nature and ability to eat a wide variety of feeds, from cactus to cardboard, makes them the first choice for millions of subsistence farmers, especially women, to enhance their food security and save for future expenses. Although there are many reasons why farmers choose to raise goats, this paper will focus on the impact goats have on the level of food security for subsistence farmers, and how this impact can be enhanced through the application of agroforestry principals. Such systems include silvopastoral practices, fodder banks, fodder hedgerows, and home gardens. Within these systems, goats, which prefer browse, contribute to food security as they help farmers manage risk, improve nutrition for their families, produce more value-added products and help maintain soil fertility for crops. As cities and farms expand into what was once pasture land, subsistence farmers are challenged to increase livestock productivity without expanding their grazing lands. Agroforestry is uniquely suited to help meet this challenge through the integration of goats and perennials and the production of fodder from multipurpose trees.

Keywords: fodder, small ruminants, browse, grazing, drought, risk reduction

INTRODUCTION

While many perceive goats as having more to do with the destruction of trees than food security, the situation is more complicated than that. The role of goats in land degradation must be seen in the light of livestock management. When goats contribute to land degradation, this is a result of poor management which subsistence farmers may believe is the best of their limited choices. Goats are often present at the latter stages of land degradation precisely because good forage is no longer abundant and they are able to utilize the remaining browse which is less palatable to cattle and sheep (García *et al.* 2012). It is their preference for tree leaves, or browse, which makes goats so well suited for integration into agroforestry systems. But as in any agroforestry system, correct planning and management are critical to the creation of a system which will maintain production on a sustainable basis, and thereby enhance food security.

GOATS: REPUTATION VS. REALITY

Goats and other ruminants have been blamed for land degradation and soil erosion around the world, often in ecologically sensitive areas like the arid highlands of North India and Pakistan (McVean and Robertson 1969). The significant role goats can play in watershed degradation prompted one author to write that the most effective achievement of their project was the reduction in the number of goats (Swarn Lata Arya *et al.* 1994). In Africa, overgrazing has seriously eroded and degraded over 80% of the grazing lands (Pimentel 2006). Once a forest has been cut down, overgrazing by goats can effectively prevent any new trees from ratooning as goats can eat all the new sprouts from the stumps of those trees (personal observation in West Africa and Haiti). This usually results in the slow death of those stumps or trees and the local elimination of those tree species. This kind of land degradation is not caused by the goats, but by the people who cut down the trees and those who manage the goats (El Aich and Waterhouse 1999; García *et al.* 2012). To blame such degradation on goats alone is both inaccurate and misleading.

The majority of land degradation in the developing world is caused by either the farming of sloped land and/or the overgrazing of rangeland (Das and Bauer 2012; Pimentel 2006). Agroforestry systems which utilize both trees and goats are well suited to address both these causes of land degradation. The age-old conflict between farmers and herders can be reduced when both food and fodder are produced from the same land, when both farmer and shepherd are committed to growing feed for their animals. Grazing land which is transformed into farmland need not cause a reduction in food for livestock if fodder trees are integrated into the system. In fact, as populations increase, there will be a need for more of such systems to replace lost forage and maintain the diversity of food sources which is so important to food security.

Because goats are browsers, they prefer to consume leaves over grass and forbs. Depending on the season, they will consume between 50-85% browse when given the choice between browse, grass and forbs. Cattle on the other hand, when given the choice, will consume between 60-70% grass, while sheep prefer a more balanced diet of 40-50% grass, 30-40% forbs and 20-40% browse (G. Animut and Goetsch 2008; Rankins and Pugh 2012). Subsistence farmers are often limited in their choice of grazing lands, and may have to make do with poor quality forage for most of the year. This increases their preference for goats which can take advantage of good quality forage when it is available, and then consume green leaves when grass and forbs are unavailable or lacking in nutritive value during the dry season (Schacht and Malechek 1990).

FOOD SECURITY

People have food security when they have access to sufficient food throughout the year to meet their needs and preferences. Negative events like drought or floods can produce shocks, e.g., crop failure or loss of livestock, which reduce food security. Subsistence farmers will use multiple techniques, such as diversification of assets or risk-spreading in space or time, to reduce their vulnerability to such shocks. Raising goats helps farmers diversify their income (through the sale of animals and value added products), expand their resource base through increased sources and varieties of feed (common lands, boundary and fence lines, roadsides and browse from trees and shrubs) and diversify their diet with meat and milk products. Headey and Ecker (2013) in their recent research on measuring food security, write that diversity of diet is one of the better indicators of food security. Goats can significantly improve such diversity for people whose diet is comprised mainly of one or two staples.

It is important to understand the interaction between “negative events”, shocks, the potential reduction in food security and the potential for goats in agroforestry systems to protect against such shocks. Negative events like drought often lead to crop failure, dry pastures and dry wells and streams. These shocks in turn can result in: a) reduced stover, b) reduced food production, c) reduced income, d) reduced forage, and e) reduced water supply. These five factors reduce food security. Goats can help reduce a farmer’s vulnerability in each of these five areas. Since goats prefer browse, they are less dependent on crop stover. Because browse is less impacted by drought, food production from goats will be less vulnerable to drought. Again, the goat’s preference for browse makes it less dependent on forage species like grasses and forbs. Some species of goats are capable of growth while only drinking once a day, and the black Bedouin goats of the Sinai desert can drink only once every four days (Silanikove 1997).

When trees are added into the system, the subsistence farmer obtains even greater protection from these five shocks of drought. The deeper root systems of trees over annual crops allow for greater drought resistance and more reliable production of fodder, food and cash crops. Fresh tree leaves are more nutritious than dried stover which is often high in ligno-cellulosic content (Ben Salem and Smith 2008). Timber/fodder trees can be kept in reserve until a time of financial need. So through the integration of goats into an agroforestry system, the subsistence farmer achieves greater protection from each of these five shocks produced by the negative event of drought (Figure 1).

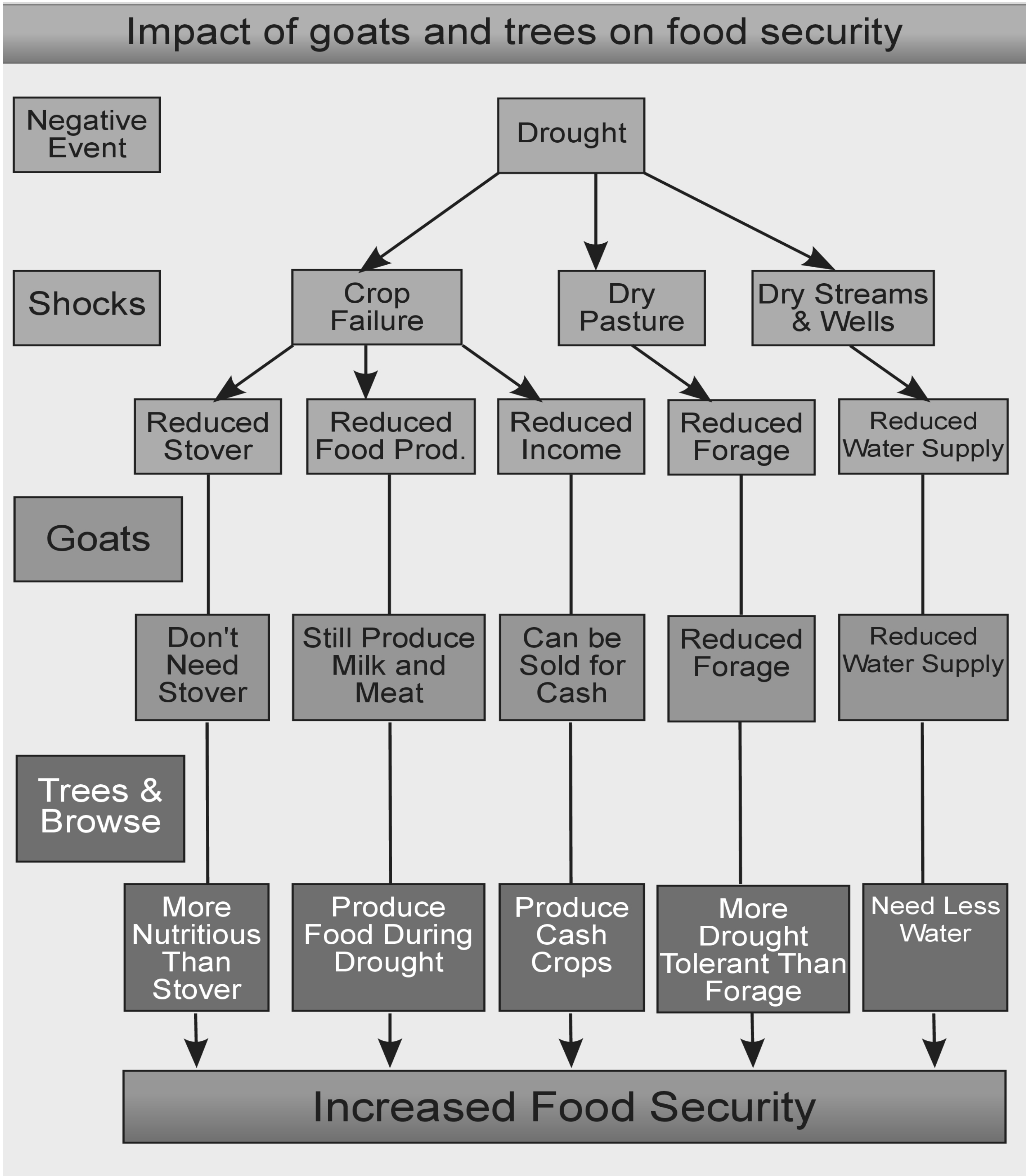

Figure 1 The impact of goats and trees on food security

As small ruminants, goats diversify risk more than larger livestock like cattle or camels, and they are more tolerant of high temperatures and low quality forage (Gwaze *et al.* 2009). Because goats are browsers, they prefer the leaves of trees and shrubs. The structure of a goat's mouth and tongue enable it to select individual leaves and blades of grass in order to maximize the nutritional value of its forage. In contrast, cattle will tend to grab large bunches of forage with their tongues and teeth (Heckman *et al.* 2007). Thus goats are better suited to consume fodder from trees and shrubs produced in agroforestry systems, compared to cattle or sheep which prefer grasses and forbs. Many trees used for timber and green manure are also well suited as browse for goats. The stability which trees and perennials lend to an agricultural system also enhances the stability of production from goats in such a system. Stability of income and food (the reduction of risk) is one of the highest priorities for the subsistence farmer. This helps explain the preference of poor farmers for goats over cattle. This is especially true for women, who are often among the poorest of farmers with access to the fewest resources (G Animut *et al.* 2000; Valdivia 2001).

THE PLACE OF GOATS IN AGROFORESTRY SYSTEMS

Although there are many configurations for such agroforestry systems, contour hedgerows are a well-known example of an agroforestry system which can produce both food for humans and fodder for animals, while conserving soil fertility and reducing erosion (S. L. Arya *et al.* 2011). In one project where hedgerows were introduced for the production of green manure to sustain soil fertility, farmers refused to follow project guidelines and instead used the leaves as fodder for their goats, and then used the goat manure on their fields (Mugwe *et al.* 2009). Research is needed to compare the differences between goat manure and tree leaves for sustaining soil fertility and reducing erosion. The lack of such research points to a failure to appreciate the significance of animals in the agroforestry systems of subsistence farmers (Magcale-Macandog *et al.* 2010).

In most silvopastoral systems in developed countries, goats would not provide a significant advantage over cattle or sheep, since lower tree branches are pruned annually for the purpose of producing saw logs. But in the developing world, where labor is cheaper, branches are often cut on a daily basis to provide browse for livestock either *in situ*, or in a cut-and-carry system. In such a system, goats will better utilize the browse than cattle or sheep. Blending the three species would also increase production, as each has different and complementary feeding preferences for grass, forbs and browse.

In the home garden, goats provide a means by which prunings and crop residue are transformed into fertilizer. Given that many subsistence farmers are unable to afford commercial fertilizer, the production of fertilizer on their own farms is essential. The fact that the farmer will also get milk and meat from the process helps explain why the above farmers were so reluctant to use trimmings for green manure. It would simply be a less productive system that would not increase food security as much as using the trimmings for fodder (Tanner *et al.* 2001). Although the use of fodder banks is often cited in the literature, in practice the subsistence farmer prefers a system which utilizes multipurpose trees in integrated systems, rather than single purpose fodder trees. It is in the farmer’s best interest to select trees which are planted for food production, but will serve as a source of fodder while growing, and a source of timber or fuel wood when cut, allowing for the continuous cycling of carbon from plant to goat to manure to field (Thomas *et al.* 2002).

CONCLUSION

The integration of goats in agroforestry systems is a common practice for subsistence farmers in the developing world. This is partly due to the need to reduce their vulnerability to shocks from negative events which reduce food security. The farmer must protect against all shocks which are known to occur in the local region through techniques of asset and income diversification and risk spreading in space and time. The integration of goats into agroforestry systems helps farmers to diversify their assets and income, and to spread risk. This is accomplished primarily through the relatively stable production of tree fodder, and the preference of goats for browse. The use of goats in agroforestry systems to improve food security deserves more research by academic, government and scientific institutions than it has received in the past. Researchers who want their work to benefit subsistence farmers should investigate the true value of goats to increase the productivity of agroforestry systems through the cycling of carbon from trees to agricultural fields and home gardens.

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MICROBIAL COMMUNITIES ASSOCIATED WITH NITROGEN CYCLING IN A TREE BASED INTERCROPPING SYSTEM

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ABSTRACT

Nitrification and denitrification are microbially driven processes that lead to nitrous oxide (N_2O) production. Our research group is examining whether a tree-based intercropping system (TBI) is an appropriate alternative agricultural system for the mitigation of N_2O emissions. In this study we will examine nitrifying and denitrifying bacteria and archaea associated with four tree species in a TBI system. A long term field experiment has been established at the University of Guelph Agroforestry Research Site, located in Guelph, Ontario. Black walnut (*Juglans nigra* L), Red oak (*Quercus rubra* L.), Norway spruce (*Picea abies* (L.) H. Karst) and Carolina poplar (*Populus x. canadensis*) were planted in a split plot design in 1987. In May 2012 and April 2013, soil cores were collected at planned intervals around trees and into the crop system. DNA was extracted and used for quantitative real-time PCR to determine the abundance of key functional genes in the nitrification and denitrification pathway. Molecular analysis is ongoing; however, preliminary results suggest that tree species can influence the abundance of key microbial groups in the soil ecosystem. If this is the case, this work may provide insight into tree species selection for reduction of microbial groups associate with N_2O emissions from agroforestry systems.

Keywords: nitrous oxide emissions, microbial diversity, denitrification, nitrification

RAVEN/MEDICINE RIVERS WATERSHEDS REFORESTATION PROJECT

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ABSTRACT

History: Over the last hundred years the North Raven and Medicine River watersheds have been experienced extensive grazing, deforestation, wetland drainage and general habitat degradation. This has led to poor water quality, signification riverbank erosion, higher water temperatures and the loss of many native fish species.

Project goals: To improve degraded riparian areas in the North Raven and Medicine watersheds on private lands. Forested watersheds tend to have a more trees and a healthier watercourse, which contribute to wildlife habitat for species that help control agricultural pests and pollinate crops.

Target area: overgrazed pasture and cultivated lands without trees along stream banks. Partners worked with landowners to replant degraded riparian zones.

Method:

- Formation of planning team.
- Public awareness campaign to attract cooperators.
- Inform landowners of riparian values.
- Install fencing, off-stream watering system and complete reforestation.
- Hire 25 000 white spruce seedlings in riparian area.

Results:

- Landowners participate on two sites along North Raven River
- Over 60 acres of forest and non-forested riparian areas were fenced
- 25 000 White spruce seedlings were successfully established in 2012
- Other landowners will be targeted in future project
- Cooperation between landowners and project team was key

POTENTIAL COMMERCIALIZATION OF OSAGE ORANGE (MACLURA POMIFERA) FRUIT GROWN ON SILVOPASTURES IN TEXAS AND OKLAHOMA

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ABSTRACT

This presentation explores the commercialization of Osage Orange fruit as a source of biofuel feedstocks and animal feed. It may be possible to harvest fruit from existing trees while at the same time planting new Osage Orange trees. The overall goal is to create silvopastures of Osage Orange trees with sufficient fruit volumes. The Osage Orange fruit must be processed to extract marketable biofuel feedstocks. Osage Orange is a tree species found naturally in Texas and Oklahoma. The Osage Orange is dioecious: all trees are either female or male. In a natural stand of trees, there is an equal distribution of male and female trees. A silvopasture can be started with the addition of female trees amongst the existing trees. There is sufficient information in the scientific literature detailing the chemical extraction of vegetable oil, carbohydrates and isoflavones from the Osage Orange fruit. The high flavonoids levels present a challenge in the separation of vegetable oil and carbohydrates. Isoflavonoids have been overlooked as a potential source of biomass for renewable energy. There is enough evidence to further explore developing renewable energy from cultivating Osage Orange (*Maclura pomifera*) in Oklahoma and Texas.

Keywords: osage orange, silvopasture, biofuel feedstocks, biomass, renewable energy, osajin, pomiferin, isoflavonoid

INTRODUCTION

Currently there are limitations to developing a large scale biofuel industry in Oklahoma and Texas. However much of the acreage that could be used for producing biofuel/biomass feedstocks are not suitable because of their persistent low yields due to high erosion potential, low water holding capacity, and extremes in weather (Redfean, 2011). One must assess the role of weather in sustaining the renewable energy crops in these two states. Farmers and ranchers recognize that the incoming supply of energy and moisture varies widely over both location and time. The climate extremes in Texas and Oklahoma are due to their position on the North America Continent (Bomar, 2008). These states have been plagued by long and persistent droughts which have caused economic havoc in the Agriculture Communities of both states. Why should Osage Orange (*Maclura pomifera*) be considering an alternative non-food feedstock for Bioenergy? There are potential feedstocks in the fruit: vegetable oil, carbohydrates, and phytochemicals (such as flavones) and remaining high protein biomass consumable as cattle feed (Clopton and Roberts, 1949). The Osage Orange (*Maclura pomifera*) is a tree that is part of the historic climax plant community in Texas and Oklahoma prior to the advent of European settlement and agriculture practices (Smith et al, 1981). The Osage Orange tree can be found in the Blackland Prairies, Post Oak Savannahs, Cross Timbers, Central Great Plains and Eastern parts of the Edwards Plateau of Texas, and also in the Central Great Plains, Cross Timbers and Central Irregular Plains of Oklahoma. Osage Orange trees can easily be spotted by the trained eye while traveling through these ecoregions. This a pioneer species forever invading exposed mineral soils, particularly over grazed pastures and abandoned crop fields(Burton, 1973). Other common names of the Osage Orange are d'arc, bodark, hedge, hedge apple, Osage apple, horse apple and bow wood. The USDA hardiness classification for Osage Orange is 5-9. Irrigation is not required as long as the tree receives 24-40 inches of rainfall per year. The tree grows fast and starts to bear fruit at 5-10 years of age, lives 150 years or more, and can reach a height of 9-12 meters. It is one of the most insect and disease resistant tree species in North America. The tree is hardy in drought, high heat, ice and high winds. It is dioecious, with different flowers on the male and female trees. If there is no male tree present during pollination, the female trees will produce a seedless fruit, which may lower the oil and protein content of the fruit. It produces an unpalatable, multiple globular fruit which is about the size of a large orange weighing about 1 pound, and 80% which is water (Burton, 1990).

In Texas, the author has observed that even after a freeze in November or December, the fallen fruit can subsequently experience several days and possibly weeks of high temperatures and low humidity. The fruit will soften and begin to dehydrate while turning brown at the surface. The fruit will stay intact until April at which time the spring rains begin to break down the outer surface, but the fruit remains on the grounds as a dehydrated ball with its seeds intact until the heavy rains in the spring. This would allow the fruit to be harvested from November to early April.

The Osage Orange fruit has three potential non-food feedstocks: vegetable oil, sugars/carbohydrates and phytochemicals. Seeds are 11% of the weight of the fruit and are composed of 5.9% water, 6.7% ash, 20.8% carbohydrate, 33.9 % protein, and 32% fat (Soloua et al., 2009). Researchers at the USDA, Bio-Oils Research Unit (Moser et al, 2011) were able to prepare biodiesel from the oil extracted from Osage Orange seeds. It had been reported that a fruit tree will yield 450 kg of fruit/tree, hence it equates to 49.2 kg of seeds and 16.2 kg of vegetable oil per tree. Assuming 100 producing female trees per hectare, one hectare would produce 1620 kg/ha or 1800 liters/ha. The fruit has been reported to contain about 15 % sugars and 7% other carbohydrates on a dry weight basis (Clopton and Roberts, 1949). If planted at a density of 100 trees/ha (10 meter centers), 1,073 liters/ha (115 gallons/ac) of ethanol could be produced annually (Seibert et al, 1986). In other studies, the fresh fruit could have as much as 46% pectin in its solids (Aliev, 1961). If the complex carbohydrate is indeed pectin, *Saccharomyces cervisiae* will not convert the galacturonic acid subunit to ethanol (van Leeuwenhoek, 2006). Certain anaerobic bacteria and yeast can convert galacturonic acid to ethanol by using anaerobic bacteria and yeasts (Edwards and Doran-Peterson, 2012). Very little has been discussed in the technical literature about the high levels of flavones and other phytochemicals present in the fruit as a potential renewable energy sources.

In past research on extracting phytochemicals from Osage Orange fruit for pharmaceutical research, antioxidant, antifungal, antibiotic and repellant products (Florian et al, 2006, Altuner et al, 2012, Wagner and Harris, 1952), the main solvents in extracting the phytochemicals have been listed in Table 1.

Water	Ethanol	Methanol	Dichloromethane	Acetone
Anthocyanins Lectins Polypetides Saponins Starches Tannins Terpenoids	Alkaloids Flavonols Polyacetylenes Polyphenols Sterols Tannins Terpenoids	Anthocyanins Flavonols Flavones Lactones Phenones Polyphenols Saponins Tannins Terpenoids	Terpenoids	Flavones

Table 1. Solvents used for active compound extraction of Phytochemicals (Cowan, 1999)

The two main phytochemicals extracted from Osage Orange discussed in the literature are pomiferin and osajin. It has been found in amounts of 10 – 15 % based on dry weight basis (Wagner and Harris, 1952). Phytochemicals (resins and pigments) were reported to be 21.67% of the dry weight (Compton and Roberts, 1949). The alcohol extract represents a mixture of phytochemicals that all have fairly high Heats of Combustion. The Heats of Combustion based on Hess' Law and bond energies are estimated for the following phytochemicals in Table 2.

Compund	Formula	Molecular Wt.	Heats of Combustion	
Phytochemical			MJ/kg	BTU/lb
Osajin	$C_{25}H_{25}O_5$	404	32.64	14,040
Iso-osajin	$C_{25}H_{25}O_5$	404	32.22	13,860
Pomiferin	$C_{25}H_{24}O_5$	420	31.10	13,380
Iso-pomiferin	$C_{25}H_{24}O_5$	420	30.54	13,140
Maclurin	$C_{13}H_{10}O_6$	262	23.85	10,260
Lupenyl acetate	$C_{32}H_{52}O_5$	468	41.00	17,640
Butyrospermol	$C_{30}H_{50}O$	410	44.70	13,140
Fuels				
Ethanol			25.00	10,755
Gasoline			46.00	19,790
Biodiesel			38.80	16,262
Diesel			48.10	13,140

Table 2. Comparative Heats of Combustion for Phytochemicals and Fuels

Unfortunately, there is very little information published on determining the levels of individual phytochemicals in the Osage orange fruit. Most of the research was conducted in and around the 1950s without the technology of GC–MS, NMR, and HPLC. The population of fruit tested was limited to one or two fruits per only one tree in one specific area or country. One of the objectives of this study was to look at several options to commercially process the fruit.

MATERIALS AND METHODS

In order to find a process that could be used to give a commercial plausible process, several trial and error experiments were performed by the author. Based on this initial work, the following is recommended:

1. Field dried fruit was preferred over fresh fruit.
2. Fruit must be blanched
3. Fruit should be macerated during steeping
4. Blanched, macerated fruits should be dried
5. Seeds should be separated from the dried fruit mass
6. Solvent extractions should be performed on separately on fruit mass and seeds.

Materials

Osage Orange fruit was collected from trees in Tarrant County, Texas. All the fruit was gathered from the ground. The first fruit was collected in December and fruit not used immediately was stored in a commercial refrigerator (34^0 to 40^0F). Fruit was collected in February which were the outer coat was changing to a brownish yellow and tissue was soft but not rotten. This unused fruit was refrigerated. Fruit collected in April and May had turned brown and in most cases was very hard. This fruit had moisture content of less than 5 % moisture on the wet wt. basis. This fruit was stored under dry conditions at ambient conditions. Solvents used were Fox Pure Reagent Hexanes, min. 99.9% C6 Hydrocarbons and Fox Pure Reagent Methanol, min. 99.9% purchased from Fox Scientific, Inc., Alvarado, TX. Tap water was used for water soluble extractions, tissue softening, and water blanching.

Methods

Moistures samples were determined by air drying for 24 to 48 hours, then dried in a vacuum oven at 80^0C for 24 hours. In the extraction trials, fruit was collected on May 5, 2013 from three different trees. All the fruit was put in a container, and randomly selected for study. The fruit was cut into pieces, about 1 inch cubes and the moisture was determined.

Water Extractions

In the first extraction, tap water was added to the weighed field dried fruit sample and brought to a temperature of 180^0F and held at this temperature for 2 hours, then allowed to steep in the blanch water for 8 hours to soften the fruit. During steeping the fruit suspension was agitated at irregular intervals. After steeping, the batch was pressed in a hand operated fruit press with a cotton filter cloth. In the second and third extraction, fresh tap water was added to the pressed solids at ambient temperature and steeped for 2 hours. During steeping the fruit suspension was agitated at irregular intervals. After steeping, the fruit mass was pressed as in first step. After the third extraction, remaining fruit mass was weighed and dried and the moisture content was determined.

Methanol Extractions

The remaining fruit solids were air dried and the moisture determined. Methanol was added to a sealable glass container with the remaining dried fruit solids. Sufficient quantity of ethanol was added to completely submerge all of the solids. The weight of ethanol was determined and recorded. The first methanol extraction was for 12 hours at ambient temperature. The container was shaken intermittently. The methanol solution was filtered from the fruit solids. This procedure was repeated four (4) times, but, the extraction time was shortened to two (2) hours on subsequent extractions. The methanol extraction solutions were distilled in a weighed round flask that was heated in a steam bath. The distillation was stopped when methanol no longer was condensing in the water cooled condenser. The flask was heated to 220^0 F in a drying oven until the extract stopped losing weight. The flask was cooled in a desiccator and weighed. The total methanol extract weight was determined.

Hexane Extractions

The ethanol extracted fruit solids (the solids were not dried to remove the methanol) were added to a sealable glass container. Sufficient quantity of hexane was added to completely submerge all of the solids. The weight of hexane was determined and recorded. All extractions were at ambient temperatures (70 -75^0 F) and the container was shaken intermittently. After 2 hours, the hexane solution was drained and filtered into a 1000 ml glass separation funnel and allowed to stand for 1 hour. The hexane solution separated to the top and the remaining ethanol solution separated to the bottom. The ethanol solution was drawn off, weighed and added to the methanol extraction solutions. The remaining hexane extraction solution was weighed. This procedure was repeated three (3) times. The hexane extraction solutions were combined and distilled in a weighed 1000ml round glass flask that was heated in a steam bath. The distillation was stopped when the hexane no longer was condensing in the water cooled condenser. The flask was heated to 250^0 F in a drying oven until the extract stopped losing weight. The flask was cooled in a desiccator and weighed. The total Hexane extract was determined.

RESULTS AND DISCUSSION

Water Extraction Results

The results of the water extractions are shown in Table 3. The amount of soluble solids in ground dried fruit was low. The hot water blanch did deactivate the enzymes because no gas formation was observed during the steeping in all three extractions. Agitation and pressing does break the fruit into smaller pieces. Based on results, it is recommended that the dried fruit be blanched and steeped for several hours under continuous agitation until the seeds easily separate from the fruit tissues. The suspended solids can be easily separated with a cloth plate or bag filter. The filtered solution can be reused in subsequent blanching and steeping operations.

Extraction	Water Added (grams)	Water Solution Removed (grams)
First Second Third	1,778 797 765	1082 822 772
Totals	3,350	2,676
The initial fruit sample was 571 grams (554 grams dry weight solids). Filtered Wet Solids - 598 grams: Moisture Content – 85% Non Water Extracted Solids – 508 grams: Soluble solids – 46 grams (calculated).		

Table 3. Water Extraction Summary

Methanol Extraction Results

Methanol was used for the phytochemical extractions of the dried fruit solids which are summarized in Table 4. The relative high level of phytochemicals in the fruit required at least five (5) extractions. It is recommended from observation that a countercurrent extraction process with heated alcohol be used to minimize the amount of alcohol used. Energy consumption is lowered by decreasing the alcohol distillation load.

Extraction	Methanol Added (grams)	Methanol Removed (grams)	Color
First	1,184	1,021	Very Dark Brown
Second	995	993	Very Dark Brown
Third	1,158	1,098	Dark Brown
Fourth	1,031	1,010	Clear Brown
Fifth	828	776	Clear Light Brown
Hexane Solution		170	Lite Yellow
Totals	5,196	5,067	
Alcohol Extractable fruit solids (phytochemicals) after distillation - 128 grams			

Table 4. Alcohol extractions

Hexane Extraction Results

Hexane extraction is the typical method used for removing vegetable oil from high oleiferous material. In these extractions, clear lite green/brown oil was produced. The hexane removed the oil quickly and was easily distilled to concentrate the oil. In the literature, the oil is found in the largest concentration in the seeds. The seeds can be separated by several methods such as sieves, gravity tables or air separators. If seeds were the only part of the fruit extracted with hexane, both equipment and energy use would be less. In Table 5, the hexane extracted solutions have been summarized. The amounts from this experiment were about half the values reported in the literature. It is possible there were not male trees in the area of the female trees to produce the maximum amount of seeds. Also, Tarrant County, Texas has been experiencing extreme drought for two (2) years. The seeds in the fruit were not ground; hence, the seed coat would prevent the soluble carbohydrates from going into solution.

Extarction	Hexane Added (grams)	Solution Recovered (grams)	Color
First (8 hours)	639	441	Dark Green
Second (2 hours)	932	873	Clear Green
Third (2 hours)	564	516	Clear Lite Green
Totals	2,135	1830	
Hexane Extractable Fruit Solids (Oil) after Distillation and Drying - 47 grams (8.5% dwb)			

Table 5. Hexane Extractions

Total Extraction and Energy Content Results

The total extraction results are covered in Table 6 for the purpose of creating a total final product energy content estimate. Based on the content weights from the extractions, the energy content has been calculated based on the yields of field dried fruit in Table 7. The amount of energy from the extracted products, the energy needed to both harvest and process have been calculated, and the net energy is positive.

Extraction	Weight Extracted (grams)	% of Solids
Water Soluble	46	8.3
Methanol Soluble	127	22.9
Hexane Soluble	47	8.5
Remaining Solids	334 (calculated)	60.3
Starting Solids	554	100.0

Table 6. Summary of Extractions

Extractions	Percentage	Weight/1000lb	Heat of Combustion (Btu/lb)	Heat Energy (Btu/1000lb)
Hexane/Oil	8.4	84	16,900	1,436,500
Alchol	22.9	229	13,380	3,064,020
Total Energy Extracted from 1000 lbs.				4,500,520
Energy Required to Harvest and Process 1000 lbs. (Huxel, 2013)				2,990,850
Net Energy Produced from 1000 lbs.				1,509,670

Table 7. Energy Content and Net Energy after Processing of 1000 Pounds of Dry Fruit Solids.

Economic Value Estimations

Though the numbers are based on many assumptions and estimates, the preliminary data suggests that the Osage Orange tree can be used as a non-food renewable energy source. The fruit produces more energy than the energy needed to harvest and produce the extractable fuels. In addition, the trees are sequestering carbon and tree pruning can be used as an energy source in the processing plant. Based on the energy produced, the final product has a market price shown in Table 8. Extending the amounts to price per pound, one would get an estimate of the Potential Value Added to an acre of land that has been turned from range land to either a silvopasture or tree crop farm. What has not been priced is the value of the remaining solids as an animal feed.

Female Trees/acre	lb/acre	$/lb	$/ac
One			
Hexane Extract	17	0.400[1]	6.80
Alcohol Extract	46	0.074[2]	3.40
Total			10.20
Silvopasture /20 trees			
Hexane Extract	340	0.400[1]	136.00
Alcohol Extract	916	0.074[2]	67.78
Total			203.78
Tree Cropping Farm/120 Trees			
Hexane Extract	2,040	0.400[1]	816.00
Alcohol Extract	5,496	0.074[2]	406.63
Total			1,222.63
Notes: 1. Crude Soybean Oil, Chicago, May 6, 2013 - $.483/lb. The oil produced is very similar to unrefined soybean oil - $0.40/lb. value. 2. Price determined at the price of $7.40/1,000,000 BTU based on Pomifera			

Table 8. Potential Value Added from a Silvopasture and a Tree Cropping Farm

CONCLUSIONS

In both Oklahoma and Texas, many livestock farms are located on land degraded by cultivation in the earl part of the 20th century, or on otherwise marginal land of inherently low productivity. The cultivation of Osage Orange trees, a native tree, on livestock farms has the potential of producing additional sustainable income without major capital expenditures and large annual input costs. The Osage Orange fruit has sufficient enough levels of vegetable oil and phytochemicals and at today's energy prices to make it a viable product for a renewable energy business. The Osage Orange trees will reduce water and wind erosion, increase habitat for wildlife, increase the retention of water, prevent soil cracking and carbon sequestration on silvopastures. What is most important is that it gives addition revenue to the livestock farmer to make their operation economically sustainable and the nation finds a new alternative source of biomass used for renewable energy.

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MODELING THE EFFECTS OF AGROFORESTRY ON CARBON BUDGETS AND TRADE-OFFS IN PRODUCTION YIELD

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ABSTRACT

Agriculture is one of the primary sources of food and income but also a major contributor of greenhouse gas emissions. Large scale operations have become focused on specializing in certain types of crops at the expense of the soil and the environment in order to maximize profit. Agroforestry practices can be used to create a profitable system while still protecting the productivity of the soil and lowering greenhouse gas emissions. This research seeks to determine a balance of maximizing profit through crop yields while still enhancing the carbon sink of agriculture through timber products by using the model *ecosys* (Grant, 2001). *Ecosys* was used in collaboration with field data collected from Guelph Elora Research Site to determine potential changes to carbon sinks over time by adding tree-based intercropping practices. Preliminary model data from Guelph indicates that there is an increased carbon uptake in the tree based intercropping system of about 909 g C m^{-2} over the twenty-two years of modeling compared to the monocropping portion, which managed to release 534 g C m^{-2} over the same period. However, this sequestration in the intercropping portion was met with a reduction of roughly 1070 g C m^{-2} of annual grain yield over the twenty-two year period. The use of *ecosys* will allow for predicting changes over time in order to best balance reduction of greenhouse gases with maximizing profit through crop, timber and carbon products.

Keywords: agroforestry, carbon, *Ecosys*

STUDYING WATER UPTAKE ZONES IN AGROFORESTRY WITH STABLE ISOTOPE ANALYSIS

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ABSTRACT

The incorporation of trees within annual cropping systems has been shown to mitigate environmental stress by reducing the need for external inputs while improving soil and water quality. However, knowledge of tree root distribution, nutrient uptake, and species competition is critical for sustaining growth under abiotic stress in these multi-species systems. Techniques for studying tree root distribution and activity *in-situ* have, to date, been limited. In the tree-based intercropping systems (TBI) at the Agroforestry Research Station, University of Guelph, tree coarse and fine root distributions for *Juglans nigra, Picea abies, Querces rubra* and *Thuja occidentalis* intercropped with wheat, corn or soybean have been determined using new geo-imaging techniques (Ground-penetrating radar). However, little is known about the activity of these roots. In this study, rooting zone activity will be studied using the 18O signature of water in trees and soil as a non-destructive natural tracer of water uptake processes. We hypothesize that in TBI systems, species occupy different niche areas to maximize water resource efficiency. To test this, we will use the δ18O signature in soil water down the soil profile at 10cm intervals and matched with the δ18O signature of non-photosynthetic tissue of the tree. Water acquisitions zones will be estimated by direct matching or mixed models. We hypothesize that within TBI systems, species-specific rooting zones will occupy different niche areas to maximize water resource efficiency. This information can be used to formulate future management techniques to maximize water uptake in TBI systems particularly under scenarios of water stress under a changing climate.

Keywords: AGGP, water, tracer

VISUAL AND PARTICIPATORY RESEARCH METHODS FOR AGROFORESTRY SOCIAL SCIENCE

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ABSTRACT

Visual and participatory social science research methods offer many benefits. They provide sources of rich qualitative as well as quantifiable data. In addition, visual and participatory methods have been shown to place study participants at ease, keep interviews on topic, and are able to elicit more specific information in greater detail and quantity. This presentation will introduce broadly applicable visual and participatory methods that were used in recent agroforestry research. Data were collected in the Adamaoua Region of Cameroon in West Africa from May to August 2012. The study focused on agroforestry preferences among Central African Republic refugees and host-national Cameroonians residing together in border villages. While the research took place in a tropical setting, this presentation will focus on transferability of methods, which are applicable for any research seeking to incorporate innovative surveying tools for qualitative and quantitative analysis in agroforestry social science.

One-hundred and twenty-two study participants across six villages responded to illustrated and visual storytelling items, and answered a 31-point questionnaire. More specifically, research questions addressed agroforestry preferences as well as individual preferences for agroforestry management between refugees and host-nationals. Intergroup identity and community dynamics were used as theoretical frameworks. We will present the illustrated and visual storytelling methods in detail and cover aspects of development and planning, along with theoretical and practical considerations for visual and participatory agroforestry research. The presentation will also generally cover correlations between the questionnaire and illustrated and visual storytelling items. Lastly, we will discuss how these methods are transferable and useful for researchers and practitioners alike.

Keywords: visual research methods, agroforestry preferences, social arrangements

HYBRID HAZELNUTS: CAN WE "MAKE IT WORK?"

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ABSTRACT

A review of the ongoing effort (collaborative research involving multiple partners) to develop Hybrid Hazelnuts as a commercially viable "third crop" is presented. Accomplishments, ongoing research and development, and remaining challenges are considered, including:

Breeding and Selection of Stable Cultivar: Ongoing and planned research includes testing new sources of EFB resistance and a systematic multi-generational breeding effort from 1st generation interspecific hybrids, field-screening clones of best performers followed by several generations of back-crossing.

Improved Propagation: Vegetative methods have limited success. Grafting is not viable. Attention focused on developing mound layering and micro-propagation techniques.

Agronomic Research: Ongoing and proposed on planting, mulching, coppicing, fertilization for developing BMPs to support an industry.

Harvesting Technology: HH bushes not compatible with existing equipment for trees. Among approaches being tested, modification of blueberry pickers.

Financial Modeling: An initial financial planning tool created, needs further development and better data from agronomic research. More detailed and accurate financial analysis needed.

Market Development: Significant potential for diversified and value-added products, (e.g. oil, lubricants) however, given limitations of world hazelnut market, major development required for regional industry viability.

Outreach and Extension: Some successful efforts in mid-west, development of extension capacity required to secure widespread adoption and build an industry.

Relevance for agroforesty and specific applications including alley-cropping designs, windbreaks, buffers and limited silvopasture potential (poultry, ducks/geese and specific sheep breeds) are discussed.

Keywords: hybrid-hazelnuts, collaborative-research, third-crop

THE PRAIRIE SHELTERBELT PROGRAM MONITORING PROJECT

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ABSTRACT

The Agroforestry Development Unit of the Agroforestry Development Centre initiated and implemented The Prairie Shelterbelt Program Monitoring Project (PSPMP) across the Prairies over the past five growing season (2009-2012). The Agroforestry Distribution and Development Units both identified the need for additional data sources to evaluate the performance and establishment of Prairie Shelterbelt Program (PSP) trees and shrubs that were produced at the AAFC-Agroforestry Development Centre in Indian Head, SK. The data collected in the areas of tree health, growth and site management has been evaluated and summarized into a poster presentation.

The results of this monitoring project have the potential to provide valuable strategic direction to the Agroforestry research and development in the Canadian Prairies.

Keywords: shelterbelt, Prairie Shelterbelt Program, monitoring

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ABSTRACT

Irrigation in southern Alberta began over 100 years ago. In the early days the system was not very efficient, resulting in a lot of "wasted" water. This waste began to inadvertently create habitat for wildlife. As irrigation improved, much of this spillage began to disappear along with the habitat that it created.

Planting trees in the short grass prairie zone of southern Alberta, with the strong Chinook winds and dry summers is a challenge at the best of times. But doing it without typical site preparation is usually a recipe for disaster. Partners in Habitat Development (PHD) have been around for fifteen years. In that time have planted upwards of one million trees and shrubs, trying to replace some of the habitat that has disappeared. They have found a way to be successful without site preparation or cultivation. They plant into existing sod, and then apply mulch. The trees are watered by the land owner and his irrigation system. These tree plantings are in the form of multi-row, multi-species shelterbelts, block plantings and riparian buffer strips.

These plantings are the combined efforts of several partners, including: agricultural producers, irrigation districts, government organizations, conservation groups, corporate and private individuals.

Keywords: irrigation, habitat

EFFECTS OF ANNUAL CROPS (WHEAT AND FABA BEAN) ON BEHAVIOR OF YOUNG AND ADULT OLIVE TREE IN AN ALLEY CROPPING SYSTEM UNDER MEDITERRANEAN CLIMATE

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ABSTRACT

In Morocco, more than 50% of olive orchards are associated with annual crops, dominated by faba bean and wheat. In this system, interactions between trees and intercropping crops are little known. Thus, with the objective to determine distances at which the interaction effects are more pronounced, the behavior of olive trees and annual crops (wheat and faba bean) was analyzed at different distances and exposures in young and adult rainfed olive orchards in the north of Morocco. The results showed that, more the faba bean is cultivated near the olive trunks more it induces beneficial effects on olive trees. Cultivated near the trunks, faba bean induced an improvement of shoots growth of young olive by 42% and yield of adult olive by 60%. However, wheat induced a depressive effect on growth and production of olive, even cultivated at the limit of tree foliage. At this intercropping distance, shoot growth of young olive trees was reduced by 10% and yield of adult olive by 37%, compared with an olive orchard cultivated alone. Wheat affected behavior of olive tree by the shading effect on basal ramifications and water competition, particularly during May and June, coinciding with the beginning of olive growth.

Keywords: Morocco, alley cropping, olive, faba bean, wheat

APEX SIMULATION: ENVIRONMENTAL BENEFITS OF AGROFORESTRY BUFFERS ON CORN-SOYBEAN WATERSHEDS

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ABSTRACT

The Agricultural Policy Environmental Extender (APEX) model has the ability to simulate the effects of vegetative filter strips on runoff and pollutant loadings from agricultural watersheds. The objectives of this study were to calibrate and validate the APEX model for three adjacent watersheds and determine optimum buffer dimensions and placement locations. ArcAPEX and APEX0604 versions were used for the simulations. The simulated corn and soybean yields were within ±13% and ±27% of the measured yields, respectively. The agroforestry, grass buffer, and control watershed models were calibrated (1998 to 2001) and validated (2002 to 2008) for event-based runoff with r^2 and Nash-Sutcliffe Coefficients (NSC) values of 0.7-0.8 and 0.4-0.8, respectively. The models could not be calibrated for sediment losses. The simulated grass and agroforestry buffers reduced average annual runoff by 5.2% and 4.3%, respectively. Increase of buffer widths to 5.5 m and 7.5 m were not effective. The buffers located on the backslopes were the most effective for the agroforestry watershed but this trend was not seen in the grass buffer watershed. The study provides guidance on how to parameterize APEX to simulate grass and agroforestry buffers. It contributes to the validation of APEX and will be useful to scientists in need of parameterizing the model for watersheds that include upland buffers.

Keywords: claypan soils, non-point source pollution, soil conservation, upland buffers, watershed modeling

INTRODUCTION

Agricultural practices have often been scrutinized for degradation of water quality in rivers, lakes and estuaries in the U.S. (USEPA 2013). Studies at various scales ranging from small plots, farms, fields, to watersheds are being conducted to evaluate conservation effects on non-point source pollution (NPSP; Mudgal *et al*. 2012; Udawatta *et al*. 2011a, 2011b). However, *In situ* studies at the watershed scale have inherent problems such as high costs due to their large scale and complex nature, private ownership of land and results not timely enough to avoid any negative consequences of current practices.

Hydrological models provide a convenient, efficient, and economically feasible method to evaluate NPSP losses provided sufficient measured data are available at the small watershed scale (Sharpley *et al.* 2003). Among many hydrological models, the Agricultural Policy Environmental eXtender (APEX) model has been widely tested and used to simulate farm level landscapes, cropping systems, and management practices such as filter-strips at both field and watershed scales (Gassman *et al.* 2010; Mudgal *et al.* 2012; Senaviratne *et al*. 2013).

Agroforestry practices have been shown to improve water and soil quality and reduce NPSP losses from agricultural land (Udawatta *et al.* 2002; Abu-Zreig *et al.* 2003). Upland contour buffers, riparian buffers and grass waterways are permanent areas of vegetation designed to remove NPSP from runoff (Dillaha *et al.* 1989). Research prove that 4-4.5 m buffer width as the optimum for 2-9% slopes (Robinson *et al.* 1996; Dillaha *et al.* 1989) and 7.5 m as the optimum buffer width for slopes around 6.5% (Schmitt *et al.* 1999).

The objective of the study was to evaluate environmental benefits of buffers through model simulation. Sub-objectives were to (1) calibrate and validate the APEX model for crop yields, runoff, and sediment for agroforestry, grass buffer and control watersheds, and (2) quantify NPSP reduction efficiencies by varying buffer widths and placement combinations.

MATERIALS AND METHODS

Watershed Characteristics

Three adjacent north-facing no-till corn-soybean (*Zea mays* L.- *Glycine max* (L.)) watersheds (East-1.65 ha, Center-4.44 ha, and West-3.16 ha; Fig. 1a) were established and instrumented in early 1991, at the University of Missouri Greenley Memorial Research Center in Knox County, Missouri, USA (40°01' N, 92°11' W). In 1997, after a 6-year calibration period, contour grass-legume strips (CGS; 4.5-m wide) of redtop (*Agrostis gigantean* Roth), brome grass (*Bromus spp*.), and birdsfoot trefoil (*Lotus corniculatus* L.) were established at 36.5-m (at lower slope positions 22.8 m) apart in the West and Center watersheds. Along the center of the grass strips of the Center watershed a tree line of pin oak (*Quercus palustris* Muenchh.), swamp white oak (*Q. bicolor* Willd.), and bur oak (*Q. macrocarpa* Michx.) were planted alternately at 3-m spacing to establish the agroforestry buffers (AGF). The East watershed was maintained as the control.

The grass waterway of each watershed consists mainly of fescue grass [*Schedonorus phoenix* (Scop.) Holub] and directs flow towards a concrete approach structure and an H-flume. For flow measurement and sampling, ISCO (Lincoln, NE, USA) bubbler flow meters and ISCO 3700 samplers were used. Runoff samples were analyzed for sediment (Udawatta *et al.* 2002, 2011b).

Simulating Watersheds with APEX

The AGF, CGS and Control watersheds were custom delineated (Fig. 1b) using ArcAPEX and ArcGIS 9.3 software. The digital elevation models (created from 25-cm contour survey maps), land use, and soil maps, management information (Udawatta *et al.* 2002, 2011b) and daily measured weather inputs of precipitation, maximum and minimum temperature, and solar radiation obtained from the Novelty weather station were used. Site specific soil data (claypan, texture, cation exchange capacity, organic carbon content, and pH) measured in 80 cores (~1-m deep) for the three watersheds were used to update the soils. The saturated hydraulic conductivity (Ksat), water content, and bulk density were obtained from Seobi *et al.* (2005).

The model options of soil moisture index (SMI) based on continuous curve number (CN) method (SCS 1985; Williams and LaSeur 1976) was selected for runoff estimation in which, the retention parameter, s, is estimated based on soil moisture depletion which is a function of potential evapotranspiration (Williams *et al.* 2012). The modified rational method (Williams 1995) of estimating peak runoff rate was selected for this study. The Hargreaves and Samani, (1985) method was selected to estimate potential evaporation. The MUSS equation (small watershed version; Williams 1995) for estimating soil erosion, which is a variant of the Modified Universal Soil Loss Equation (MUSLE; Williams 1975), was selected for this study. Crop land, buffers, and grass waterways were simulated using subarea parameters (Table 1).

The APEX model was calibrated using the most sensitive parameters reported by Senaviratne *et al.* (2013) for the pre-buffer watersheds and the APEX user manual *(*Williams *et al.* 2008). Storm events (14 events) from 1998 to 2001 were used for the calibration and those from 2002 to 2008 (21 events) were used for the validation of the model. The coefficients of determination *(*r^2), Nash Sutcliffe coefficient (NSC; Nash and Sutcliffe 1970) and percent bias (Pbias) were used to compare the model predictions against the measured outputs.

RESULTS AND DISCUSSION

Crop yields

The APEX model was calibrated and validated for corn and soybean yields with $r^2 > 0.80$ and NSC > 0.72 for AGF, CGS and Control watersheds except for the validation by the CGS watershed (r^2 0.68 and NSC 0.42; Table 2). Pbias values were within ±15% except for the validation. On the same watersheds, Senaviratne *et al.* (2013) reported crop yields within ±13% of the measured yields for the 1991-1997 period. Hu *et al.* (2007) calibrated corn and soybean yields to be within -10 to 6% of measured yield for Soil and Water Assessment Tool model and Mudgal *et al.* (2012) calibrated the APEX model for crop yields to be within ±9% of the measured yields. Proper calibration and validation of the model for crop yield is a requirement for proper simulation of the nutrient balances of the watersheds (Hu *et al.* 2007; Nair *et al.* 2011; *Mudgal et al.* 2012) and proper evaluation of management scenarios *(*Arnold *et al.* 2012).

Runoff

Figure 2 shows the APEX predicted and measured event-based runoff with the corresponding rainfall events of AGF (a), CGS (b) and Control (c) watersheds during the calibration and validation. APEX model was well calibrated and validated for event-based runoff of AGF, CGS and control watersheds with r^2 values ranging from 0.78 to 0.84 for calibration and 0.68 to 0.78 for validation (Table 2). NSC values ranged between 0.68 and 0.76 for calibration and 0.43 and 0.58 for validation for event-based runoff. Performance indicators for event-based runoff were better for the Control watershed than for the other two. Pbias values were within ±25% for calibrations and validations of the watersheds. Observed goodness of fit values were highly satisfactory as specified by Wang *et al.* (2012) for the APEX model. According to Wang *et al.* (2012) $r^2 \geq 0.6$, NSC ≥ 0.5, and Pbias within ±25% are satisfactory for monthly flow calibrations of the APEX model and could be further relaxed for daily or event-based simulations.

No study has calibrated and validated the APEX model for upland contour buffer strips in row-crop watersheds for event-based runoff with long-term data (10 years). Hence this study presents unique results obtained with the APEX model which has satisfactorily simulated the cropland, agroforestry and grass buffers, and grass waterways and their effects on event-based runoff with strong model performance coefficients for calibration and validation.

Sediment

Figures 3a, b, and c illustrate the measured and simulated event-based sediment loadings from AGF, CGS buffer, and Control watersheds, respectively. The model was not well calibrated for event-based sediment; r^2 and NCS values were < 0.1 for all three watersheds. The model over predicted the largest event on the 10th of April, 1999. Annual average sediment loss was within ±10-14% of the measured value when this over predicted value was excluded. The APEX model study for the pre-buffer period reported that the model was calibrated for sediment only for events larger than 50 mm rainfall (Senaviratne *et al.* 2013). They also reported that the sediment depositions at the flume bed prior to sampling point especially during low flow events could have caused under representation of larger sediment particles in the samples and under-estimation of total sediment (Senaviratne *et al.* 2013). Mudgal *et al.* (2008) also reported sediment deposition at the weirs that affected the calibration of the APEX model for event-based sediment especially at low flow events. In-addition, they have observed that event-based sediment was over predicted at high flow events.

The average measured event-based sediment loadings ranged from 0.0084 T ha^{-1} for the AGF and CGS buffer watersheds to 0.0092 T ha^{-1} for the Control watershed. The average measured sediment loadings for pre-buffer Center and West watersheds ranged between 0.099 and 0.1 T ha^{-1} and that for the control ranged between 0.077 and 0.1 T ha$^{-1.}$ (Senaviratne, *et al.* 2013). Post buffer average sediment losses were 88-95% less than pre-buffer losses.

Scenario analysis -- Buffer width and placement of buffers

The calibrated and validated APEX model for AGF and CGS watersheds were simulated with expanded buffer widths from 4.5 m to 5.5 and 7.5 m. The results indicate no significant reduction in average annual runoff (Fig. 4). Studies have found diminishing return in pollutant filtration with the increase of buffer width (Dillaha *et al.* 1989; Robinson *et al.* 1996; Schmitt *et al.* 1999). Studies indicate that increasing the buffer width beyond four to seven meters produce marginal reductions in NPSP (Robinson *et al.* 1996; Schmitt *et al.,* 1999). A review on vegetative filter strips by Liu *et al.* (2008) revealed that the efficiency of a particular buffer width mainly depends on the slope of the land. The results of the current study also revealed that the increase of buffer width from 4.5 m to 5.5 and 7.5 m marginally reduced runoff, possibly because the average slopes of the AGF, CGS, and Control watersheds were 1.3%, 0.9%, and 2.1%, respectively (Udawatta *et al.* 2004).

The models were also simulated to test the effect of location of buffers on runoff by removing all buffers and buffers at summit, shoulder and back slope, and foot slope positions of the landscape at a time (Fig. 5). The simulated AGF and CGS buffers did not significantly reduce average annual runoff but showed 4.3% and 5.2% respective reductions compared to non-buffer simulations. The buffers at the shoulder and back slope positions contributed to the highest reductions in runoff in AGF (1.7%) and CGS (2.4%) buffer watersheds (Fig. 5).

CONCLUSION

The APEX model was reasonably calibrated and validated for crop yield and event-based runoff of the long-term monitored study watersheds located at the Greenley Memorial Research Center, in Northeast Missouri, with upland contour agroforestry and grass buffers, and the control treatment. The r^2 and NSC values were over 0.68 for runoff for calibration and they were over 0.43 for validation. The model was not calibrated for event-based sediment probably due to low concentration as a result of buffers as well as low intensity rainfall events during the study periods. Underestimation of larger particles in the measured samples due to sedimentation on flume beds prior to the sampling point may also have affected sediments calibration results. The long-term scenario analysis showed 4.3 to 5.2% reductions in annual runoff by the buffers. The higher reductions in annual runoff were observed for the CGS buffer watershed. The results of this unique study demonstrated that APEX can be used to evaluate environmental benefits of upland filter strips, provided sufficient long-term data are available for calibration and validation.

Table 1. Subarea parameters used to simulate crop land, buffers, and grass waterways of the three watersheds at the paired watershed study, Greenley Research Center, Missouri, USA.

Parameter	Crop	Agroforestry buffer	Grass buffer	Grass waterway
LUN-Land use number *	5	25	25	22
CHN-Manning's "n" for channel **	0.01 5	0.14	0.14	0.14
UPN-Manning's "n" for upland **	0.3	0.4	0.4	0.4
RCHN-Channels Manning's for routing reach) **	0.05	0.14	0.14	0.14
RCHC-USLE crop-management factor**	0.01	0.0001	0.0001	0.0001
RCHK-USLE erodibility factor**	0.3	0.2	0.2	0.2
Filter Strip Code**	0	1	1	0
FFPQ fraction of floodplain flow**		0.5 - 0.8 (depending on the buffer	0.5 - 0.8 (depending on the buffer	
RFPW Buffer/Floodplain width**		(Drainage area *10000)/(Floodp lian length *1000)	(Drainage area *10000)/(Flood plian length *1000)	
RFPL Buffer/Floodplain length**		Buffer/Floodplai n in km	Buffer/Floodpla in in km	

* Operation schedule file, ** Subarea file (Williams *et al.* 2008)

Table 2. Agricultural Policy Environmental Extender (APEX) model performance for coefficient of determination (r^2), Nash-Sutcliffe Coefficient (NSC), and Pbias values for crop yield and event runoff for agroforestry buffer, contour grass buffer, and control watersheds at Greenley Research Center, Missouri, USA for calibration (crop yields: 1998 to 2002; runoff events 1 to 14) and validation (crop yields: 2003 to 2008; runoff events 15 to 35).

Model output		Model performance	Agroforestry buffer	Contour grass buffer	Control
Crop yield	Calibration	r^2	0.96	0.97	0.99
		NSC	0.88	0.89	0.98
		Pbias	15.42	-15.91	0.89
	Validation	r^2	0.88	0.68	0.80
		NSC	0.77	0.42	0.72
		Pbias	15.48	22.45	-4.38
Runoff	Calibration	r^2	0.78	0.84	0.80
		NSC	0.68	0.75	0.76
		Pbias	10.98	-22.58	22.63
	Validation	r^2	0.68	0.73	0.78
		NSC	0.58	0.51	0.43
		Pbias	5.06	-23.65	25.85

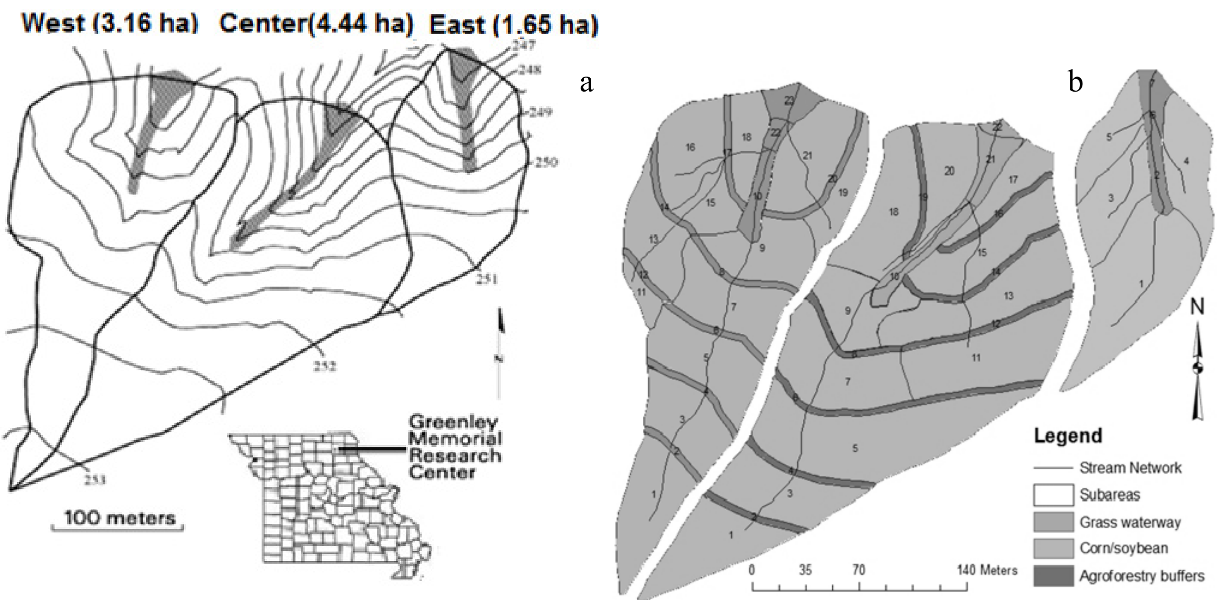

Figure 1. Topographic map (0.5-m interval) of West, Center and East watersheds (a; After Udawatta *et al.* 2004). Grey lines represent contour lines (thin) and grass waterways (wide). The inset map shows the approximate location of watersheds in Knox County, Missouri. ArcAPEX model delineated subareas, and stream network of the three watersheds (b).

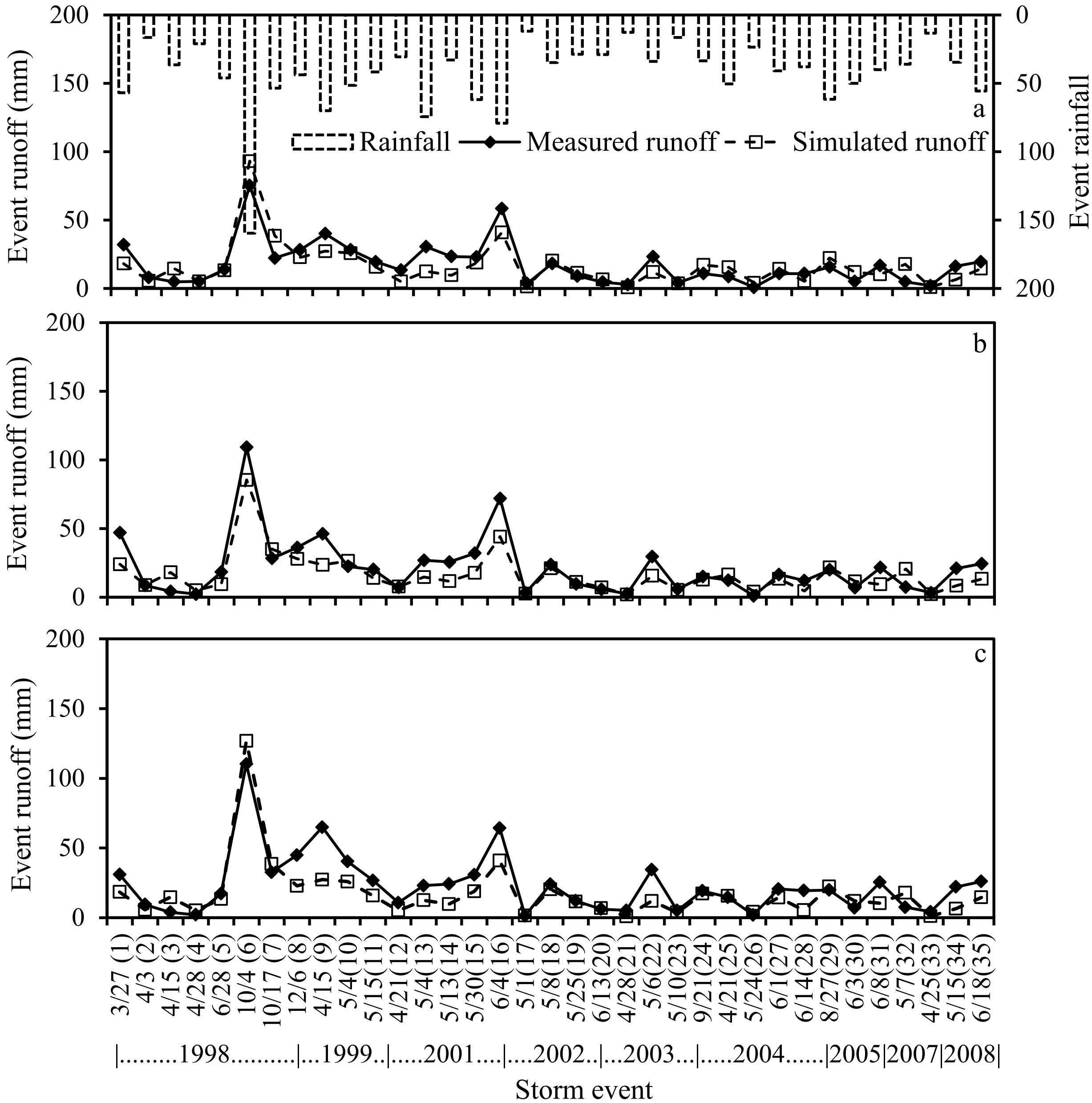

Figure 2. Measured and simulated event-based runoff for Agroforestry buffer (a), Grass buffer (b), and Control (c) watersheds during the study period at the paired watershed study, Greenley Research Center, Missouri, USA. The events 1 to 14 (1998-2001) represent results for calibration while events 15 to 35 (2002-2008) represent results for validation of all three watersheds.

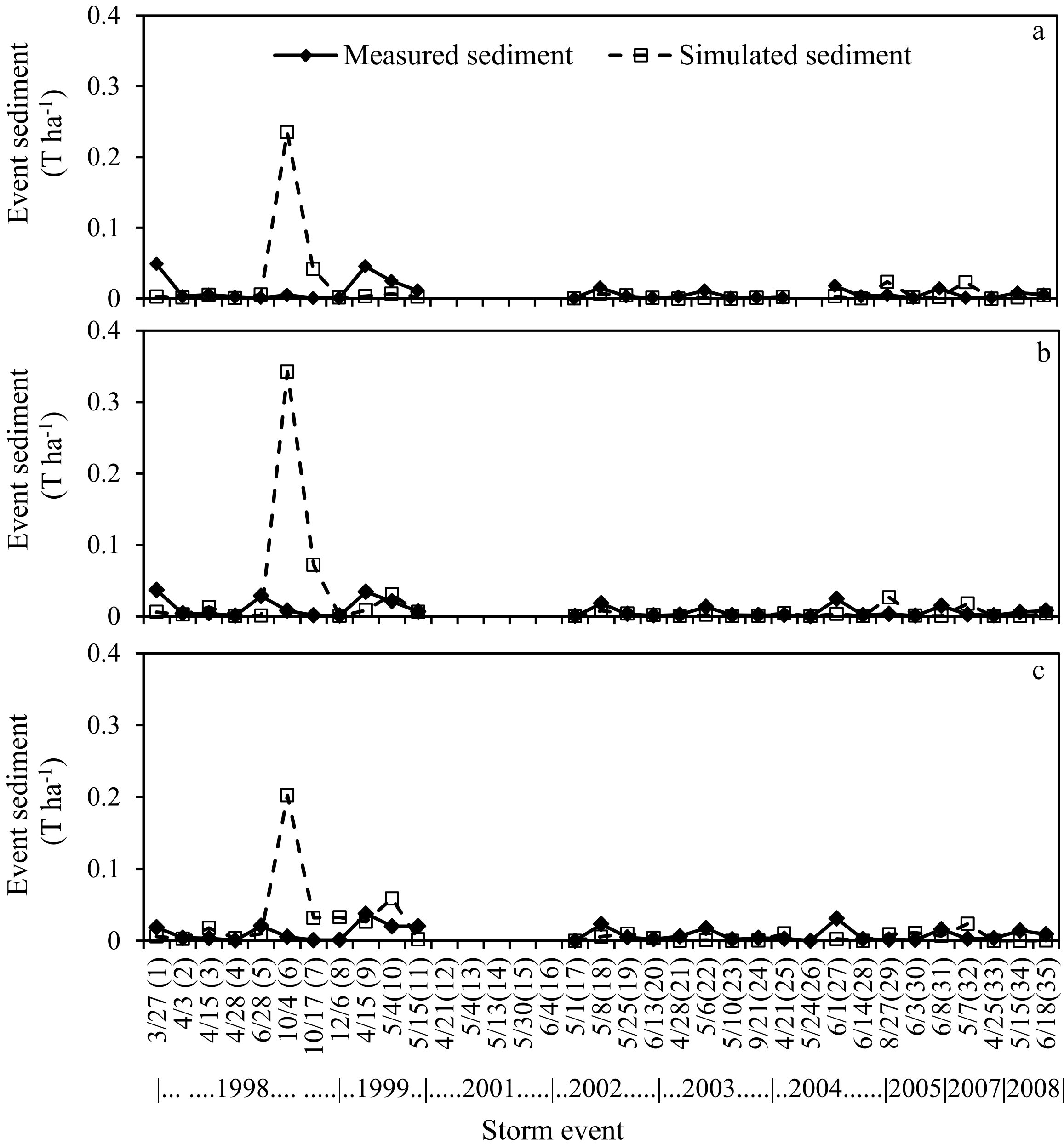

Figure 3. Measured and simulated event-based sediment for Agroforestry buffer (a), Grass buffer (b), and Control (c) watersheds during the study period at the paired watershed study, Greenley Research Center, Missouri, USA. The events 1 to 14 (1998-2001) represent results for calibration while events 15 to 35 (2002-2008) represent results for validation of all three watersheds.

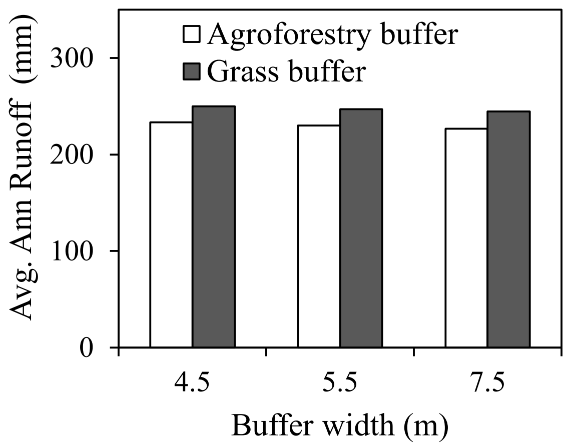

Figure 4. APEX model predictions for average annual runoff for agroforestry and grass buffer watersheds, at the paired watershed study, Greenley Research Center, Missouri, USA, with 4.5, 5.5, and 7.5 m buffer widths.

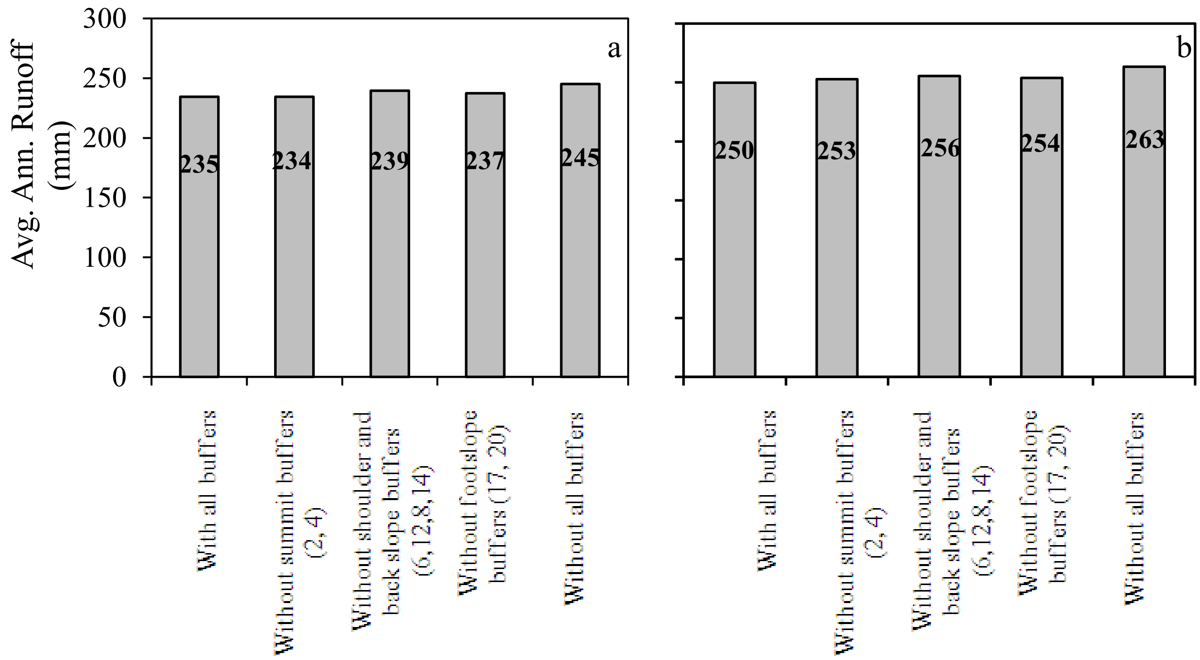

Figure 5. APEX model predictions for average annual runoff for agroforestry buffer (a) and grass buffer (b) watersheds, at the paired watershed study, Greenley Research Center, Missouri, USA, with varying buffers at summit, shoulder and back slope, and foot slope positions of the watershed landscape.

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PRODUCTION AND ECONOMICS OF PERENNIAL-BASED WOODY AND HERBACEOUS BIOMASS CROPS INCLUDING ALLEY-CROPPING SYSTEMS

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ABSTRACT

The emerging bioeconomy presents new opportunities for farmers and other land managers to improve economic return and reduce risk through the integration of bioenergy crops into the farming enterprise. This proposal will focus on understanding productivity and economics in perennial woody and herbaceous crops including alley-cropping systems. The objectives of this study are to 1) aggregate production data and refine enterprise budgets for perennial-based biomass cropping systems, and 2) integrate production and economic data into a decision support tool. Our goal is to explore ways that perennial-based biomass cropping systems can be deployed in order to maximize yield potential across a range of environments while improving economic outcomes. This information will be used to improve the accuracy of economic models and provide a basis for design of an applied decision support system that can be used by farmers and other land managers to make more informed decisions. This project will also create a common protocol for collection of yield and production data from across the region into a common database. In doing so, we will be able to provide short and long-term economic and production estimates to ensure that they reflect real-world data linked to local biophysical and economic conditions. We will develop a comprehensive strategy for communicating the outcomes of our research to a diverse set of stakeholders.

Keywords: perennials, economics, production

EFFECT OF SWITCHGRASS ON SHORTLEAF PINE GROWTH IN WEST-CENTRAL ARKANSAS

Ray Stoner, Randy King, George Rheinhardt and Alayna Jacobs

ABSTRACT

Growing switchgrass (*Panicum virgatum* L.) between rows of shortleaf pine (*Pinus echinata* Mill.) for biofuel may have potential as an agroforestry practice for landowners in western Arkansas. However, there is limited information on the effects on growth and production of shortleaf pine from competition of switchgrass interplanted between the rows. Objective of our study is to determine the effect of switchgrass on growth of shortleaf pine. The study is conducted at the USDA-Natural Resources Conservation Service Plant Materials Center in Booneville, Arkansas, USA on a Leadvale silt loam. Shortleaf pine was established in a block (14' x14'), double row (8' x 8') and single row (8' x 24') tree arrangement in January 2006. Stocking rate for block, double row and single row tree arrangement was 222, 227 and 226 trees acre^{-1}, respectively. Tree arrangements were planted as a randomized complete block with thee replications. Switchgrass was interplanted between tree rows in April 2006. Post frost measurements of tree height and diameter in November 2010 and 2011 were not affected by the switchgrass ($P>0.05$). However, diameter was significantly reduced in 2012 compared to control (no switchgrass) ($P<0.05$). It appears the decrease in tree diameter may have been attributed either to less leaf area caused by self pruning of lower limbs from shading of switchgrass or combination of shading and extreme drought conditions in western Arkansas in 2012. Future studies will evaluate varying degrees of canopy loss, effects of planting arrangements, canopy development, and management schemes on switchgrass production.

Keywords: switchgrass, shortleaf pine, alley cropping

EXPLORING THE HEALTH BENEFITS AND ECONOMIC OPPORTUNITIES OF THE BIOACTIVE COMPOUNDS ISOLATED FROM EASTERN REDCEDAR IN MISSOURI

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ABSTRACT

To explore health benefits and economic opportunities of bioactive compounds isolated from Eastern Redcedar (ERC), a widely spread tree species in Missouri, we integrated the interdisciplinary expertise in natural product chemistry, bacterial molecular genetics, medical microbiology, structural biochemistry, and biophysics to 1) elucidate the novel modes of action of the isolated bioactive compounds against a wide range of human and animal pathogenic bacteria including MRSA (Methicillin-resistant *Staphylococcus aureus*), and 2) develop a cost-effective and environmentally friendly pilot-scale bioprocessing production procedure through collaboration with our industrial partner. The mode of action of the antibacterial compounds was elucidated by studying the enzymatic degradation profiles, examining the effects of diterpenoids on polymerization of cytoskeleton cell division protein *FtsZ*, calculating diterpenoid-*FtsZ* binding kinetics using computational docking algorithms, comparing the sequence differences between induced resistant mutants and sensitive parent strain utilizing Illumina high throughput genomic sequence analysis. Our results have confirmed that inhibition of enzymatic degradation was not the antibacterial mechanism. Three diterpenoids-*FtsZ* binding pockets were tentative identified. In addition, mutations unique to the resistant strains were identified. Interestingly, no point mutation mapped to *ftsZ* or any other known cell division gene. Supercritical carbon dioxide extraction has shown to be an efficient and environmentally friendly extraction technique to isolate the bioactive compounds from ERC. This project will not only provide critical information for future drug design against drug-resistant pathogens, but also provide the opportunity to turn the abundant, low value, renewable materials from the ERC into a lucrative high tech industry in Missouri.

SOIL PHYSICAL AND BIOLOGICAL PROPERTIES IN A LONG TERM TEMPERATE ALLEY CROPPING SYSTEM

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ABSTRACT

Soil physical and chemical properties in the cropped areas and tree rows in alley cropping configuration varies greatly due to differences in litter quality and microclimate in areas under trees compared to those in the alleys. Soil properties greatly impact microbial diversity and function and thus in alley cropping systems, the microbial composition and diversity could be different between soils in tree rows and cropped areas. The objective of this study was to compare and contrast the soil microbial diversity and composition in the cropped areas and tree rows in a 21 year old alley cropping system. Soils samples were taken in three parallel transects to a depth of 10 cm in the tree row and at the middle of the alley in a silver maple (Acer saccharinum) alley cropping system with a companion maize (Zea mays) – soybean (Glycine max) rotation. Soil bulk density, %C, and %N were similar between the different transects while minor differences were observed between cropped areas and tree rows. No significant difference in microbial diversity was observed between the tree rows and cropped soil based on soil DGGE profiles, band richness (19.6 and 22.8) and Shannon-Weiner diversity (2.958 and 3.099) respectively. Identification of bacterial genera revealed dominance of gram +ve as well as gram –ve bacteria in both soil types. Ordination plot revealed no clustering effect based on location (transect) or on the cropping system in the different samples. Microbial diversity in cropped areas most likely were influenced by the expanding tree roots as well.

AUTHOR INDEX