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Evaluating Productivity of Southern Agroforestry for Fiber, Biofuels, and Wildlife Habitat

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Evaluating productivity of southern agroforestry for fiber, biofuels, and wildlife habitat

By

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Evaluating productivity of southern agroforestry for fiber, biofuels, and wildlife habitat

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Wildlife habitat values associated with agroforestry systems in Mississippi are not fully understood. Landscape matrix changes resulting in close location of various agricultural and tree crops can provide habitat more suitable for use by game wildlife. This study examined the feasibility of improving habitat value by adopting agroforestry alley cropping practices. A completely randomized block design was utilized to ascertain production values for two different even-aged crop trees, shortleaf pine (*Pinus echinata Mill*.) and loblolly pine (*Pinus taeda L*.), and four different agricultural crops, corn (*Zea mays L*.), switchgrass (*Panicum virgatum L*.), grain sorghum (*Sorghum bicolor L*.), and soybeans (*Glycine max L*.). Breeding bird surveys and camera surveys were used to quantify wildlife use and determine habitat improvement produced by this agroforestry management. If agroforestry land management improves wildlife habitat quality so hunters are willing to pay higher premiums, landowners can generate additional economic return from hunting leases.

Key words: Alley cropping, Game wildlife, Hunting, Mississippi

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CHAPTER I

LITERATURE REVIEW

Agroforestry Defined

Before the European settlement of North America, Native Americans utilized agroforestry systems much like subsistence farmers in other parts of the world and were more active as land managers than is commonly acknowledged (Anderson and Nabhan, 1991; Bainbridge, 1997). A common example an agforestry practice utilized by Native Americans was the use of fire to burn the landscape stimulating forage plant growth and directing animal movements (Biles, 1984; MacCleery, 1992). However, these practices and many others likely employed, such as small plot farming with several plants cultivated in symbiosis with one another, were not recognized as agroforestry until many years later. This primitive form of agroforestry has since accumulated hundreds of years of resource management experience and created an extensive knowledge on natural interactions and genetics to accomplish present agroforestry objectives (Biles, 1984).

When agroforestry was first described in the late 1970s, certain practices common in North American agriculture were identified as agroforestry: forest range and farm woodlot management, syrup production, plantations on marginal lands, and windbreak systems (Williams et al., 1997). Since the concept of agroforestry was identified, many traditional practices have been relabeled and new practices have developed (Williams et al., 1997). However, from the time that agroforestry practices were first described there has been strong debate over their true definition. The World Agroforestry Centre (ICRAF) defines agroforestry as a mixture of the following components: agri-silviculture, silvopastoral systems, agro-silvo-pastoral systems, and multipurpose forest tree production systems. Sinclair (1999) defined agroforestry as "the set of land use practices that involve deliberate combination of trees (including shrubs, palms, and bamboos) and agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence such that there are significant ecological and economic interactions between tree and agricultural components." Others have defined agroforestry simply as the intentional integration of annual and perennial crops on the farm (Holzmueller and Jose, 2012). Today, most agroforestry practices can be grouped into one of the following: (i) windbreak systems, (ii) silvopastoral systems; (iii) integrated riparian management systems; (iv) forest farming systems; and (v) inter cropping or alley cropping systems (Williams et al., 1997; Reitveld and Irwin, 1996; and Garret and Buck, 1997).

Agroforestry practices differ from traditional forestry or agriculture because they are intentional, integrated, intensive, and interactive in nature (Hill and Buck, 2000). Agroforestry does however conform to sustainable agriculture, as defined by the United States Department of Agriculture and the United States Congress. This definition of sustainable agriculture states, "sustainable agriculture is an integrated system of plant and animal production practices having a site-specific application that will, over the long term: satisfy human food and fiber needs; enhance environmental quality and the natural resource base upon which the agriculture economy depends; make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm operations; and enhance the quality of life for farmers and society as a whole (Gold, 2007).

Windbreak Systems

Windbreak agroforestry systems or shelterbelts are barriers placed on the land surface and used to reduce wind speed by obstructing wind flow patterns on both the windward and leeward aspects of the barrier. (Brandle et al., 2000). Windbreaks or shelterbelts have their origins in the mid-1400s when the Scottish Parliament urged the planting of tree belts to protect agricultural production (Droze, 1977). Windbreak programs were established in the United States following the Dust Bowl with the authorization of the Prairie States Forestry Project and have been established in other countries around the world (Brandle et al., 2000). Some of the many benefits of windbreak systems include: increased rates of growth and development in sheltered plants, reductions in wind speed and wind erosion, protection of livestock by lowering animal stress, improving health, increasing feed efficiency, and providing positive economic returns (Brandle et al., 2000; Atchinson and Strine, 1984; Quam et al., 1994).

The downwind area of effective protection will extend 10 to 20 times the height of the trees, provided windbreaks are established at right angles to the prevailing wind direction (Reitveld and Irwin, 1996). Using the general yield responses as described by Kort (1988), field windbreak systems that occupy between 5 and 6% of the crop field provide positive economic returns to producers based solely on the increased yields found in sheltered areas (Brandle et al., 1984, 1992, 2000). In modeling additional maize (*Zea mays*) yields required to offset cost of windbreaks in the Midwestern USA, Grala and Colletti (2003) state that additional maize yields necessary to break even vary significantly across windbreak scenarios, lifespans and lengths of the protected zone. However, the opportunity cost of extending a windbreak lifespan is relatively small and windbreaks with longer lifespan and larger protected zones are more likely to attain additional yields required for the practice to break even (Grala and Colletti, 2003).

Windbreaks have other ecological implications that can have benefits which support the operation of the farm such as snow control, farmstead windbreaks which provide protection for the working and living human environments of the farm, increased property values, and wildlife habitat (Brandle et al., 2000; Wight et al., 1991; Williams et al., 1997). Windbreak and riparian areas offer the only woody habitat for wildlife in many agricultural areas (Johnson et al., 1994).

Silvopastoral Systems

Silvopastoral systems or silvopastoralism is an agroforestry practice that intentionally integrates trees, forage crops, and livestock into a structural practice of planned interactions managed intensively to simultaneously produce wood products, high quality forage, and livestock on an environmentally sustainable basis (Clason and Sharrow, 2000). By producing cattle along with timber, landowners can diversify their income, thus reducing exposure between long harvest periods (Stainback and Alavalapati, 2004). Silvopasture offers a means of placing degraded and unimproved pasture into productive forests while allowing the landowner to retain some aspects of pasture function (Williams et al., 1997). Silvopasture systems can offer landowners the potential to produce more income per land acre, more control in stabilizing income, and the ability to dictate understory vegetation (Mosher, 1984). These benefits come at the cost of a higher level of management than with livestock or trees alone and increased investments in newly added components (Mosher, 1984).

Other benefits associated with silvopastures include nutrient cycling in the system and reduced soil erosion (Mosher, 1984). In Florida, water soluble phosphorus was less prevalent in soil profiles managed under silvopasture when compared to adjacent pasture (Nair et al., 2007). Nair et al. (2007) also noted that the capacity of soils under silvopasture to receive additional phosphorus is greater than under treeless pasture and may be better in reducing nutrient loss from soil to surface water.

In Florida, combining slash pine with cattle production is not competitive with conventional ranching, but combining longleaf pine production with cattle ranching is more profitable than conventional forestry or cattle ranching (Stainback and Alavalapati, 2004, and Stainback et al., 2004) Citing longer rotation lengths, pine silvopasture practices in the southeastern United States could have as much as a 4.5% rate of return on investment and shorter rotations can have rates of return from 0.5 to 3.5% (Lundgren et al., 1982). In an economic analysis of a silvopastoral system in Mississippi, Grado et al. (2001) found that silvopastoral treatments compared favorably with some grazing treatments. When revenues from tree harvests are considered, the outcomes improved even further over commercial tree operations (Grado et al., 2001). In addition, fees from hunting were possible and provide for added value (Grado et al., 2001). Alavalapati et al., 2004, stated that in Florida, attributes of landowners with silvopasture such as willingness to pay estimates for wildlife habitat improvements ranged from $41.06 to $49.68 per year per household for five years, and that adoption of silvopasture was more likely if landowners currently used their ranches for recreational hunting. Trees in silvopasture often grew faster than trees under conventional forest management (Gibson et al., 1994; Hughes et al., 1965; Sharrow, 1995; Clason and Sharrow, 2000). Burner (2011) found that loblolly pine planted in a configuration suited for alley cropping or silvopasture had heights equal to those of standard plantation plantings but that diameter at breast height (DBH) was significantly smaller in plantings designed for silvopasture or alley cropping configurations in Arkansas. Burner (2011) also observed two and three row designs would, "offer the best compromise for combining timber and alley crop/livestock production from establishment to mid-rotation." Conifers are the primary tree component in most silvopastures as hardwoods constitute a smaller total area of silvopature practice tree components because hardwoods tend to be more palatable to livestock and thus susceptible to damage while also valuable as a potential source of forage (Clason and Sharrow, 2000).

Integrated Riparian Management Systems

The USDA Forest Service (Welsch, 1991) defines a riparian area as: "the aquatic ecosystem and the portions of the adjacent terrestrial ecosystem that directly affect or are affected by the aquatic environment. This includes streams, rivers, lakes, and bays and their adjacent side channels, floodplain, and wetlands. In specific cases, the riparian area also may include a portion of the hillside slope that directly serves as streamside habitat for wildlife." Integrated riparian management systems or riparian forest buffers are "an area of trees usually accompanied by shrubs and other vegetation, that is adjacent to a body of water and which is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering, and converting sediment, nutrients, and other chemicals, and to supply food, cover, and thermal protection to fish and other wildlife" (Palone and Todd, 1997; Schultz et al., 2000). Riparian forest buffers function to improve water quality, recharge groundwater, provide streambank and channel stability, habitat for terrestrial and aquatic wildlife, floodwater abatement, floodplain protection, sequester large amounts of carbon, improve landscape aesthetics, provide harvestable products including fiber and nonfiber products, recreational opportunities, market and nonmarket benefits, and provide wind and visual barriers (Josiah and Kemperman, 1996; Schultz et al., 2000; Shultz et al., 2004). Studies conducted in Missouri clearly indicate that that agroforestry and contour strip practices, when incorporated directly into corn-soybean watersheds can be used to effectively reduce runoff volume and sediment and nutrient loss (Udawatta et al., 2002).

Forest Farming Systems

Forest farming systems entail creating suitable microenvironments in natural forest stands for growing specialty crops typically sold for ornamental, culinary, or medicinal uses (Garret and Buck, 1997). Examples of this intentionally created and intensively managed system include: maple syrup production, medicinal plants (ginseng, goldenseal, blue cohosh, and bloodroot), craft materials, mushrooms, native fruits, nuts, berries, apiculture products, aromatics, and pine straw (Williams et al., 1997; Reitveld and Irwin, 1996; Hill and Buck, 2000). Forest farming can provide supplemental income to a family's farm economy, yield significant cash flows at times of the year when agricultural crops may not be salable. In addition, harvestable non-timber products from the ecosystem leave the bulk of the forest intact to provide watershed protection, clean water, reduced erosion, continual production of oxygen, carbon sequestration, physical barriers to inclement climatic forces, and habitat for wildlife (Hill and Buck, 2000).

Alley cropping Systems

Alley cropping is the main agroforestry practice associated with this project and thus it will be examined further. Alley cropping consists of planting trees at spacings that allow the cultivation of crops among them (Williams, et al., 1997). Garret (1994) broadly defined alley cropping as the planting of rows of trees (single or multiple), at wide spacings, creating alleyways within which agricultural or horticultural crops are produced. There are many possible combinations for alley cropping systems. Christmas trees, many species of pine cultivated for timber production, high value hardwoods such as pecans (*Carya illinoensis*) and black walnut (*Juglans nigra*) with markets for both wood and nuts can be integrated into alley cropping systems (Workman et al., 2003 and Garret and McGraw, 2000). Numerous studies have documented the cultivation of tree and agricultural crops, e.g. corn soybean, milo, wheat, barley, potato, oat, pea, and cotton (Garrett and McGraw, 2000 and Allen et al., 2004). By intercropping annual and perennial crops that yield varied products and revenues at different times, a landowner can more effectively use available space and resources (Garrett and McGraw, 2000). This can be partially financially beneficial during the early years of timber or fruit tree production because revenues can be obtained before or during the maturing of timber or fruit crops (Garrett and McGraw, 2000). Haying may be a consideration for generating income as trees develop and begin to partially shade the alley (USDA, 2002, and Garret and McGraw, 2000).

In addition to the direct financial benefits, alley cropping also contributes to soil and water conservation, improved wildlife habitat, filtering and biodegrading of excess nutrients and pesticides, microclimate moderation, and improved landscape aesthetics

(Workman et al., 2003, and Garret, 2001). The USDA (2002) affirms this finding and states that soil erosion can be reduced with alley cropping because trees in an alley cropping system take up excess water and create a stable zone of permanent vegetation. Agroforestry practices have often been shown to increase levels of wildlife biodiversity on farm land and have been hypothesized to play a supporting role in conservation of biodiversity in remnants of natural habitat (McNeely and Schroth, 2006). Alley cropping practices can be customized to reflect landowner needs and site potential (USDA, 2002). Valuations of alley cropping utilizing marginal quality land have demonstrated land expectation values comparable to those of tradition row crop agriculture (Lottes, 1985; Garrett and Buck 1997).

In the United States, forestry and agriculture are both faced with the challenge of meeting an increasing demand for goods, as well as an expanding array of ecological services, such as clean water, recreation, soil conservation, and wildlife habitat, often from the same lands (Schoeneberger and Ruark, 2003, Ruark, 2006). Agroforestry practices can reduce erosion, improve water infiltration and quality, moderate microclimate, enhance nutrient cycling, and provide wildlife habitat (Sanchez, 1995). At the same time, agroforestry practices can be more beneficial to the landowner than traditional practices (Garret et al., 2000). The USDA (2002) states, “Agroforestry can contribute substantially to generate the ecosystem diversity and processes that are so important to long-term sustainability and profitability.” Adoption of agroforestry systems includes influencing factors such as improved market identification and access, policy change and support, increased research, institutional, and outreach support (Josiah and Kemperman, 1998).

Biofuel Production in Agroforestry Systems

The need to reduce food and crop surpluses, find productive use of agricultural land in industrialized countries experiencing overproduction of food, limit dependence on foreign oil, and insight that industrial practices and consumption patterns seriously damage the environment has raised interest in biomass' potential as an important domestic, renewable resource to meet demand for environmentally benign feedstocks in industry as well as fuel production (Berndes, 2006). Biomass based energy, created from renewable sources, may be a solution to this crisis and can take many forms as a source of fuel such as: bioethanol, biodiesel, or biologically synthesized hydrogen (Rupprecht, 2006; Johnston and Holloway, 2007; Perez-Verdin et al., 2009).

"Within farming systems, biomass production can occur simultaneously with the management of marginal lands, riparian buffer strips, manure management or other production systems, and the biomass can be used for on-farm energy, for sale as bedding, or as forage" (Williams, et al. 1997). Agricultural crops with the potential for bioenergy production and energy development are sugarcane (*Saccharum officinarum L.*), corn (*Zea mays*), soybeans (*Glycine max*), and grain sorghum (*Sorghum bi-color*). Agricultural crops or starch-based crops, though recent studies indicate a positive net fossil energy value and reduced CO2 emissions, are highly valued in the food industry and involve intensive management that requires significant water supplies, cause soil erosion, contribute to loss of biodiversity, and create nitrate pollution, possibly making them less desirable as a displacer of non-renewable energy sources (Perez-Verdin et al., 2009).

Feedstocks other than agricultural crops with the potential for energy development include lignocellulosic or cellulose biomass, the largest potential feedstock for ethanol, which can be derived from timber harvests or traditional agriculture crop residues (e.g. corn sotover, crop straws, sugar cane bagasse), herbaceous crops (e.g. alfalfa (*Medicago, L.,*) switchgrass (*Panicum virgatum, L.*)), short rotation woody crops (e.g. willow (*Salix nigra*), hybrid poplar (*Populus sp.*), forestry wastes or residues, wastepaper, and other wastes (Kim, 2007 and Perez-Verdin et al., 2009).

Corn Ethanol Production

America is the world's largest corn producer, profitably marketing record crops of corn in recent years as demand for feed corn has expanded with rising incomes for more people overseas (Avery, 2006). Currently, the United States produces the majority (90%) of its biofuels from corn grain, which is grown with some of the highest fertilizer inputs of any major U.S. crop and the highest inputs of any biofuel crop (USDA NASS 2007, NAS 2008). A voluminous increase in ethanol production using current cornstarch-based technology may not be practical because corn production for ethanol will have significant arable land requirements competing for limited agricultural land needed for food and feed production (Sun and Cheng, 2002). High nitrogen inputs from crops, particularly corn, in the Mississippi watershed are implicated in the expansion of the hypoxic zone in the Gulf of Mexico (Rabelais et al. 2002; NAS 2008).

Given all the inputs, corn ethanol delivers barely more energy than it takes to make it (Avery, 2006; Pimentel and Patzek, 2005; National Geographic). The United States already uses its highest quality lands for crop production and clearing forested lands for crop production would return lower crop yields on newly cleared lands and decrease biodiversity (Avery, 2006). The world's food and feed demand is set to double by 2050 with a human population peak between 8 and 9 billion by 2040 (Avery 2006).

All of these factors combine to make corn a less attractive choice as a biofuel solution to a possible energy crisis. However, in a review of several studies, corn ethanol does reduce fossil fuel consumption when used to displace gasoline (Hammerschlag, 2006).

Grain Sorghum Ethanol Production

Grain sorghum is another agriculture crop that is a viable feedstock for bioethanol production though little research has been done on differing genotypes and varying ethanol yields (Wang et al., 2008). Grain sorghum has greater resistance to drought than most agricultural crops in the United States (Paterson et al., 2009). Thus, the crop can be cultivated in areas with reduced yields or conditions unsuitable for corn or soybean production. Grain sorghum is technically acceptable, fits infrastructure already in place, and can be economically viable for ethanol production making it a possible contributor to the fuel ethanol requirements in the United States (Wang et al., 2008, and Wu et al., 2007). In a study of the feasibility of an ethanol plant in Texas, financial projections for plants utilizing grain sorghum showed greater potential for generating interest from equity investment over plants utilizing corn as a feedstock (Herbst et al., 2003).

Switchgrass Biofuel Production

Switchgrass, a perennial warm season C4 native grass of North America, growing from 55 degrees North latitude to central Mexico (Lewandowski, 2003). Switchgrass has been selected by the Department of Energy for research as a model bioenergy crop and is compatible with existing farming operations over much of the United States (McLaughlin, 2002). Switchgrass has been explored more extensively than most feedstocks, which has led to improvements in yield and energy extraction including the development of site-specific agricultural best practices (Parrish and Fike 2005, Groom et. al. 2008). Other benefits associated with switchgrass cultivation include less intensive agricultural management practices, reductions in agrochemical consumption and positive effects on soil and wildlife quality (Dunn et al., 1993). Hohenstein and Wright (1994) estimated a 95% reduction in soil erosion rates and a 90% reduction in pesticide use for switchgrass relative to annual row crops corn and soybean. Suitable grassland bird habitat is one of the positive impacts on wildlife that would be provided by switchgrass cultivation (Roth et al., 2005). Switchgrass is a promising feedstock for bioethanol production, thermal energy conversion, and pulping applications. The positive environmental benefits associated with switchgrass include enhancement of wildlife diversity, improvement of soil and water quality, reduced pesticide use and carbon sequestration (Keshwani and Cheng 2009).

Lignocellulosic Ethanol Production

Technologies such as lignocellulsoic biomass for ethanol fuel production and algal biomass feedstock fuels are developing and could provide alternative energy solutions. Cellulosic technology will almost certainly be required for the large-scale use of ethanol for fuel (Farrel et al., 2006). Future analysis of fuel ethanol should more carefully evaluate ethanol production from cellulosic feedstocks because cellulosic ethanol production is undergoing major technological development and because the cultivation of cellulosic feedsocks is not as far advanced as corn agriculture, suggesting more potential for improvement (Farrel et al., 2006).

Forest residues are a viable raw material for cellulosic ethanol because they can be produced from a widespread resource base and have relatively low production costs

(Perez Verdin et al., 2009). In Mississippi four types of woody biomass feedstock: logging wastes, small-diameter trees, mill residues, and urban waste totaling 4 million dry tons were estimated to produce 1.2 billion liters of ethanol each year (Perez-Verdin et al., 2009).

Algae grown in bioreactors or in large ponds can be utilized as a biomass feedstock for the production of biologically synthesized hydrogen as an alternative fuel source or as a high energy yielding feedstock for biodiesel fuel production (Groom, 2008, Rupprecht, 2006, and Sheehan, 1998). Algal biomass production is also advantageous because production can occur on non-arable lands eliminating competition with food production and could occur using marine algae or cyanobacteria, eliminating freshwater use (Rupprecht, 2006, and Sheehan, 1998).

Focusing on research questions such as how to produce biofuels without degrading natural habitats, how to manage production lands for both economic and ecological sustainability, and how biofuel cultivation might be used to restore severely degraded lands, conservation biologists can influence biofuel policy in meaningful and powerful ways. Local growing conditions and agricultural practice will influence strongly the impacts of any biofuel crop. Biofuels that require fewer inputs, use native species, and emphasize perennial species, particularly polycultures or multiyear rotations, will be more biodiversity friendly than energy intensive monocultures of annual crops (Groom et al., 2007). CO_2 emissions may significantly increase if forested lands are cleared for energy crops (Giampietro et al. 1997; Junginger et al. 2006). Conservation tillage or non-tilling farming techniques are also being stressed to reduce erosion rates and enhance soil fertility (Groom et al. 2006).

Soybean Biodiesel Production

Soybean biodiesel has major advantages over corn grain ethanol. Biodiesel provides 93% more usable energy than the fossil fuel energy needed for its production, reduces greenhouse gases by 41% compared to diesel, reduces several major air pollutants, and has minimal impact on human and environmental health through N, P, and pesticide release (Hill et al., 2006). An inherent problem with soybean biodiesel production is that each soybean acre produces approximately 40 bushels of soybeans, or one-third of the grain yield of corn (Avery 2006). This will make replacement of fossil fuel with soybean biodiesel unfeasible. However, biodiesel can also be produced from other sources such as palm oil, sunflower oil, rapeseed oil, as well as naturally occurring vegetable oils and animal fats, though these other sources will still not likely be enough to replace global fossil fuel demand (Johnston and Holloway, 2007).

Wildlife Habitat in Agroforestry

The economic benefits of agroforestry or alley cropping can be derived from several sources. These benefits can come from decreasing the need for chemical, water, energy, and/or labor inputs, and revenues from the crops planted in the alleys, tree harvest, livestock sales, specialty crop harvest (i.e. nut production, pine straw, forest botanicals, apiculture, and carbon sequestration credits), or leasing to hunters (Garret and McGraw 2000, Lassoie and Buck, 2000, and Grado, 2004). Crop and timber values will be based upon market valuation at the time. Farmers who diversify by growing more than one type of crop are in a better position to weather the storms of market downturns or crop failure (Workman et al., 2003).

Leasing land for hunting is a growing market. Hunting has become an important income source for many private landowners, paying for property taxes and some management expenditures in the southern US (Jones et al., 1998). However, this opportunity is not realized by all the private landowners because only 14% of surveyed landowners viewed enhancement of wildlife habitat as a benefit associated with agroforestry systems (Zinkhan and Mercer 1997). Another study reported that many landowners have experienced increased wildlife return with diversification of system components over time and many generated profits from developing recreational and hunting enterprises on their land (Workman and Nair 2002). Only few studies have examined the monetary aspects of wildlife or pine straw production for agroforestry systems (Grado and Husak, 2002).

Previous works have also noted the lack of knowledge about the benefits of alley cropping in controlling erosion or improving food and habitat for wildlife (Garret and McGraw 2000). Garret and McGraw (2000) also note that incorporation of alley cropping into and agricultural landscape increases the habitat diversity for wildlife which improves habitat conditions and increases wildlife use. This fact would be true of other agroforestry practices with their inherent nature of creating landscape diversity. Tree species selection in agroforestry practices such as alley cropping can provide protective corridors for wildlife movement with linear plantings and the incorporation of fruit-bearing trees can provide numerous wildlife benefits such as a food source (Garret and McGraw 2000).

Further studies are needed to determine the specific wildlife benefits attributable to varying agroforestry practices in different regions. Yahner (1982) studied avian use of shelterbelts in Minnesota, and notes these man-made, spatially restricted management practices were beneficial to avian communities in intensively farmed regions especially when certain tree species were used in their creation. One recent study concluded that morning dove abundance increased on silvopastoral sites planted with corn grazed by cattle when compared to other sites managed traditionally (Manning, 2005).

In a Florida longleaf pine (*Pinus palustris*) silvopasture red-cockaded woodpecker (*Picoidel borealis*) habitat may be created and enhanced by cattle grazing of understory vegetation increasing the associated land value and environmental improvement (Stainback and Alavalapati, 2004). The relationship between forests, agricultural crops, and wild biodiversity can be made most productive through adaptive management approaches that recognize local knowledge and practice incorporating ongoing research (McNeely and Schroth, 2006). Integrated management for diverse products over time, optimal use of production and space helps farmers increase revenue streams, promote more efficient use of natural resources, and ensure their sustainable use into the future (Workman and Nair, 2002).

Summary

Through the application of agroforestry's alley cropping principles, traditional agriculture crops can be transformed into combinations of trees and crops without financial loss to the owner and with much gain to society (USDA 2002). Landowners must be educated that if they practice alley cropping the accrued benefits, including profits earned, will offset the costs. Other benefits of agroforestry practices not mentioned previously in this review include: reduced flooding, filtering and biodegrading of excess nutrients and pesticides, diversified rural economies, and restoration of degraded ecosystems (USDA, 2002). These "other" benefits may not generate income for the landowner that adopts and practices agroforestry land management techniques but they are important positive impacts for society. Even given agroforestry's known value to conservation and the overall land management values it is capable of providing, it is unlikely that it will be adopted on even marginal lands in intensive agricultural areas such as the Lower Mississippi Alluvial Valley and WRP enrollment seemed more likely on those marginal lands (Frey et al, 2010). Revenues from agroforestry could also be supplemented by carbon sequestration credits as this has the potential to develop into a growing market for forest landowners (Frey et al., 2010).

If cellulosic ethanol is to become the fuel of the future, several grasses suited to agroforestry practices would be ideal crops for the production of fuel feedstocks, however, these feedstocks and crops may not be necessary if already widely available agricultural crop residues can be used similarly (Frey et al., 2010).

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CHAPTER II

ALLEY CROPPING PRODUCTION

Introduction

Conifer cultivation in other agroforestry practices such as silvopasture is common in the southeastern United States and has been shown to be more profitable when compared to land-use practices concentrating on production of a single output (Alavalapati et al., 2004, Clason and Sharrow, 2000, and Grado, 2001). Similarly, alley cropping practices in other regions of North America (most notably the Midwestern United States) consist primarily of hardwood tree cultivation in association with various agricultural crops including: corn (*Zea mays*), soybean, (*Glycine max*), milo (*Sorghum bicolor*), wheat (*Triticum* L.), and others (Garret and McGraw, 2000). Agroforestry alley cropping in the southeastern United States is practiced but not widely acknowledged by landowners (Workman, 2003). Alley cropping practices used in this region primarily consist of pecan (*Carya illinoinensis* (Wangenh)) intercropped with hay or clover, or vegetable production in the alleys (Workman, 2003). However, little information exists on conifer cultivation in alley cropping systems though the opportunity is excellent (Garret and McGraw, 2000).

Pine alley cropping systems are becoming more popular in the southern United States (Zamora et al., 2009). However, many needs remain to facilitate large scale usage by landowners. This is evidenced by a survey of landowners in Alabama and Florida which cites a lack of familiarity, demonstrations, and information as a major obstacle to adoption of agroforestry practices (Workman, 2003). Zamora et al. (2009) recognized the need for information on the interactive dynamics of nitrogen in southern pine agroforestry. In an examination of a 9 year old loblolly pine (*Pinus taeda*) alley cropping practice with rotational crops of annual ryegrass (*Lolium L.*) and pearl millet (*Pennisetum glaucum* L.) in Arkansas using subsoiling or trenching to prevent tree root growth into the alley, pearl millet herbage yield increased but the increase was not enough to offset costs of subsoiling, especially if tree growth is reduced (Burner et al., 2009).

There is a need for research on the feasibility and growth and yield responses of producing pine trees in association with agricultural crops in the early years of a southern alley cropping agroforestry practice. This is especially prevalent as communities around the world strive to produce crops for a growing population and as an alternative source of fuel in an environmentally friendly manner on lands that may be considered marginal.

Methods and Materials: Study I

Study one was alley-crop cultivated and monitored from November 2007 to September 2009. The site was located on the Mississippi Agriculture and Forestry Experiment Station Northeast Branch (the "Holly Spring experiment station") seven miles north of Holly Springs, MS. The Holly Springs experiment station is located in the north central hills geographic region of Mississippi on the edge of the loess hills with slopes of 2 to 5 percent. Soils on the Holly Springs experiment station are Grenada silt loam and Providence silt loam series, in the Alfisol soil order with a fragipan approximately two feet deep (Kushla, 2009). Average annual rainfall for Holly Springs

MS is 56 inches. Average high temperatures for the region are 90 F while average low temperatures reach 27 F. The area on which the study was developed was previously used for row crop agriculture trials and cultivation of corn to sustain a dairy operation (Kushla, 2009).

Loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) bareroot 1-0 seedlings were planted on the site in March of 2005. Planting of trees was structured in equidistant rows of homogenous species in sets of two at a ten foot by seven foot spacing with a forty-foot alley between respective sets of rows. Rows of trees were oriented in a north-south direction. Four replications of each row were planted on the same study area but were not contiguous. Trees were mechanically planted with no subsoiling prior to planting.

Within the alley the agricultural crops: corn (*Zea mays*), milo (*Sorghum bi-color*), soybeans (*Glycine max*), and switchgrass (*Panicum virgatum* L.) of the Alamo cultivar were assigned to agronomic scale research plots of 13 feet by 100 feet directly adjacent to either side of the 2 row tree planting in a complete randomized block design with covariate analysis. Planting occurred in April of 2007 and in May of 2008 and 2009. See Appendix C for a diagram of the study design and Appendix F for photographs of the study. Crops were planted utilizing no-till agricultural practices. Planting rates for respective species were as follows: corn, 28,000 seed/acre with 36 inch spacing and 2 inch depth; grain sorghum, 6 lbs. per acre at a depth of 1.5 inches; soybean, 150,000 seed/acre with 36 inch spacing and ½ inch depth; switchgrass, 6 pounds of Pure Live Seed (PLS) with a no-till grain drill into a conventionally tilled stale seed bed at ¼ inch depth and cultipacked following planting. Corn and grain sorghum received 450 lbs/acre of ammonium nitrate (34-0-0) at planting. No other fertilizer was applied to any other crop plots as per soil test recommendations. Corn and grain sorghum received herbicide applications of Dual Magnum at a rate of 1.33 pt/acre, Atrazine at a rate of 2 qt/acre, and Roundup Weathermax at a rate of 32 oz/acre. Soybean and switchgrass received an application of Roundup Weathermax at a rate of 32oz/acre to control existing weeds at planting. Roundup Weathermax was re-applied to corn and soybean plots at a rate of 22 oz/acre as needed for in-season weed control. Gaps between the crop plots serving as buffer zones were used as control treatments in the complete randomized block design. Cropping alleys were randomly subsampled for 30-ft^2 (10-ft x 3-ft swath) on the corn and 1-ft^2 on the grain sorghum. There were no soybeans or switchgrass to harvest either year.

Pine trees adjacent to each agricultural crop plot assigned to the complete randomized block design and each buffer zone serving as a control were measured. Ten trees were randomly selected for measurement on each of the two rows lying between the adjacent identical agricultural crop plots cultivating the same agricultural crop. Trees were not sampled ten feet on either side of the crop plot edge to reduce edge effects. Measurements occurred during a period of three months from January to March of 2008 and 2009 after the trees had formed a dormant bud and before the dormant bud was broken in the spring. Ground line diameter (GLD) was measured using calipers placed and read at ground level for each tree measured. Height (HT) of the trees was taken at the time of the basal diameter measurement using meter sticks. A calibrated height pole was used after the height of trees exceeded three meters. Measurements for trees were collected in Metric units and converted to English units in anticipation of publication in local Extension guidance papers. Row crops were harvested using standard harvest equipment for each specific crop and the yields obtained were converted and extrapolated to pounds per acre.

Methods and Materials: Study II

Study 2 was cultivated and monitored on the Mississippi Agriculture and Forestry Experiment Station Pontotoc Ridge Flatwoods Branch (“Pontotoc experiment station”) located approximately seven miles south of Pontotoc, MS. The Pontotoc experiment station is located in the Pontotoc Ridge Flatwoods geographic region of Mississippi. Soils on the Pontotoc experiment station include the Atwood silt loam series in the Alfisol soil order (Kushla, 2009). Average annual rainfall for Pontotoc Experiment Station is 58.96 inches. The average high temperature for Pontotoc is 91 F while average low temperatures reach 30 F. The area on which the study was established was previously used for row crop agriculture trials.

Bare root 1-0 loblolly pine seedlings were planted on the site in March of 2008. This planting was a re-establishment of the pine trees due to low survival following planting the previous year. In 2007 loblolly pine seedlings were planted in an identical manner but sustained low precipitation during the growing season possibly leading to poor survival. Trees were hand planted with a dibble bar into rows which had been subsoiled prior to planting. Trees were planted in groups of six rows at a ten foot by seven foot spacing oriented north to south with a twenty foot alley between each set of six rows of trees. This planting was replicated four times in a completely randomized block design on the study area. A banded application of Ouster herbicide at a rate of 12oz/A was administered to the pine seedlings in May of each year.

Switchgrass, Alamo cultivar, was planted in the 20 foot alleys between the sets of six rows. To establish switchgrass 6 pounds of Pure Live Seed (PLS) were drilled with a no-till grain drill into a conventionally tilled stale seed bed at ¼ inch depth and cultipacked following planting. Select herbicide was applied at a rate of 16oz/ac to the alley prior to planting the switchgrass seed to control existing weeds at planting. Various rates of chicken litter were applied in February of each year to the alleys via a USDA chicken litter spreader calibrated to distribute the given amount. The rates applied were 0 kg/ha, 2,677 lb/ac (3000 kg/ha), 6,691 lb/ac (7500 kg/ha), and 10,706 lb/ac (12000 kg/ha). Tree growth parameters are the response variable tested against two levels of factors regarding the chicken litter application. The two levels of these factors are the rate of chicken litter applied and the distance of the planted tree from the application site. The application of litter in the alleys had been practiced with the previously attempted establishment of the same practice in which the trees were re-planted and may have residual effects on the newly established planting. No broiler litter was applied in 2008. Attempts at establishing switchgrass were also undertaken in the years prior to re-establishment of the trees but were also unsuccessful.

Pine trees were measured at the time of planting in March of 2008 and in January of 2009 after the trees had formed a dormant bud and growth had ceased for the season. Trees were randomly selected from the rows which contained 13 total trees per replication row. Random numbers were selected to determine six of the thirteen trees to be measured. The same trees were measured again the following year. Ground line diameter (GLD) was measured in millimeters using calipers placed and read at ground level for each tree measured. Height (HT) of the trees was taken at the time of the basal diameter measurement using meter sticks. Measurements were taken in metric units and later converted to English units. The size measurements (GLD, HT, VOL) of trees at the time of planting served as the covariate for statistical analysis.

Results: Study I

Agricultural crop yield responses for years one through three are listed in Table 1. Responses listed as bushels per acre (Bu/A) indicate actual harvestable crop yields whereas responses listed as pounds per acre (lb/A) indicate a forage or fodder yield for livestock. Yields were greatest in 2007 and lowest in 2008 for both corn and grain sorghum. In 2009, no yield was recorded for any harvestable agricultural crop other than forage or fodder yields.

Table 1 Mean agricultural crop yields in years 2007, 2008, and 2009 adjacent to both species of pine trees

Agricultural Crop	Loblolly (*Pinus taeda*)	Shortleaf (*Pinus echinata*)
2007		
Corn (*Zea mays*)	4871.4 (lb/A)	4,368.6 (Bu/A)
Soybean (*Glycine max*)	--	--
Switchgrass (*Panicum virgatum)*	--	--
Grain sorghum (*Sorghum bi-color*)	5370.4 (lb/A)	7005.6 (lb/A)
2008		
Corn (*Zea mays*)	1.3 (Bu/A)	1.7(Bu/A)
Soybean (*Glycine max*)	--	--
Switchgrass (*Panicum virgatum*)	7840.2 (lb/A)	7078.5 (lb/A)
Grain Sorghum (*Sorghum bicolor*)	896 (lb/A)	683.2 (Bu/A)
2009		
Corn (*Zea mays*)	--	--
Soybean (*Glycine max*)	--	--
Switchgrass (*Panicum virgatum*)	10527 (lb/A)	7986 (lb/A)
Grain Sorghum (*Sorghum bicolor*)	27225 (lb/A)	30492 (lb/A)

Measurements are given in pounds (lb) per acre (A).

Tree growth responses to agricultural cropping treatments are presented in Tables 2 and 3. Ground-line diameter for loblolly pine ranged from 2.79 to 2.55in among crop plots in 2009 and from 1.61 to 1.85in among crop plots in 2008. Height of loblolly pine ranged from 97.32 to 107.62in in 2009 and from 60.35 to 68.66in in 2008. Ground-line diameter of shortleaf pine ranged from 1.45 to 1.60in in 2008 and from 2.30 to 2.09 in 2009. Height of shortleaf pine ranged from 47.28 to 55.39 in 2008 and from 70.28 to 76.97 inches in 2009. Table three displays the differences in growth between years 2008 and 2009.

Table 2 Mean pine tree growth in years 2008 and 2009 adjacent to crop treatments

Agricultural Crop	--------Tree Species --------					
	Loblolly			Shortleaf		
	--------Measurement Metric--------					
	HT	*GLD*	*VOL*	*HT*	*GLD*	*VOL*
2008						
Control	68.66	1.85	64.45	53.58	1.56	40.68
Corn (*Zea mays*)	64.37	1.61	54.86	54.25	1.50	35.94
Soybean (*Glycine max*)	64.80	1.72	64.49	47.28	1.45	30.22
Switchgrass (*Panicum virgatum*)	62.56	1.75	58.06	52.40	1.51	34.12
Grain sorghum (*Sorghum bi-color*)	60.35	1.64	46.78	55.39	1.60	42.43
2009						
Control	107.64	2.79	238.31	75.19	2.22	110.00
Corn (*Zea mays*)	102.48	2.68	221.60	76.97	2.21	109.45
Soybean (*Glycine max*)	100.90	2.71	222.91	69.96	2.09	89.72
Switchgrass (*Panicum virgatum*)	101.26	2.68	212.14	77.60	2.30	115.26
Grain sorghum (*Sorghum bi-color*)	97.32	2.59	182.94	78.15	2.30	117.97

Measurements: Height (HT) and ground line diameter (GLD) are given in inches, and volume index (VOL) in in^3.

Table 3 Mean pine growth change between years 2008 and 2009 adjacent to crop treatments

Agricultural Crop	Loblolly			Shortleaf		
	HT	GLD	VOL	HT	GLD	VOL
Control	38.98	0.93	170.85	22.60	0.67	69.32
Corn	38.11	1.07	266.74	22.72	0.71	73.52
Grain Sorghum	36.97	0.94	136.16	22.68	0.65	59.50
Soybean	36.10	0.99	160.43	25.20	0.79	81.14
Switchgrass	38.70	0.93	154.07	22.76	0.70	75.54

Measurements: Height (HT) and ground line diameter(GLD) in inches, and volume index (VOL) in in^3.

A volume index (VOL) for each tree was created as follows: VOL = $(1/3)*\pi*radius(cm^2)*$ HT . Measurements calculated in centimeters were converted to inches. This standard equation was adapted for use from Richard Burington, 1901. Volume indexes are listed in Tables 2 and 3. Volume indexes were statistically tested for effects from the associated crop treatment but no significant differences were found at the alpha $\alpha=0.05$ level of significance.

Tables 4 through 7 are ANOVA tables with mean square calculations generated using the GLM procedure utilizing SAS statistical software (SAS 9.2, SAS Institute, Inc. Cary, NC). Mean squares are provided for ground-line diameter and height for each species, year, and respective crop treatment. Neither height, nor ground line diameter, nor volume of tree growth were significantly affected by the crop treatments within year and species at alpha $\alpha=0.05$ level of significance.

Table 4 Loblolly analysis of variance for 2008 of height and ground line diameter growth by crop treatment

	Df	GLD Mean Square	Total Height Mean Square
Model	12	1103.68	7685.58
Crop Trt.	4	495.15	5193.81
Aspect	1	162.45	55.48
Crop Trt. X Aspect	4	44.37	952.64
Error	385	108.38	1615.99

Analysis of Variance measurements were conducted in metric units rather than converted English units.

Table 5 Loblolly analysis of variance for 2009 of height and ground line diameter growth by crop treatment

	Df	GLD Mean Square	Total Height Mean Square
Model	12	1013.57	14829.1
Crop Trt.	4	373.7	9019.24
Aspect	1	418.9	4880.35
Crop Trt. X Aspect	1	162.17	2446.41
Error	385	201.73	3101.7 (384 df)

Analysis of Variance measurements were conducted in metric units rather than converted English units.

Table 6 Shortleaf analysis of variance for 2008 of height and ground line diameter growth by crop treatment

	Df	GLD Mean Square	Total Height Mean Square
Model	12	407.52	10093.30
Crop Trt.	4	303.02	4891.07
Aspect	1	67	2.26
Crop Trt. X Aspect	4	95.25	1033.02
Error	389	116.76	1724.33

Analysis of Variance measurements were conducted in metric units rather than converted English units.

Table 7 Shortleaf analysis of variance for 2009 of height and ground line diameter growth by crop treatment

	Df	GLD Mean Square	Total Height Mean Square
Model	12	407.52	10093.30
Crop Trt.	4	303.02	4891.07
Aspect	1	67	2.26
Crop Trt. X Aspect	4	95.25	1033.02
Error	389	116.76	1724.33

Analysis of Variance measurements were conducted in metric units rather than converted English units.

Results: Study II

Loblolly pine first year mean growth responses to applied litter rates in cropping alleys planted in switchgrass are listed in Table 8. Mean ground-line diameter, height, and volume index are given for each respective litter rate application. Ground-line diameter means for all litter application rates and distances are with one millimeter ranging from 0.24 to 0.28in. Mean height growth ranges from 12.36 to 14.61in across the study. Table 9 is a survival index calculated from measured trees which lived through the first year after planting for each tree and distance. Overall first year survival was 93.6 percent when averaged across all distances and treatments.

Table 8 Mean loblolly tree growth in year 2008 by proximity to switchgrass with chicken litter

Distance from Alley		10 feet	20 feet	30 feet
Litter Treatment	Loblolly Measurement			
0 lb/acre	GLD	0.0094in	0.0098	0.0110
	HT	13.03in	12.72	12.91
	VOL	0.8177in^3	0.8909	1.8062
2,677 lb/acre	GLD	0.0102	0.0110	0.0102
	HT	13.58	14.49	12.36
	VOL	0.7994	0.9764	0.8238
6,691 lb/acre	GLD	0.0106	0.0098	0.0110
	HT	13.66	14.61	12.36
	VOL	0.9581	1.013	0.9215
10,706 lb/acre	GLD	0.0106	0.0110	0.0102
	HT	12.83	14.57	12.91
	VOL	1.477	1.013	0.8604

Measurements: Height (HT) and ground line diameter(GLD) in inches, and volume index (VOL) in in^3.

Table 9 Loblolly pine survival the first year by proximity to switchgrass with chicken litter

Distance from Alley	10 feet	20 feet	30 feet	All Distances
Litter Treatment				
0 lb/acre	97.9	97.9	95.8	
2677 lb/acre	91.7	95.8	91.7	
6691 lb/acre	100	93.8	93.8	
10706 lb/acre	87.5	87.5	89.6	
Overall Survival	94.3	93.8	92.7	93.6

Percentages out of 100

A regression analysis was used to determine any effects on tree growth from alley litter rate applications and distances from the alley in which the litter rate was applied. Preliminary ANOVA calculations to test for treatment affects using the GLM procedure in SAS 9.2 Software produced F-Calc statistics that were not significant at $\alpha=0.05$ significance level. Treatment affects were measured using height, ground-line diameter, and volume as the dependent variable.

Discussion: Study

Row crop production values throughout the study were lower than anticipated. The growing season in years 2007 and 2008 contained extended periods of high temperatures and low precipitation during the months of June, July, and August. Crops were planted later than desired for years 2008 and 2009. A late planting combined with 3.39 inches of rain during June and July resulted in no harvestable production for 2008. It is noteworthy that fertilizers applied for corn and grain sorghum cultivation did not significantly affect loblolly or shortleaf pine growth. Soybeans were difficult to cultivate due to herbivory by wildlife most notably white-tailed deer (*Odocoileus virginianus*). One-meter squared exclosures were placed randomly in soybean plots following planting in 2009 to ascertain a sampling plot for soybean yield in a given cropping plot in an alley. Additionally, an adjacent 10-acre area to the east of the agroforestry study area was planted with soybeans intended to lure deer away from the agroforestry study area in an attempt to obtain a soybean yield on the study plots. The exclosures and the adjacent soybean planting were ineffective at accomplishing their objective and herbivory contributed to a lack of soybean production. Though it was hot and dry in June of 2009, the average high temperature in July of 2009 was two degrees cooler and six inches more rainfall fell. Crop production appeared high in 2009 corn plots but the plots were destroyed in August by wildlife believed to be wild hogs (*Sus scrofa*). Grain sorghum plots were planted at an incorrect planter calibration in 2009 and produced low plant densities with little or no harvestable yield. Switchgrass was difficult to establish in each year of the study and a uniform stand was not successfully established in any of the plots. We attempted to drill the switchgrass and cultivate it without tillage according to the methods described in this chapter in 2007 and 2008 but elected to till and sow the switchgrass in 2009 to establish a stand in the research plot after failing to do so in 2007 and 2008. Light tilling a seedbed and sowing switchgrass in 2009 also failed to establish a stand of switchgrass. A forage or fodder yield is given for the switchgrass and other crops which did not attain a yield in a given year.

Discussion: Study II

As in Study I, switchgrass was difficult to establish and various no-till methods were applied to cultivate and establish switchgrass but none were successful. The decision not to apply litter in 2008 means that measures of treatment effects on pine growth in comparison to the litter application rate were residual for the first year of growth. Switchgrass establishment the second year continued poor, although survival of loblolly seedlings was better. Later studies in Mississippi did have success establishing switchgrass with tillage (Shankle and Garrett, 2014). The residual fertilizer effects did not influence pine seedling growth in the second year of the study. It appears that trying to measure pine seedling growth effects adjacent to cropping requires a longer-term approach to evaluation for results. Pine seedlings require a couple years to develop root systems, so cropping effects are difficult to measure during pine seedling establishment.

Conclusion: Study I

Loblolly and shortleaf pine tree growth in total height, ground line diameter, and volume index did not significantly differ by cropping treatment effects. Loblolly and shortleaf may differ from one another with respect to growth rates in an alley cropping agroforestry system. A lack of differences resulting from soybean and switchgrass cultivation coupled with the previous statement imply that landowners implementing such practices may be able to cultivate alleys with more desirable agricultural crops for a given economic climate or ease of production without affecting loblolly or shortleaf pine tree growth.

Conclusion: Study II

Loblolly pine growth was statistically not significant compared to different litter application rates at various distances from the alley in which they were applied. Without a switchgrass yield or litter application in the first year of growth, it is difficult to presume what interactions may occur between loblolly pine and switchgrass in an agroforestry alley cropping system with chicken broiler litter applied as a fertilizer. Pine tree survival was more acceptable on the second attempt at establishment.

Conclusion: Both Studies

Since little previous research has been conducted on pine tree growth in agroforestry alley cropping regimes in the Southeast there is little comparison for these results. However, research is ongoing and identifying economic advantages while consistently calling for increased research efforts (Susaeta, et al., 2012 and Blazier et al., 2012). In a loblolly agroforestry planting design study in Arkansas, for any given year, tree diameter was greatest in the two-row design, and the four-row design had greater tree diameter than a rectangular, standard planting design and spacing in 2004 to 2007 (Burner, 2013). Trees in exterior rows in the four-row design had greater diameter than interior rows (Burner, 2013). Depending on design, plantations might be useful for alley cropping, silvopasture, or pine straw (Burner, 2013). Agroforestry alley cropping in the southeast is an alternative to traditional row crop farming which may be a more profitable and desirable practice given continued research can guide landowners to sound decisions on establishment and management of such systems. Moving forward, continuing research should focus on larger study areas in which crops are cultivated in a production style setting which can more accurately replicate possible effects of the treatments over a larger area and provide a demonstration area which will allow landowners to view a more realistic agroforestry alley cropping land management alternative.

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CHAPTER III

WILDLIFE AND HERBACEOUS VEGETATION SURVEYS

Introduction

The incorporation of alley cropping into an agricultural landscape increases the habitat diversity for wildlife and thus improves habitat conditions and wildlife usage (Garret and McGraw, 2000). The creation of multiple edges and ecotones, as well as an increase in ecotone width would be of great value to and preferred by several species of wildlife including game (Yarrow and Yarrow, 2005). In a study of crop field edges adjacent to woody habitat in Nebraska, greater than 56 percent of foraging by thirteen of seventeen common bird species was observed within twenty meters of the crop field from the edge (Puckett et al., 2009). Birds typically concentrate foraging efforts within fifty meters of the edge due to proximity of escape or protective cover (Best et al., 1990). However, research on the amount of wildlife usage in agroforestry practices is limited. In a 1982 study of farm shelterbelts in Minnesota, Yahner (1982) indicated these practices may be beneficial for some small mammal populations. One study measuring wildlife abundance in a southern agroforestry practice in which loblolly pine was alley cropped with corn subsequently steer harvested noted higher numbers of mourning dove (*Zenaida macroura*) and white-tailed deer when compared to thinned pine plots or unmanaged pine plots (Manning, 2005).

Wildlife benefits were an important boon of agroforestry management practices ranked by landowners in a survey of landowners in Alabama and Florida (Workman, 2003). Wildlife benefits can allow for diversified income from timber and agricultural operations with fee hunting (Jones et al., 1998). Agroforestry practices such as silvopastural systems in Mississippi create the opportunity for additional income through hunting leases (Grado et al., 2001 and Husak and Grado, 2002). Alavalapati et al. (2002) found that internalizing red cockaded woodpecker (*Pecoidel borealis*) habitat benefits and carbon sequestration on longleaf pine (*Pinus palustris*) could significantly increase associated land values. These same benefits may be possible for alley cropping agrforestry practices in Mississippi and other locations in the southeastern United States. Direct wildlife usage data and habitat indices from native vegetation grown in conjunction with agroforestry practices in southern United States are lacking and would be useful for correlations between wildlife and economic valuations in agroforestry practices.

Methods

An alley cropping agroforestry site was cultivated and monitored from November 2007 to September 2009. The site was located on the Mississppi Agriculture and Forestry Experiment Station (MAFES) Northeast Branch Experiment Station seven miles north of Holly Springs, MS. The experiment station is located in the north central hills geographic region of Mississippi on the edge of the loess hills with slopes of 2 to 5 percent. Soils on the Holly Springs experiment station are Grenada silt loam and Providence silt loam series of the Alfisol soil order with a fragipan approximately two feet deep (Kushla, 2009). Average annual rainfall for Holly Springs Mississippi is 56 inches. Average high temperatures for the region are 90ºF while average low temperatures reach 27ºF. The area on which the study was developed was previously used for row crop agriculture trials and cultivation of corn to sustain a dairy operation (Kushla, 2009).

Loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) bareroot 1-0 seedlings were planted on the site in March of 2005. Planting of trees was structured in equidistant rows of homogenous species in sets of two at a ten foot by seven foot spacing with a forty-foot alley between respective sets of rows. Rows of trees were oriented in a north-south direction. Four replications of each set of rows were planted on the same study area but were not contiguous. Trees were mechanically planted with no subsoiling prior to planting.

Within the alley the agricultural crops: corn (*Zea mays*), milo (*Sorghum bi-color*), soybeans (*Glycine max*), and switchgrass (*Panicum virgatum* L.) (Alamo cultivar) were assigned to agronomic scale, research plots of 13 feet by 100 feet directly adjacent to the set of tree rows on each side of the respective tree row according to a complete randomized block design. Planting occurred in April of 2007 and in May of 2008 and 2009. Crops were planted utilizing no-till agricultural practices, except for switchgrass. Planting rates for respective species were as follows: corn, 28,000 seed/acre with 36 inch spacing and 2 inch depth; grain sorghum, 6 pounds per acre at a depth of 1.5 feet; soybean, 150,000 seed/acre with 36 inch spacing and ½ inch depth; switchgrass, 6 pounds of Pure Live Seed (PLS) with a no-till grain drill into a conventionally tilled stale seed bed at ¼ inch depth and cultipacked following planting. Corn and grain sorghum received 450 lbs/acre of ammonium nitrate (34-0-0) at planting. No other fertilizer was applied to any other crop plots as per soil test recommendations. Corn and grain sorghum received herbicide applications of Dual Magnum at a rate of 1.33 pt/acre, Atrazine at a rate of 2 qt/acre, and Roundup Weathermax at a rate of 32 oz/acre. Soybean and switchgrass received an application of Roundup Weathermax at a rate of 32oz/acre to control existing weeds at planting. Roundup Weathermax was re-applied to corn and soybean plots at a rate of 22 oz/acre as needed for in-season weed control. Cropping alley plots were mowed following harvest in the fall.

Additional agroforestry alleys, not included in the agronomic trial complete randomized block design, were planted with 4 rows of shortleaf pine or loblolly pine at the same time as the two row cropping study trees. In February of 2008 the alleys were disked, harrowed, and a mixture of Durana white clover (*Trifolium repens*) and Patriot white clover (*Trifolium Repens*) from Pennington Seed Inc.was drilled at 8 pounds per acre. These clover agroforestry alleys were sampled for forage/fodder production values. Three one-meter squared plots, from three randomized line transects at distances of three and seven meters from the adjacent tree crop species, were removed of all standing vegetation. This vegetation, predominantly the clover which had been seeded in late winter of 2008, was collected from ground level, bagged in paper sacks, weighed, and dried in a plant drier. After 14 days of drying, the bags were removed, weighed, and the weight of the bag was subtracted from the final measurement of fodder yield.

Bird surveys were conducted according to guidelines established by Hamel et al. (1996). Surveys were conducted in the cultivated alley cropping agroforestry area, a loblolly pine plantation area, a shortleaf pine plantation area, and a pasture cultivated with Marshall rye grass (*Lolium* L.). Survey locations were selected at random and the starting location was initially selected at random with each subsequent location sampled in a rotational order so as to limit early morning disturbance of the survey location and the start of the surveys was rotated so each location was sampled at the earliest and latest time within the acceptable survey period. Bird identification was completed utilizing Peterson field guides and MSU ornithology sound tracks for song identification (Peterson, 2010). Species were recorded using alpha codes described by the United States Bird Banding Laboratory (USGS, 2009). Each survey point was located on the MAFES Northeast Branch Experiment Station at a distance of at least 250m apart from other survey points and at least 100 m from the edge of the habitat type. Surveys were conducted at each point count station for a ten-minute period during dawn hours to 10:00 a.m. on days with favorable weather conditions according to Hamel et al. (1996). A total of fourteen bird count surveys, counting at each designated point in the study and totaling 560 survey minutes, were conducted by a single observer in May and June of 2009. Point counts in the agroforestry area were not designed to distinguish bird usage between different pine tree species and agricultural crop plantings present in the area. Other habitat types surveyed were homogeneous in nature.

Vegetation surveys were conducted in the agroforestry alley cropping area (Krebs, 1998). Vegetation surveys were conducted along transect lines randomly placed in the area between the tree rows in each agroforestry cropping plot as well as in the crop plot itself. Three one-meter squared quadrats placed along a randomly selected 10 meter transect inside the sampling area were used as sampling units. Edge areas between the tree row planting and the crop planting were not included in the vegetation sampling because these areas were rarely greater than a meter in width and were treated with agricultural chemicals consistent with those applied in the adjacent plots. The study area was largely designed in this manner to ascertain values associated with interaction between tree production and crop production management in the agroforestry area.

Camera surveys were conducted in both the agroforestry study area and the adjacent pine plantation. Camera surveys were also conducted in a more recently planted and developed agorforestry area located adjacent to the agroforestry study area (to the west). Cameras were placed at locations randomly determined from a grid quadrat overlay placement system. Cameras were then placed in an area to maximize the range of the camera located within the randomly selected quadrat which would maximize the range of the camera.

Results

Vegetation surveys produced an overall species richness of 46 (including an unknown) species for all samples, excluding planted row crops. Species richness, excluding planted row crops, for crop plots was 21 species (excluding unknowns). Species richness for alleys between trees was 44 species (excluding unknowns).

Table 10 Herbaceous growth form species richness by crop treatment and forest cover

Ground Cover	Corn		Milo		Soybean		Switchgrass		Overall	
	Tree	Crop	Tree	Crop	Tree	Crop	Tree	Crop	Tree	Crop
Native	14	3	17	4	16	7	19	11	31	15
Nonnative	11	4	11	3	10	5	9	5	13	6
Forbs	14	2	16	3	15	6	15	6	27	14
Grasses	10	5	13	4	10	6	11	10	15	10
Woody Vines	1	0	0	0	1	0	2	0	2	0
Overall	25	7	30	7	26	12	28	16	44	21

Using "no crop numbers" and excluding unknowns

Table 11 Mean herbaceous growth cover (as percent) by crop treatment and forest cover

Ground Cover	Corn		Milo		Soybean		Switchgrass		Overall	
	Tree	Crop	Tree	Crop	Tree	Crop	Tree	Crop	Tree	Crop
Native										
Nonnative	94.74	89.96	87.75	85.08	85.10	44.75	85.54	82.82	88.64	78.01
Forbs	2.42	2.29	3.74	7.92	3.97	42.66	3.44	2	3.36	9.06
Grasses	97.57	97.71	96.26	92.08	95.88	57.34	96.23	98	96.53	90.94
Woody Vines	.01		0		.14		.32		.1	
Percentage Bareground	6.4	79.2	13.6	81	13	70.4	22.5	31.7	13.7	65.1

Bareground is by itself, Values for nonnative are overall (no elimination of unknowns or crops), values for grasses, forbs, and vines
Using "no crop numbers" (no crops were counted) and excluding unknowns

Differences in herbaceous vegetation species composition in the alleys between like crop plots (the herbaceous vegetation between the planted tree rows dividing the crop plot) were measured using a Chi-Squared analysis. We tested the null hypothesis that there was no difference in distribution of herbaceous vegetation among the crop plot treatment types. The Chi-Squared analysis indicated the herbaceous vegetation's composition in the alleys between each crop plot type varied significantly from one other at alpha .05 significance level. Alleys between corn crop plots yielded a Chi-Square value of 783. 89. Alleys between milo crop plot plantings yielded a value of 487.19. Alleys between soybean and switchgrass crop plots yielded values of 1430.11 and 884.37 respectively. Thirty six species of herbaceous vegetation were observed throughout sampling, creating 35 degrees of freedom and a Chi-Square significance level of 22.465 at the alpha .05 significance level.

To further compare the herbaceous plant communities growing between tree rows in the alley cropped agroforestry area, we ran an analysis of variance (ANOVA) to test the null hypothesis that there was no difference in the overall number of herbaceous plants growing within tree rows between a respective crop treatment. The analysis of variance yielded an F-Calc statistic of 1.26 and an associated probability of P= 0.306. A P-value of 0.05 or less is required to conclude there were significant differences in the overall size of the herbaceous plant community among crop treatments.

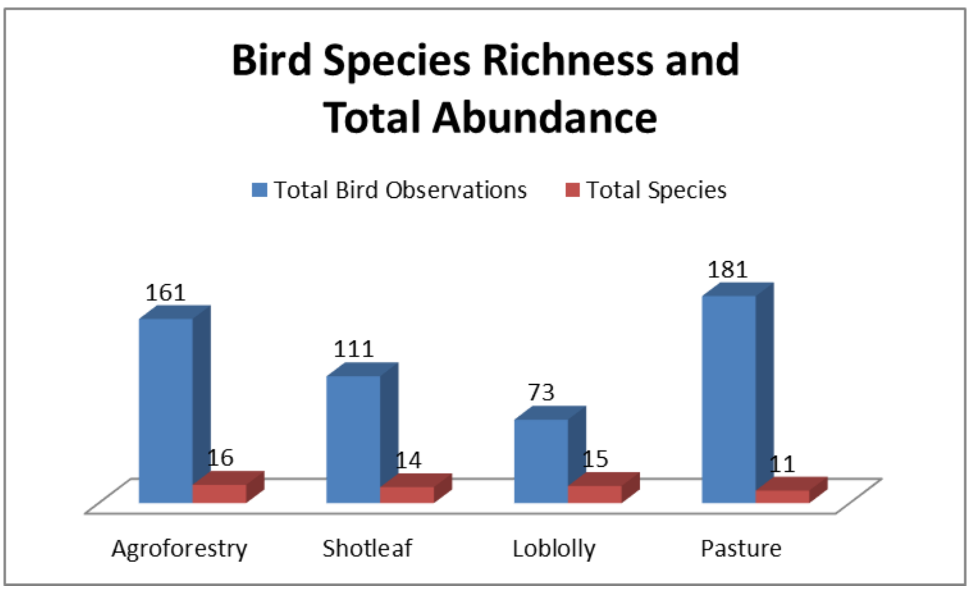

Figure 1 June 2009 point count for bird species richness and total abundance

Fifty-six point call count surveys in 2009 yielded a total of 25 bird species and 526 individual observations. However, 9 additional species were observed on the experiment station during the sampling period though they were not observed while conducting bird surveys. Bird species richness was highest in the agroforestry area with 16 species observed among 161 individual observations. Species richness was lowest in the pasture sampling area with 11 species observed but the 181 individual observations was highest among all survey habitat types. The shortleaf pine point count station had a species richness of 14 with 111 individuals observed. The loblolly pine point count station had a species richness of 15 and the lowest number of individual observations with 73 observations.

Only four bird species were observed at all count stations during the survey period. These four species were American Goldfinch, Barnswallow (*Sprinus tristis*), Dicksissel, and the Northern Bobwhite. Ten bird species were unique to a single count site and nine of the ten species were also unique to a single point count. The species with the greatest abundance within the agroforestry study area were Dicksissel (mean abundance 4.29), Chipping Sparrow (mean abundance 1.21), Eastern Meadowlark (1.14), Northern Bobwhite (0.79), and European Starling (0.79). Species with the greatest abundance in the loblolly pine plantation habitat type were Field Sparrow (1.14), Indigo Bunting (1.14), American Goldfinch (0.71), Chipping Sparrow (0.43), and Dicksissel (0.36). In the shortleaf pine plantation habitat type the bird species with the greatest observed abundance were Field Sparrow (1.86), Dicksissel (1.43), Indigo Bunting (1.36), American Goldfinch (0.57), and Northern Bobwhite (0.57). Bird species with the greatest observed abundance in the pasture habitat type included Mourning Doves (4.21), Eastern Meadowlark (3.14), European Starling (1.21), Northern Bobwhite (1), Red-winged Blackbird (0.86), and Dicksissel (0.86). Bird species with the greatest abundance across all habitat types (measured by DPUE in terms of observation days (14) rather than by total counts performed (56)) were Dicksissel (6.93), Northern Bobwhite (4.79), Field Sparrow (3.43), Indigo Bunting (2.71), European Starling (2.29), and American Goldfinch (2.28). For a complete list of bird species observed on the experiment station in late spring of 2009 and the DPUE value of birds observed during point count surveys, see Appendix A.

Mean dry weight for the three clover forage plots from each the three transects at a distance of 9.84 (3 meters) from shortleaf pine crop trees was 1.17 pounds. Plots on transects 22.97 feet (7 meters) from the shortleaf pine crop trees averaged 1.31 pounds. Mean dry weight for clover forage plots 9.84 feet from loblolly pine crop trees was 1.66 pounds. Plots on each of the three transects 22.97 feet from the loblolly pine crop trees averaged 1.7 pounds.

Camera surveys produced photographic evidence of white-tailed deer using the agroforestry area and the adjacent study areas where camera traps were located, see Appendix E. Camera surveys neither produced a large or consistent amount of photographs documenting usage by white-tailed deer in a specific portion of the study area (in an amount which could be used to accurately determine population dynamics or metrics) nor provided any accurate representation of the amount of deer utilization. Field observations of big game animals during vegetation surveys, site visits, and bird surveys were greater than the amount of observations captured by the camera survey.

Discussion

Vegetation survey data yielded a high proportion of Bermuda grass (*Cynodon*). Bermuda grass was observed throughout the agroforestry sampling area regardless of pine tree species or adjacent row crop variety. High abundance of Bermuda grass is common among old field conversion, afforestation sites (Harrold et al., 1970). Bermuda grass is a nonnative agronomic grass that provides little forage value to native wildlife and is not a beneficial habitat component for many species (USDA Plants Database, 2015). Herbaceous vegetation management, including mechanical and chemical site preparation prior to agroforestry establishment, could provide for a vegetation complex that is more beneficial to native wildlife and increase wildlife habitat values of the system. In the alternative, it could be more beneficial for a landowner on a similar parcel to forgo enhancing wildlife habitat and instead encourage bermuda grass and establish a silvopasture agroforestry practice that benefits from the bermuda grass occurring on the site.

Though camera surveys only captured white-tailed deer utilization of the study areas, feral hogs and wild turkeys were observed on the agroforestry area and the experiment station during the vegetation sampling study period. Herbivory of soybean crop plots was so heavy that soybean harvest yield data were unable to be obtained in either the 2008 or 2009 growing seasons, see Appendix D. This occurred despite placing one meter exclusion cages over soybean seedlings in the planting and planting soybeans in a 10 acre field directly adjacent to the agroforestry study site in 2009. The deer were most likely utilizing the agroforestry area with greater frequency than camera survey data reflected.

Deer utilization of the agroforestry study area and herbivory of soybean plots indicated that deer found this habitat suitable to meet their needs at given times. Enhanced deer activity on a property coupled with cultivated open alleys could provide improved hunting and harvest opportunities for deer hunters. Deer hunting lease values have been higher on lands with bottomland hardwoods, or where the landowner knew how to enhance wildlife habitat (Hussain et al., 2007).

During late May and early June of 2009, when bird surveys were conducted, the temperature was well above the average temperature for that time of year and heat advisories were issued for most days during the survey period. The excess heat may have influenced bird behavior potential (Visser, et al. 2009). The heat may have also altered plant community composition during the survey period when compared to a year in which temperatures remained closer to average. More specifically, the heat may have shortened the longevity of winter annuals observed while taking winter tree growth measurements but not observed in late spring vegetation surveys.

Breeding bird surveys in the small, limited agroforestry study areas provided a sample that was too small to discern breeding bird use within their home range. Breeding birds observed in the agroforestry area of note include Eastern meadowlark and Dicksissel. Eastern meadowlarks are in decline and this finding could provide alternative land uses that are beneficial to landowners and eastern meadowlarks (Partners in Flight Science Committee, 2012). Identifying these associations within agroforestry land management practices could have broad ranging implications for future funding of current conservation funding

The experimental design for the wildlife sampling was not a true complete randomized block design. Therefore, the experimental design for this study limited the amount and type of statistical comparisons available for analysis. Tree species planted in the sets tree rows (2 rows per set) were not randomly assigned to their row(s) and sets of rows and their adjacent cropping alley were not contiguous with other sets of rows and their adjacent cropping alleys within the study. The area of the experiment station planted in agroforestry cropping regimes with pine trees was contiguous but the study design itself was not contiguous within this area, see Appendix B. For instance, two sets of loblolly rows and their adjacent alleys were contiguous and directly adjacent to one another, but they were separated, not in the same contiguous block, from the other sets of rows and their adjacent cropping alleys by a set of four tree rows planted in shortleaf pine with adjacent cropping alleys.

Agroforestry has the potential to greatly enhance wildlife values while also producing high returns through wide ranging agricultural practices occurring in highly integrated and intensive temporal and juxtapositional or stratified scales. Wildlife values can be enhanced not only in terms of species specific criteria but also in terms of enhancing landscape biodiversity, genetic diversity, and decreasing forest fragmentation. Specific wildlife usage values were difficult to ascertain from a study which focused on the interaction of different agricultural row crops and two tree crop species. Similar agroforestry research has indicated that loblolly pine trees and wildlife benefits could provide economic advantages in an alley cropping agroforestry system in North Carolina (Cubbage, et al., 2012). Wildlife habitat values will likely change with neighboring land usage and cropping monoculture utilization in agroforestry systems, among tree crop species selected and annual row crop selection beneficial to producers. Values will also vary with aging of the agroforestry system implemented and its effects on stand composition and characteristics as well as annual row crop selection. Some observations from this study may be maintained through the complete rotation cycle of this agroforestry plantation as one researcher observing young agroforestry stands in Florida noted, canopy closure in the stand may not pose a direct threat to early successional plant species that inhabit the planting (Hagan, 2009). This would result from a potential to maintain the required sunlight to sustain these species though composition could change with time and further management of the agroforestry stand as it matures.

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APPENDIX A

LIST OF BIRDS OBSERVED AT HOLLY SPRINGS EXPERIMENT STATION AND DAYS PER UNIT EFFORT DETECTION RATIOS FOR SPECIES OBSERVED DURING POINT COUNT CALL SURVEYS

	DPUE(DAYS)
American Crow *Corvus brachyryhncos*	0.2857
American Goldfinch *Sprinus tristis*	2.2857
American kestrel *Falco sparverius*	0.1429
Barn Swallow *Hirundo rustica*	1.0714
Barred Owl *Strix varia*	
Blue Grosbeak *Passerina caerulea*	
Brown Thrasher *Toxostoma rufum*	0.0714
Chipping Sparrow *Spizella passerina*	2.0714
Dickcissel *Spiza americana*	6.9286
Eastern Bluebird *Sialia sialis*	0.1429
Eastern Kingbird *Tyrannus tyrannus*	0.2857
Eastern Meadowlark *Sturnella magna*	4.5
Eastern Phoebe *Sayornis phoebe*	
Eastern Wood-Pewee *Contopus virens*	0.0714
European Starling *Sturnus vulgaris*	2.2857
Field Sparrow *Spizella pusilla*	3.4286
Great Horned Owl *Bubo virginianus*	
Green Heron *Butorides virescens*	0.0714
Indigo Bunting *Passerina cyanea*	2.7143
Killdeer *Charadrius vociferus*	0.2143
Mourning Dove *Zenaida macroura*	4.7857

Northern Bobwhite *Colinus virginianus*	2.5
Northern Mockingbird *Mimus polyglottos*	0.2857
Prairie Warbler *Setophaga discolor*	0.2143
Red-bellied Woodpecker *Melanerpres carolinus*	0.0714
Red-headed Woodpecker *Melanerpes erythrocephalus*	
Red-tailed Hawk *Buteo jamaicensis*	
Ruby-throated hummingbird *Archilochus colubris*	0.1429
Red-winged Blackbird *Agelaius phoeniceus*	1.5714
Tufted Titmouse *Baeolophus bicolor*	0.0714
White-eyed Vireo *Vireo griseus*	0.2143
Black Vulture *Coragyps atratus*	0.0147

APPENDIX B

LIST OF PLANT SPECIES OBSERVED AND IDENTIFIED ON THE NORTH MISSISSIPPI BRANCH EXPERIMENT STATION

Aster
Aster spp.
Barnyard Grass
Echinocloa muricata
Bedstraw
Galium aparine
Beggartick
Bidens bipinnatta
Desmodium obtusum
Bermuda Grass
Cynodon dactylon
Broadleaf signalgrass
Urochloa platyphylla / Brachiaria platyphylla
Broomsedge
Andropogon virginicus
Carolina geranium
Geranium carolinianum
Carolina horsenettle
Solanum carolinense
Common Mullein
Verbascum thapsus
Common Dandelion
Taraxacum officinale ssp. *officinale*
Crabgrass
Digitaria ciliaris
Dewberry
Rubus trivialis
Downy oat grass
Danthonia sericea
Eastern Baccharis
Baccharis halimifolia
Elephant's foot
Elephantopus tomentosus
Everlasting
Gamochaeta purpurea
False Dandelion
Pyrrhopappus carolinianus
Fescue
Festuca arundinacea
Fleabane
Erigeron annus
Fireweed
Erechtites hieracifolia

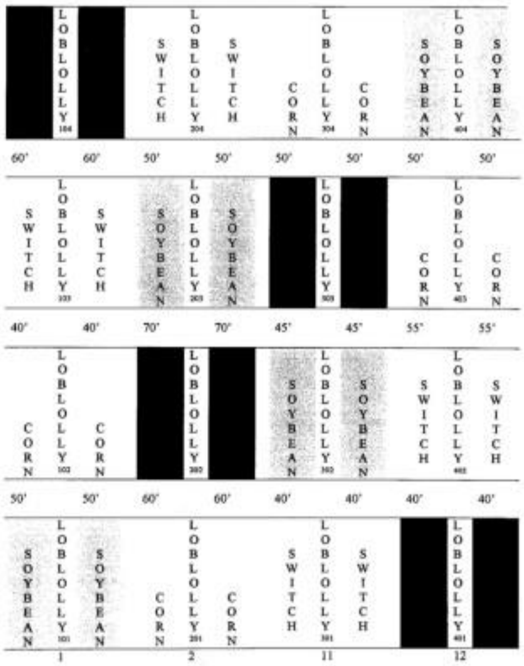
Foxtail
    Setaria parviflora
Globe Flatsedge
    Cyperus echinatus
Goldenrod
    Solidago canadensis
Groundcherry
    Physalis L.
Heartwing Sorrel
    Rumex hastatulus
Horseweed
    Conyza canadensis
Johnson Grass
    Sorghum halepense
Largebracted plantain
    Plantago major
Lettuce
    Lactuca canadensis
Little Bluestem
    Schizachyrium scoparium
Morning Glory
    Ipomoea purpurea
Nutgrass
    Cyperus rotundus
Nutrush
    Slercia trigomerata Michx.
Panic Grass
    Dichanthelium spp.
Pigweed
    Amaranthus retroflexus L.
Poorjoe
    Diodia teres
Purpletop
    Tridens flavus
Purple lovegrass
    Eragrostis spectabilis
Roundhead Sedge
    Cyperus echinatus
Spurge
    Euphorbia pubentissima
Thistle
    Crisium lecontei
Vetch
    Vicia (sativa sssp. nigra)
Virginia Creeper

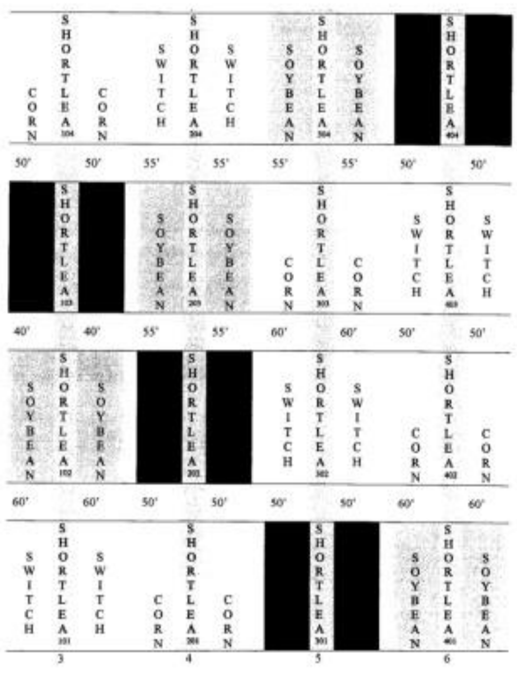
Parthenocissus quinquefolia
Wild Garlic
Allium vineale
Wooly Croton
Croton capitatus Michx.
Dandelion
Taraxacum spp.
Pokeweed
Phytolacca americana
Heller's cudweed
Gnaphalium helleri
Rabbittobacco
Gnaphalium obtusifolium

APPENDIX C

HOLLY SPRINGS AGROFORESTRY STUDY DESIGN MAP

Holly Springs Trees





APPENDIX D

PHOTOGRAPHS OF SOYBEAN EXCLOSURES AND HERBIVORY

APPENDIX E

CAMERA SURVEY PHOTOGRAPHS OF WHITE-TAILED DEER IN AGOROFRESTRY STUDY AREAS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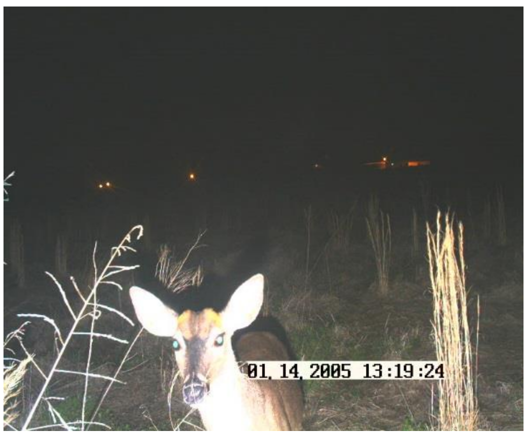
01, 21, 2005 13:00:21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01, 04, 2005 14:30:01


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APPENDIX F

PHOTOGRAPHS OF HOLLY SPRINGS STUDY AREA