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Effects of Intercropping Switchgrass in Managed Pine Stands on Plant Communities and White-Tailed Deer Forage Production

Bradley Robert Wheat

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By

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Interest in renewable energy and governmental mandates has motivated land managers to consider cellulosic feedstocks for bioenergy. I investigated plant community response to a system including switchgrass (*Panicum virgatum*) as a feedstock intercropped with loblolly pine (*Pinus taeda*). I estimated plant species evenness, richness, and diversity and biomass production, with emphasis on white-tailed deer (*Odocoileus virginianus*) forages. I detected 225 species in 2,220 1-m^2 quadrats, and 7,495 biomass samples (96.4 kg dry weight) from 960 quadrats. Intercropping reduced plant species diversity, total non-pine tree biomass, and biomass of deer forages during switchgrass establishment. These effects were no longer apparent at treatment level two years after switchgrass establishment, except that deer browse and total deer forage biomass remained less in intercropped interbeds. Intercropping in managed pines may temporarily effect plant communities but further studies are needed to examine longer term effects and to quantify effects on nutritional carrying capacity for deer.

DEDICATION

I dedicate this thesis to two individuals: my brother Ryan and to Dr. Sam Riffell.

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CHAPTER I

INTERCROPPING SWITCHGRASS AS BIOENERGY FEEDSTOCK

Interest in renewable fuels for bioenergy production has increased and vegetative biomass (hereafter "biomass") is a potential feedstock source for bioenergy production (Perlack et al. 2005). The Renewable Fuel Standard (RFS) program was created as the first renewable fuel volume mandate under the Energy Policy Act (EPAct) of 1995 (Public Law 109-58). More recently, the Environmental Protection Agency (EPA) amended standards with release of the 2014 RFS, which mandated 1.28 billion liters of biomass-based diesel for 2014 and 2015, and 77.3 million liters of biofuels derived from cellulosic feedstocks for 2014 (EPA 2013).

Switchgrass (*Panicum virgatum*) is a source of lignin and cellulose suitable for feedstock in next-generation biofuels (those not dependent on grain crops as feedstocks), including biobutanol (Simmons et al. 2008, Kumar and Gayan 2011). Switchgrass is a promising feedstock candidate in the eastern United States as it is a native species with perennial growth, high biomass production potential, low water and nutrient demand, and multitudes of secondary uses and potential ecosystem contributions (McLaughlin and Walsh 1998, Parrish and Fike 2005, Sanderson et al. 2006, Mitchell et al. 2008, Schmer et al. 2008, Keshwani and Cheng 2009, Wright and Turhollow 2011).

The southern United States is a vital region for commercial forestry and consists of 15.8 million ha (19%) of planted pine (*Pinus* ssp.) forests (Wear and Greis 2012).

Twelve million of these 15.8 million ha are managed loblolly (*Pinus taeda* L.) and shortleaf (*Pinus echinata* L.) pine forests (Smith et al. 2009). Intensively managed forests are a potential source of biomass feedstocks (Hinchee et al. 2011, Riffell et al. 2011a, 2011b, Zalesny et al. 2011), including a novel approach of intercropping switchgrass (hereafter "intercropping"), which is a recently developed method of producing biomass within managed loblolly pine forests by establishing switchgrass in "interbeds" between pine beds (Riffell et al. 2012; see Figure A.1). Interbeds encompass the area between planted rows of pines which are referred to as pine beds. Intercropping in intensively managed loblolly pine forest may be a feasible source of significant cellulosic feedstock that does not affect pine growth (Sucre and Leggett 2011).

Catchlight Energy LLC, a joint venture between Chevron and Weyerhaeuser Company, established research stands on properties owned and managed by Weyerhaeuser Company in Kemper County, Mississippi, USA, to investigate environmental consequences of intercropping switchgrass in intensively managed loblolly pine forests. Plant and animal community responses to this novel land-use practice have been the subject of only a few studies to date (Marshall et al. 2012, Iglay et al. 2012, Loman et al. 2013, Briones et al. 2013, Homyack et al. 2013 and 2014, Loman et al. 2014, and King et al. 2014). This study, in conjunction with additional ongoing research, seeks to better understand effects of intercropping on biodiversity. Silvicultural practices that help meet biodiversity and habitat objectives (e.g., Sustainable Forestry Initiative Inc. 2010) are important and commonplace in commercial forestry (Conde et al. 1983, Fredericksen et al. 1991, Miller et al. 1995, Miller and Miller 2004), and intercropping switchgrass has potential to provide habitat structure that may benefit biodiversity as a whole (Riffell et al. 2012).

In this research, I identified effects of intercropping switchgrass in intensively managed loblolly pine stands on associated plant communities during establishment and 1 year post-establishment of intercropped switchgrass. I investigated the following objectives, which correspond to chapters within my thesis: 1) effects of intercropping switchgrass on plant species evenness, richness and diversity; 2) effects of intercropping switchgrass on total plant biomass production, and specifically, biomass production of important high- and moderate-use white-tailed deer (*Odocoileus virginianus*) forages.

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CHAPTER II

PLANT SPECIES DIVERSITY RESPONSE TO ESTABLISHMENT OF INTERCROPPED SWITCHGRASS IN MANAGED PINE FORESTS

Intercropping switchgrass (hereafter "intercropping") is a recently developed multiple land-use practice that establishes switchgrass in interbeds between planted pine (see Figure A.1) aimed to provide renewable biomass feedstocks on intensively managed pine forests in the southeastern United States (Riffell et al. 2012). Switchgrass is a native perennial grass species, as opposed to non-native counterparts also proposed as feedstocks such as reed canary grass (*Phalaris arundinaceae*; Casler et al. 2009), giant miscanthus (*Miscanthus* x *giganteus*; Bellamy et al. 2009), and potentially other species. Intercropping may allow forest managers to provide cellulosic bioenergy feedstocks along with traditional forest products while limiting potentially negative ecological outcomes associated with introducing potentially invasive, non-native species. Intercropping will likely create a more grass-dominated landscape than traditionally managed pine, which may improve habitat conditions for vertebrates dependent on this type of habitat condition (Riffell et al. 2012, Loman et al. 2014) while potentially negatively impacting others. This change may affect floral and faunal diversity, much like past changes in forest management practices (Swindel et al. 1989, Fredrickson et al. 1991, Miller et al. 1995, Iglay et al. 2012).

Intercropping switchgrass requires two treatments in addition to traditional stand establishment in intensively managed pine stands. One of these is a more extensive coarse woody debris (CWD) removal/displacement to facilitate planting (Loman et al. 2013), which has the potential to decrease available nitrogen and carbon (Huston 1996, Beauvais et al. 2010, Sucre and Leggett 2011) and alter plant diversity (Wilson and Tilman 1995). An additional application of non-selective herbicide is applied to interbeds to facilitate establishment. This non-selective herbicide suppresses vegetation and facilitate switchgrass seeding and survival but may set back succession and temporarily decrease plant diversity (Swindel et al. 1989, Fredrickson et al. 1991, Iglay 2010).

Numerous biological studies have focused on plant species diversity in response to changes in land use practices, which often reduce plant diversity (Wilsey and Potvin 2000, and references therein). Two important metrics that measure diversity are species richness and evenness (Wilsey and Potvin 2000). Species richness refers to number of species in a specified area (Spellerberg and Fedor 2003) and species evenness is reflective of number of individuals and their distribution over number of species in a specified area (Peet 1974, Heip et al. 1998). Together, species richness and evenness can be used to estimate species diversity (Heip et al. 1998, Spellerberg and Fedor 2003) and are taken into account in many available indices for estimating species diversity.

Past studies reveal that intercropping may increase coverage of forbs and graminoids and increase forb richness in early rotational, intensively managed pine stands (Iglay et al. 2012). These findings occurred in pine stands that were at least 5 years old when intercropped with switchgrass and had overstory loblolly pines. Plant diversity relative to intercropping in stands with pine trees < 5 years old is largely unknown. Initial effects of intercropping switchgrass in recently established pine stands on plant species evenness, richness and diversity has not been investigated prior to this study. Furthermore, understanding how intercropping functions as a disturbance is necessary to predict how widespread adoption of intercropping would influence forest plant diversity. Therefore, I compared plant communities within three treatment types (traditionally managed, switchgrass intercropped, and switchgrass monocultures) during site preparation and 1 year post-establishment of switchgrass to determine changes in plant communities.

I hypothesized that the additional site preparation for intercropped switchgrass would increase diversity in pine beds compared to pine beds in traditionally managed pine. Increased light availability associated with the added disturbance may release competition and increase plant diversity (Wilson and Tilman 1993, and references therein), and intercropping in older intensively managed pine stands has shown to increase forb species richness in pine beds during establishment year and 1 year post-establishment (Iglay et al. 2012). I also hypothesized that diversity would be lower in intercropped interbeds compared to interbeds in traditionally managed stands because and the additional banded herbicide application. I considered stand level effects on biodiversity to be a function of plant diversity in intercropped interbeds and non-intercropped pine beds.

Methods

Study Area

I collected data within early-rotation, intensively managed loblolly pine stands on land owned and managed by Weyerhaeuser Company in Kemper County, Mississippi, USA. Catchlight Energy LLC, a joint venture between Chevron and Weyerhaeuser

Company, established experimental plots, as outlined below, within this landscape. Stands were located in the Interior Flatwoods Soil Resource Region (Pettry 1977), with the 25,000 ha surrounding landscape comprised of loblolly pine stands (70%), mature pine-hardwood (17%), mature hardwoods (10%), and non-forested areas (3%). Climate was subtropical with an average annual temperature and precipitation of 16.8 °C and 143.2 cm, respectively (National Oceanic and Atmospheric Administration 2014). I collected data during May and July, 2012 and 2013.

Study Design

I used a randomized complete block design with four sampling stands (blocks). Each stand had 4, 10-ha experimental plots with randomly assigned treatments that were part of a broader study on biofuel feedstocks (Loman et al. 2013, 2014). Each experimental plot was an intensively managed pine stand clearcut harvested during 2009 and 2010. Treatments were: (1) traditionally managed pine (hereafter referred to as PINE): standard Weyerhaeuser Company site preparation for plantation establishment, which included a V-blade plow, bedding plow, and subsoil ripper to establish pine beds. Pine seedlings were planted with a spacing of 1.5 m by 6.1 m (approximately 1,100 trees/ha) resulting in widths of 1.2 m and 4.9 m for pine beds and interbeds, respectively. During the first growing season post-planting, a banded application of imazapyr (0.29 L/ha; Arsenal® AC, BASF Corp., Research Triangle Park, NC) and sulfometuron-methyl (0.15 L/ha; Oust®, E. I. du Pont de Nemours and Company, Wilmington, DE) was applied to pine beds to temporarily reduce woody and herbaceous competition; (2) switchgrass monoculture (hereafter referred to as MONO): non-intercropped, switchgrass monoculture (no pines were planted in these plots) prepared with complete CWD removal using a V-blade plow pushing debris to plot edges followed by a broadcast application of glyphosate (2.34 – 4.68 L/ha; Accord®XRT, Dow AgroSciences, Indianapolis, IN) to reduce competition prior to disking and broadcast seeding switchgrass; (3) switchgrass intercropped (hereafter referred to as IC): same site preparation as traditionally managed pine with addition of more extensive CWD removal. Following bedding for pine trees, a V-blade plow was used to push CWD from interbeds into pine bed edges. Following CWD clearing in interbeds, a banded application of glyphosate (2.34 – 4.68 L/ha; Accord®XRT, Dow AgroSciences, Indianapolis, IN) was applied to interbeds only. Interbeds were then disked and broadcast seeded with switchgrass once glyphosate control was complete. Intercropped plots were originally seeded in spring 2011 and reseeded in 2012 due to low success of initial seeding. During reseeding, interbeds were sprayed again with a banded application of glyphosate, disked, and seeded. Switchgrass harvest for bioenergy feedstock did not occur during 2012, but IC plots were mowed and baled during fall 2012.

I generated three midpoints along the southeast to northwest diagonal axis $\geq$ 50 m from plot edges to avoid edge effects (i.e., one point in southeastern corner $\geq$ 50 m from the edge, on in plot center, and one in the northwestern corner $\geq$ 50 m from the edge). I randomly generated 10 additional paired points (each paired point contained one pine bed and one interbed point) $\leq$ 50 m from each of these diagonal points (n = 30 pine bed and n = 30 interbed; Figure 2.1). For MONO plots, I generated three diagonal pointsas indicated above), but randomly generated only 10 individual points $\leq$ 50 m from each of these diagonal points (n = 30) considering no pine beds or interbeds were present. I sampled vegetation as each point using 1 m^2 quadrats (Roberts-Pichette and Gillespie

1999) recording each plant species detected that was ≥ 1 cm in height and had ≥ 2 true leaves (Dollar 2011). I sampled plant communities in May and July to capture floristic periods (Dollar 2011). I based scientific and common plant names on the U.S. Department of Agriculture Plant Database (USDA 2014). I used literature and local experts to identify and verify plant species (Radford et al. 1968, Miller and Miller 1999, Bryson and DeFelice 2009, Schummer et al. 2012).

Statistical Methods

I used Shannon's Diversity Index (hereafter "diversity"), species richness (hereafter "richness"), and species evenness (hereafter "evenness"; Hill 1973) to assess plant community effects resulting from IC and MONO treatments. I used Shannon's index because it may be more sensitive to species of intermediate importance and more reflective of equitability than other diversity indices (Peet 1974).

I used generalized linear models in R to compare community metrics (Bolker 2008, R Core Team 2014). I tested for year, treatment, and year × treatment interactions for each response variable (evenness, richness and diversity) for each year (2012 and 2013). I used both treatment (IC, MONO, PINE) and year (2012, 2013) as a categorical explanatory variables. I compared pine beds to interbeds interacting with treatment and year for PINE and IC to further understand how intercropping effects plant communities within intercropped plots in treated areas (interbeds) versus non-treated areas (pine beds). For richness, a Poisson response variable had better model fit due to non-normality of data (Zuur et al. 2009). For post hoc-tests I used a Sidak adjustment to control overall experiment-wise type I error rate (Sidak 1967). I accounted for differences in sampling intensity for species richness between MONO (n=30) and IC/PINE (n=60). I used a log-linear species accumulation curve with 100 randomized iterations of MONO data at n=60 to provide predicted richness estimates (Colwell and Coddington 1994). I considered results significant at $\alpha = 0.05$.

Results

I detected 225 species from 64 families in 2,220 1-m^2 quadrats (Table A.1). I sampled 1,020 quadrats during 2012 and 1,200 during 2013.

Species evenness did not differ by treatment ($F_{2,17} = 1.29$, $P = 0.301$) and year ($F_{1,17} = 0.08$, $P = 0.778$) and there was no treatment × year ($F_{2,17} = 1.44$, $P = 0.265$) interaction.(Table 2.1). There were also no interactions for species evenness when beds and interbeds and their interaction with treatment were compared ($F_{1,24} = 0.004$, $P = 0.950$; see Table 2.2).

I found treatment ($\chi^2_{1,20} = -25.78$, $P < 0.001$), year ($\chi^2_{2,21} = -22.98$, $P < 0.001$) , and treatment × year ($\chi^2_{2,19} = -27.92$, $P < 0.001$) interaction effects on species richness (Table 2.1). Contrasts of treatments × year revealed that MONO had 39% fewer species than IC and 48% fewer species than PINE in 2012 (Table 2.3). In 2013, species richness was similar in all treatments (Table 2.3).

Species richness also exhibited treatment ($\chi^2_{1,29} = -15.72$, $P = 0.017$), year ($\chi^2_{1,29} = -17.25$, $P < 0.001$) interbed/pine bed × treatment × year interactions ($\chi^2_{4,28} = -16.70$, $P = 0.002$). In direct contrasts of interbed/pine bed × treatment × year interactions I revealed that IC interbeds had 32% fewer species than IC pine beds, 40% fewer than PINE interbeds, and 35% fewer than PINE pine beds in 2012 (Table 2.4)

I found no year ($F_{1,17} = 3.26$; $P = 0.090$) effects or treatment × year ($F_{2,17} = 1.47$, $P = 0.257$) interactions for species diversity. However, I did reveal treatment ($F_{2,17}$

=11.19, $P < 0.001$) effects on species diversity estimates (Table 2.1). Like species richness estimates, treatment differences were reflective of less diversity MONO (H^1 = *1.76)* compared to IC ($H^1 = 2.87$; $T_{2,17}$ = -4.50, P = 0.001) and PINE (H^1 = 2.73; $T_{2,17}$ = -3.92, P = 0.003; see Table 2.1).

I found no treatment ($F_{1,24}$ = 0.65, P = 0.429) or interbed/pine bed × treatment × year ($F_{1,24}$ = 0.49, P = 0.491) interactions for species diversity between IC and PINE or within each treatment type. Comparisons of species diversity in pine beds and interbeds revealed year ($F_{1,24}$ = 5.07, P = 0.034) interactions only (Table 2.2). Direct comparisons of years revealed that there was less diversity in pine beds and interbeds in 2012 than 2013 (H^1 = 2.46 versus H^1 = 2.85; $T_{1.24}$ = -2.25, P = 0.034; see Table 2.2).

Discussion

Plant communities (species richness and diversity) in intensively managed pine respond both positively and negatively to changing and/or additional site preparation for facilitating pine establishment (Swindel et al. 1989, Miller et al. 1995, Jones et al. 2009, Lane et al. 2011, Grace et al. 2011, and many others). Here I further support these studies by revealing additional site preparation to facilitate intercropping switchgrass in intensively managed pine causes reductions in plant species richness and diversity depending on scale/intensity of intercropping (IC versus MONO). My results indicate that seeding switchgrass within pine stands does not negatively affect plant communities at the stand level. However, planting blocks of switchgrass (i.e., MONO in my study) will initially reduce richness and diversity. Reductions in the MONO plots were likely caused by the broadcast application of glyphosate compared to banded application in IC. Species richness was reduced in traditionally managed pine that received broadcast application compared to banded application (Jones et al. 2009, Lane et al. 2011) and broadcast application reduced diversity within treatment year (Lane et al. 2011).

Intercropping in loblolly pine at least 5 years post-establishment has been shown to increase richness of forbs (Iglay et al. 2012) in both interbeds and pine beds (individually), but it is likely that intercropping in older pine stands causes a disturbance not present in traditionally managed pine (at that point in time) that facilitates an influx in species richness compared to non-intercropped pine stands. Considering that switchgrass was seeded using a seed drill following a single herbicide application and V-shearing in stands with overstory pines and more developed understory vegetation (Iglay et al. 2012). Although I revealed that richness was negatively affected in IC interbeds, differences in plant community response in my study is understandable considering establishment was conducted in younger pine stands and site preparation intensity was greater. In my study, switchgrass was reseeded in 2012 due to low germination rates in 2011 (Darren Miller, *personal communication*). Consecutive applications (2011 and 2012) of herbicide to IC interbeds and MONO plots increased intensity and extended time of site preparation presumably reducing species richness (in IC and MONO in 2012) and species diversity (in MONO in 2012 and 2013). Broadcast herbicide applications can affect species richness more so than banded applications in pine stands (Jones et al. 2009, Lane et al. 2011), and 2 years of broadcast applications can further reduce species richness in year 2 and year 3 (Jones et al. 2009). Greater reductions in richness (2012) and diversity (2012 and 2013) in MONO compared to IC and PINE was likely due to broadcast applications occurring in both 2011 and 2012.

Disking can increase plant species richness (Benson et al. 2007), but mechanical site preparation (combination plow to 40 cm in depth) following herbicide application can reduce richness in managed pine forests (Jones et al. 2009). In my study, disking followed herbicide application to facilitate switchgrass seeding and may have further reduced richness in IC interbeds and MONO and caused less diversity in MONO. One year following switchgrass establishment species richness recovered in IC interbeds and MONO plots, while diversity remained less in MONO than IC and PINE in 2013. Most site preparation that effects plant communities (positively or negatively) generally do not persist much beyond treatment year (Jones et al. 2009, Iglay et al. 2012), and become mostly similar as stands approach canopy closure regardless of site preparation (Jones et al. 2012, Campbell et al., *in press*). Even in older pine stands intercropped with switchgrass, benefits to forb species richness in interbeds was only present immediately following site preparation (Iglay et al. 2012). Considering MONO plots will not experience canopy closure, species richness and diversity may remain static while IC and PINE slowly lose species as canopy closure approaches.

Loss of nutrients associated with coarse woody debris removal in IC and MONO treatments may have been the cause of the reduced richness and diversity (Wilson and Tilman 1995, Huston 1996, Beauvais et al. 2010, Sucre and Leggett 2011). Additionally, reduced species richness and/or diversity were likely more prominent in MONO than IC and PINE due to the drastically reduced CWD presence in MONO (Loman et al. 2013). Removal of CWD in combination with 2 years of broadcast herbicides likely explains MONO plots being less diverse than IC and PINE in both 2011 and 2012.

Annual switchgrass harvest may implement additional disturbance to IC and MONO further changing plant communities. Iglay et al. (2012) revealed increased forb richness in pine beds of switchgrass intercropped pine stands 1 and 2 year following switchgrass establishment and 2 consecutive switchgrass harvests. Although my initial predictions that intercropping in younger pine stands would increase species diversity in pine beds due to increased light availability (Wilson and Tilman 1995) did not hold true, subsequent harvests as stand succession advances may produce results similar to Iglay et al. (2012). Mowing with vegetation removal (i.e. harvest) in early- and late-summer increases grass species richness by 42% and 25%, respectively (Fynn et al. 2004). A smaller percentage increase in grass species due to post-summer timing of harvest can be expected. In California coastal grasslands, the first haying created a significant increase in plant diversity, especially in native forbs (Maron and Jefferies 2001). As consecutive early-fall switchgrass harvests (haying) continue, plant diversity may benefit in IC and MONO plots. Although harvesting switchgrass in early-fall may not benefit plant diversity as much as early-summer harvest (Fynn et al. 2004), there will be less negative impacts on other species such as nesting songbirds (Perlut et al. 2006, and references therein), Northern bobwhite (*Colinus virginianus*; Roseberry and David 1994), and wild turkey (*Meleagris gallopavo*; Sisson and Speake 1994) .

Biodiversity is a popular and extensively studied ecological concept (Edwards and Abivardi 1998, Purvis and Hector 2000, Heller and Zavaleta 2009, and may others). Among the plethora of studies investigating plant diversity, importance of understanding and maintaining certain plant assemblages for the sake of biodiversity as a whole is clear. One example is the relationship between plant composition and insect assemblages.

Many insect and spider assemblages can be predicted by plant compositions indicating direct relationship between plants and insects (Schaffers et al. 2008). Insects are equally important to ecosystem services such as dung burial, pest control, pollination and as wildlife food sources (Losey and Vaughan 2006). Recent estimates indicate that these ecosystem services are of economic value to the United States worth ≥ $57 billion annually (Losey and Vaughan 2006). Because MONO plots had less plant diversity during and immediately following switchgrass establishment, use of this approach to land management may affect responses of other organisms, such as insects and spiders. Given that plant communities remained similar in IC and PINE during the establishment phase, there is likely little to no effect on other organism assemblages during a similar time frame.

Plant diversity is also important to biodiversity in intensively managed forests. It is well known that intensively managed forests have potential to host many species of flora and fauna (Miller et al. 2009, and references therein). Changes in site preparation causing additional disturbances in these forested systems may affect plant diversity, in turn, limiting or enhancing biodiversity in these widespread habitat types (Swindel et al. 1989, Fredrickson et al. 1991, Miller et al. 1995, Jones et al. 2009, Grace et al. 2011, Lane et al. 2011, Iglay 2012). Here I further support previous research and reveal that intercropping has potential to limit plant diversity (potentially limiting other species diversity) with most intense applications (MONO). Some researchers have speculated that annual harvest of intercropped switchgrass may increase biodiversity by implementing a grass-dominated landscape and a mosaic of habitat structure within largely forested systems (Riffell et al. 2012). In the scope of my study, intercropping switchgrass with pine did not affect plant diversity at stand level in any way, but future research is needed to investigate plant diversity (and other species diversity) responses to repeated annual harvests to resolve past speculations regarding changes in habitat structure benefiting biodiversity in these systems.

Although there may be difficulty in determining all effects of intercropping switchgrass in managed pine on biodiversity, results of this study reveal that overall effects on plant diversity is minimal during site preparation and immediately following establishment. Provided future research, the time period between site preparation and initial establishment (as in my study) and response to consecutive switchgrass harvest may be determined. Considering switchgrass harvest can continue in these plots upwards of 10 years, understanding plant community response during this time period is critical in understanding the overall effects of intercropping on biodiversity in these systems.

Management Implications

It is clear that intercropping switchgrass in managed loblolly pine forests may negatively affect plant community species richness and diversity during establishment. These reductions were short-lived and did not affect plant communities the second year. Although past research reveals that establishment practices, and additional treatments in managed pine forests can benefit plant species richness and diversity it appears that intercropping provides no additional benefits to plant communities beyond that of previous advancements in silvicultural practices. Although my results suggest that intercropping switchgrass within managed pines will have only temporary impacts on plant communities, further studies are needed to examine effects beyond two years post establishment.

Table 2.1 Plant species evenness, richness, and diversity for each treatment by year.

Community Response	Year	Treatment								
		IC			MONO			PINE		
		$\bar{x}$	LCL	UCL	$\bar{x}$	LCL	UCL	$\bar{x}$	LCL	UCL
Evenness	2012	0.69^{A}	0.54	0.84	0.60^{A}	0.43	0.77	0.54^{A}	0.39	0.68
	2013	0.66^{A}	0.51	0.80	0.52^{A}	0.38	0.67	0.68^{A}	0.54	0.83
Richness	2012	4.24^{B}	4.12	4.36	3.75^{A}	3.57	3.92	4.41^{B}	4.35	4.52
	2013	4.32^{C}	4.21	4.44	4.45^{C}	4.35	4.56	4.52^{C}	4.41	4.62
Diversity (H^{l})	2012	2.91^{B}	2.41	3.41	1.53^{A}	0.95	2.11	2.36^{B}	1.86	2.87
	2013	2.83^{B}	2.33	3.34	1.98^{A}	1.47	2.48	3.09^{B}	2.59	3.60

Mean estimates for plant species evenness, richness, and diversity for each treatment level (IC = switchgrass intercropped, MONO = switchgrass monoculture, PINE = traditionally managed pine) based on differences in establishment (2012) for switchgrass intercropping and post-establishment of switchgrass (2013) in Kemper Co., MS. Diversity was estimated using Shannon's Diversity Index. Species richness means and upper and lower confidence levels (UCL and LCL, respectively) are log transformed estimates. Differences among treatments means are designated by different letters within rows. Levels of significance refer to least square means and were considered significant at α=0.05.

Table 2.2 Plant species evenness, richness, and diversity for IC and PINE treatments by year for both pine beds and interbeds.

Community Response	Year	Bed/Interbed	Treatment					
			IC			PINE		
			$\bar{x}$	LCL	UCL	$\bar{x}$	LCL	UCL
Evenness	2012	Bed	0.69^{A}	0.59	0.79	0.52^{A}	0.41	0.62
	2012	Interbed	0.69^{A}	0.58	0.79	0.58^{A}	0.47	0.68
	2013	Bed	0.73^{A}	0.62	0.83	0.70^{A}	0.59	0.81
	2013	Interbed	0.65^{A}	0.54	0.76	0.67^{A}	0.56	0.78
Richness	2012	Bed	4.10^{AC}	3.96	4.22	4.14^{AC}	4.02	4.27
	2012	Interbed	3.71^{B}	3.55	3.86	4.23^{AC}	4.12	4.35
	2013	Bed	4.15^{C}	4.02	4.27	4.31^{C}	4.20	4.43
	2013	Interbed	4.10^{C}	3.95	4.21	4.13^{C}	4.00	4.25
Diversity (H^{l})	2012	Bed	2.80^{A}	2.30	3.30	2.14^{A}	1.64	2.64
	2012	Interbed	2.47^{A}	2.00	2.97	2.44^{A}	1.94	2.94
	2013	Bed	3.01^{B}	2.51	3.51	3.01^{B}	2.51	3.51
	2013	Interbed	2.62^{B}	2.12	3.12	2.76^{B}	2.26	3.26

Mean estimates for plant species evenness, richness, and diversity for each treatment level (IC = switchgrass intercropped, and PINE = traditionally managed pine) based on differences in establishment (2012) for switchgrass intercropping and post-establishment of switchgrass (2013) in Kemper Co., MS. Species richness means and upper and lower confidence levels (UCL and LCL, respectively) are log transformed estimates. Differences among treatments means are designated by superscript letters within rows. Levels of significance refer to least square means and were considered significant at α=0.05.

Table 2.3 Treatment by year contrasts for species richness.

Contrast	Year	Estimate	Z-statistic	P-value*
IC – MONO	2012	0.49 (0.11)	4.59	0.001*
IC – PINE	2012	-0.17 (0.08)	-2.11	0.413
MONO – PINE	2012	-0.66 (0.10)	-6.36	<0.001*
IC – MONO	2013	-0.13 (0.08)	-1.61	0.816
IC – PINE	2013	-0.19 (0.08)	-2.47	0.184
MONO – PINE	2013	-0.06 (0.08)	-0.86	0.999

Contrasts treatment by year for plant species richness for each treatment level (IC = switchgrass intercropped, MONO = switchgrass monoculture, PINE = traditionally managed control) based on differences in establishment (2012) for switchgrass intercropping and post-establishment of switchgrass (2013) in Kemper Co., MS 2012–2013. Species richness means and standard errors (SE) are log transformed estimates. Levels of significance refer to least square means and were considered significant at α=0.05. *P*-values* represents significant interactions.

Table 2.4 Contrasts of beds and interbeds by treatment and year for species richness.

Contrast	Year	Estimate	Z-statistic	P-value*
IC^{B} – PINE^{B}	2012	-0.05 (0.09)	-0.59	1.000
IC^{B} – IC^{I}	2012	0.38 (0.10)	3.77	0.005*
IC^{I} – PINE^{I}	2012	-0.53(0.10)	-5.33	<0.001*
IC^{B} – PINE^{B}	2013	-0.17 (0.09)	-1.96	0.766
IC^{B} – IC^{I}	2013	-0.07 (0.09)	0.77	1.000
IC^{I} – PINE^{I}	2013	-0.05 (0.09)	-0.54	1.000

Contrasts of beds(denoted by "B") and interbeds (denoted by "I") by treatment (IC = switchgrass intercropped, PINE = traditionally managed pine) and year based on differences in establishment (2012) for switchgrass intercropping and post-establishment of switchgrass (2013) in Kemper Co., MS 2012–2013. Species richness means and standard errors (SE) are log transformed estimates. Levels of significance refer to least square means and were considered significant at α=0.05. *P*-values* represents significant interactions.

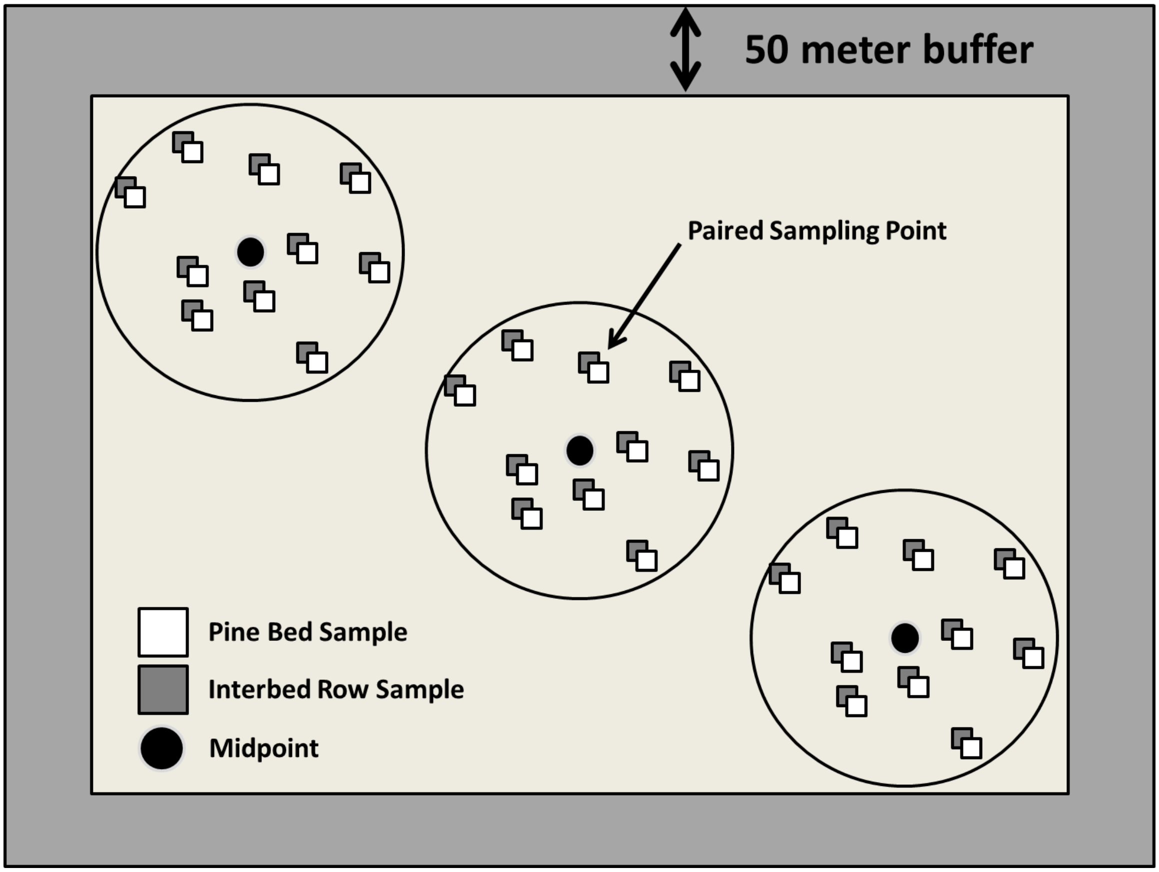

Figure 2.1 Sampling design for species diversity for each experimental plot.

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CHAPTER III

PLANT BIOMASS PRODUCTION AND DEER FORAGE RESPONSE TO ESTABLISHMENT OF INTERCROPPED SWITCHGRASS IN MANAGED PINE STANDS

Previous work has demonstrated value of intensively managed forests for conservation of biological diversity (e.g., Wigley et al. 2000, Miller et al. 2009), which may include quality habitat conditions for white-tailed deer (*Odocoileus virginianus*; hereafter, "deer"; Demarais et al. 2000). However, deer forage biomass production responds to changes in forest management practices (Edwards et al. 2004, Jones et al. 2009, Mixon et al. 2009, Iglay et al. 2010b). The social and economic value of deer in the southeastern United States (Grado et al. 2007, Mozumder 2007), justifies the evaluation of new forest management practices relative to deer habitat quality.

Increasing interest in using managed forests for alternative and renewable energy resources (Hinchee et al. 2011, Rifeell et al. 2011a, Riffell et al. 2011b, Zalesny et al. 2011) may produce changes in deer forage biomass production via changes in forest management similar to past changes (Edwards et al. 2004, Jones et al. 2009, Mixon et al. 2009, Iglay et al. 2010b). Research is being conducted investigating switchgrass (*Panicum virgatum*) as a potential candidate for intercropping between rows of loblolly pine (*Pinus taeda*; hereafter, "intercropping"). Understanding effects of intercropping on total plant biomass and biomass of deer forages is important for understanding how producing bioenergy feedstocks in intensively managed forests impacts habitat quality for deer.

Studies investigating deer forage response to forestry practices have mostly examined stand establishment regimes (Jones et al. 2009) or mid-rotation application of herbicide and prescribed burning (Edwards et al. 2004, Mixon et al. 2009, Iglay et al. 2010b). However, intercropping switchgrass introduces additional disturbance factors, including coarse woody debris displacement (Loman et al. 2013), altered and increased herbicide use, and potential for additional competition with a pre-established competitor (i.e., switchgrass), which could lead to changes in biomass production, composition and diversity of vegetation communities (Iglay et al. 2010a). Therefore, I measured total plant biomass (in kg) production (further separated into biomass of growth forms) and biomass of deer forages (consumable plant parts) from 2011 to 2013 immediately following traditional establishment (2011), during switchgrass establishment (2011 to 2012) and immediately following switchgrass establishment (2013) to provide understanding of how intercropping switchgrass in intensively managed pine may affects biomass and deer forage production. My objectives were to 1) determine if intercropping affects total biomass production between traditionally manage loblolly pine and intercropped plots during the establishment phase, and 2) to reveal differences, if any, between traditionally managed and intercropped pine in deer forage production during summer, an important period for recruitment with increased nutritional requirement for lactating females (Iglay et al. 2010, and references therein). I predicted that intercropping switchgrass would reduce biomass production of woody and subshrub species (defined below), while increasing biomass production of forbs and graminoids (including switchgrass).

Likewise, I expected a reduction in total browse biomass driven by reduced woody plant cover, and increased biomass of forb and grass browses (excluding switchgrass).

Methods

Study Area

I collected data within early-rotation, intensively managed loblolly pine stands on land owned and managed by Weyerhaeuser Company in Kemper County, Mississippi, USA. Catchlight Energy LLC, a joint venture between Chevron and Weyerhaeuser Company, established experimental plots, as outlined below, within this landscape. I collected data during summers of 2011-2013 between 1 July and 8 August each year (hereafter "July"). Stands were located in the Interior Flatwoods Soil Resource Region (Pettry 1977), with the 25,000 ha surrounding landscape comprised of loblolly pine stands (70%), mature pine-hardwood (17%), mature hardwoods (10%), and non-forested areas (3%). Climate was subtropical with an average annual temperature and precipitation of 16.8 °C and 143.2 cm, respectively (National Oceanic and Atmospheric Administration 2014).

Study Design

I used a randomized complete block design with 4 sampling stands (blocks). Each stand had 4, 10-ha experimental plots with randomly assigned treatments that were part of a broader study on biofuel feedstocks (Loman et al. 2013, 2014), but only 2 of 4 treatments (2 of 4 10-ha experimental plots) were used for purposes of estimating biomass production. Each experimental plot was an intensively managed pine stand clearcut harvested during 2009 and 2010. Treatments used to compare biomass production and deer forage response were: (1) traditionally managed pine (hereafter referred to as PINE): standard Weyerhaeuser Company site preparation for plantation establishment, which included a V-blade plow, bedding plow and subsoil ripper to establish pine beds. Pine seedlings were planted with a spacing of 1.5 m by 6.1 m (approximately 1,100 trees/ha) resulting in widths of 1.2 m and 4.9 m for pine beds and interbeds, respectively. During the first growing season post-planting, a banded application of imazapyr (0.29 L/ha; Arsenal® AC, BASF Corp., Research Triangle Park, NC) and sulfometuron-methyl (0.15 L/ha; Oust®, E. I. du Pont de Nemours and Company, Wilmington, DE) was applied to pine beds to temporarily reduce woody and herbaceous competition; (2) switchgrass intercropped (hereafter referred to as IC): same site preparation as traditionally managed pine with addition of more extensive CWD removal. Following bedding for pine trees, a V-blade plow was used to push CWD from interbeds into pine bed edges. Following CWD clearing in interbeds, a banded application of glyphosate (2.34 – 4.68 L/ha; Accord®XRT, Dow AgroSciences, Indianapolis, IN) was applied to interbeds only. Interbeds were then disked and broadcast seeded with switchgrass once glyphosate control was complete. Intercropped plots were originally seeded in spring 2011 and reseeded in 2012 due to low success of initial seeding. During reseeding, interbeds were sprayed again with a banded application of glyphosate, disked, and seeded. Switchgrass harvest for bioenergy feedstock did not occur during 2012, but IC plots were mowed and baled during fall 2012.

I generated three points along the southeast to northwest diagonal axis ≥ 50 m from plot edges to avoid edge effects (i.e., one point in southeastern corner > 50 m from the edge, one in plot center, and one in the northwestern corner > 50 m from the edge). I randomly generated 8 additional points ≤ 50 m from each of these diagonal points (n = 24 per experimental plot), from which pine beds and interbeds were sampled equally (n = 12 interbed and n = 12 pine bed per experimental plot; see Figure 3.1). I collected aboveground biomass of all plants (except planted pines) ≤ 2 m above ground and within a 1-m^2 quadrat using hand shears at each random point. Upon collection, I sorted clipped plants to species and stored samples in paper bags in a freezer until the end of each field season. I categorized plant species into four growth forms: forbs, graminoids, subshrubs and woody (hereafter referred to as "plant classes"). I derived all plant classes and plant species names (both scientific and common) using the U.S. Department of Agriculture Plant Database (USDA 2014). Species of blackberry (*Rubus* ssp.) and Eastern poison ivy (*Toxicodendron radicans*) were the only species I detected classified as subshrubs (USDA 2014). Woody contained woody shrubs, trees and vines. I used literature and local experts in identifying and verifying plant species identification (Radford et al. 1968, Miller and Miller 1999, Bryson and DeFelice 2009, Schummer et al. 2012).

I composed a list of moderate- and high-use summer deer forages from available literature (Warren and Hurst 1981, Miller and Miller 1999, Gee et al. 2011). Switchgrass was noted as a moderate-use summer deer forage (Warren and Hurst 1981), but I excluded it from my list of forages based on a recent survey of deer biologists in Alabama, Mississippi, and Louisiana (Ethan Greene, Mississippi State University, *unpublished data*). I further classified these forages into forage classes (forb forages, grass forages, and browse). I also composed a list of low-use forages and forages known to be unused by deer and lumped them into a single classification (low- and no-use forages). I separated consumable (leaves and growing stem tips only) and non-consumable plant parts of forage species during collection. Following collection, I dried plant samples in a forced-air oven at 60°C for 72 hours and then weighed (g) samples to estimate dry matter biomass (kg/ha) for each forage (Iglay et al. 2010b) and non-forage species to estimate total plant biomass production for each treatment.

Statistical Methods

I used repeated-measures mixed model analysis of variance in SAS Proc Mixed (SAS Institute Inc., Cary, NC) to test predicted responses of total biomass production, biomass production of plant classes, biomass production of individual forage classes, and total deer forage biomass production were affected by treatments, years, and a treatment × year interaction. I used treatment (IC or PINE) as a fixed effect, stand as random effect (block, n = 4), and year (2011–2013) as a repeated measure. I used Kenward-Roger denominator degrees of freedom correction to avoid inflated type I error (Littell et al. 2006, Gutzwiller and Riffell 2007). I used Sidak correction (Sidak 1967) to adjust for multiple comparisons in post-hoc year × treatment contrasts (Littell et al. 2006). I used the LSMEANS SLICE to identify treatment effects within years and LSMEANS PDIFF to conduct pair-wise comparisons among treatments (Littell et al. 2006). I considered results significant at $\alpha = 0.10$.

I conducted analyses of pine beds and interbeds separately to directly compare differences between treated and untreated areas among years and treatments using analytical methods as described above. I only distinguished pine beds and interbeds quadrats in 2012 and 2013 because separation between bed and row was difficult in 2011 due to large amounts of CWD that was resultant of preparing interbeds for switchgrass establishment.

Results

Total Biomass

I collected 7,495 biomass samples from 960 quadrats totaling to 96.4 kg (dried weight) from 189 identified species (see Table A.1) during 2011-2013. The 9 most prominent species, common ragweed (*Ambrosia artemisiifolia*), sawtooth blackberry (*Rubus argutus*), switchgrass (*Panicum virgatum*), winged sumac (*Rhus copallinum*), openflower rosette grass (*Dichanthelium laxiflorum*), Japanese honeysuckle (*Lonicera japonica*), cypress panicgrass (*Dichanthelium dichotomum*), tapered rosette grass (*Dichanthelium acuminatum*) and Canada goldenrod (*Solidago canadensis*), comprised approximately 50% of total biomass collected in all years. Of these 9 species, common ragweed and sawtooth blackberry comprised 11% and 10%, respectively, of total biomass.

Total biomass production (individual plant classes + switchgrass biomass) was less in IC than in PINE only in 2012 during switchgrass establishment (Table 3.1). However, biomass production of each individual plant class (forbs, graminoids, subshrubs, woody) remained similar in IC and PINE during 2012 and 2013 (Table 3.1).

For interbed biomass estimates, I found treatment × year interactions in total biomass production ($F_{1,9}$ = 9.59, P = 0.013), graminoid biomass production ($F_{1,12}$ = 6.54, P = 0.025), forb biomass production ($F_{1,12}$ = 3.37, P = 0.091), and forb forage ($F_{1,12}$ = 3.68, P = 0.079). Biomass production was less in interbeds of IC than PINE in 2012 and 2013 (Table 3.2). Considering that switchgrass presence was minimal immediately following 2011 establishment and re-establishment in 2012, PINE had greater biomass in interbeds (Table 3.2). I found no difference in total biomass production between interbeds of IC and PINE in 2013 once switchgrass became fully established (Table 3.2).

Forb biomass production was less in IC interbeds in 2012 only, but subshrub biomass production was less in 2012 and 2013 (Table 3.2). Woody biomass production in interbeds was similar between IC and PINE in 2012, but PINE experienced a two-fold increase in woody biomass compared to IC in 2013 resulting in less production in IC plots (Table 3.2). Graminoid biomass production remained similar in interbeds of IC and PINE (Table 3.2).

Total pine bed biomass production and biomass production of individual plant classes was similar in IC and PINE in 2012-2013 (Table 3.3)

Deer Forage Biomass

I found treatment × year interactions in biomass production of moderate- and high-use forages ($F_{2,15} = 3.02$, $P = 0.079$). Moderate- and high-use deer forage biomass production was less in interbeds of IC compared to PINE in 2012 and 2013 (Table 3.2). Biomass production of all forage classes was less in interbeds of IC compared to PINE in 2012, but forb forage and grass forage biomass production was similar in both treatments in 2013 (Table 3.2). Browse biomass production remained less in IC in 2013 (Table 3.2).

Biomass production of moderate- and high-use deer forages and individual forages classes was similar in pine beds of IC and PINE in 2012-2013 (Table 3.3).

Discussion

Total Biomass

Consistent differences in total biomass, biomass of plant classes, and biomass of forages between PINE and IC plots indicated that intercropping affected important vegetative characteristics of intensively managed pine stands during establishment. Vegetation growth during the first growing season in all stands was minimal, and a large percentage of ground cover was CWD and bare ground (Loman et al. 2013, 2014), which explains similarity in biomass production between treatments during the first year of establishment. However, as biomass production increased in 2012 across treatments, differences became noticeable.

These initial reductions in biomass were most likely due to herbicide treatments and mechanical site preparation used to facilitate pine planting and switchgrass seeding. Combinations of imazaypyr and sulfometuron to pine beds and glyphosate to interbeds in IC plots in 2011 resulted in complete herbicide application at the plot level (similar to broadcast application). Additionally, interbeds of IC plots were retreated with glyphosate in 2012 causing further reduction in biomass production, which is likely the principal reason for reduced biomass in IC plots in 2012 compared to PINE. Past results reveal that in intensively managed pine stands using 2 years of broadcast herbicide application compared to 1 year for vegetative competition control experience greater reductions in biomass production (Jones et al. 2009). Although a second broadcast application was not applied to IC plot in 2012, I suspect that biomass production would have remained similar in IC and PINE if retreatment to interbeds had not occurred. Once established in

2013, switchgrass presence seems to have no effect on total biomass and biomass production of other vegetation.

I hypothesized that methods used to facilitate intercropping (plowing, herbicide applications and disking) would act as additional disturbances that would complement recolonization and growth of more herbaceous ruderal species (many of which are forbs), based on Grime's (1977) C-S-R theory that states that there are three primary strategies in plants: 1) competitors are species that prosper at levels of low stress and disturbance, 2) stress tolerant species thrive at levels of low competition and high stress, 3) ruderal species prefer levels of low stress and high disturbance. Contrary to my expectations, forb biomass was mostly unaffected in IC stands both during and after establishment. Disking potentially promotes forb growth (Bozzo et al. 1992, Carver et al. 2001), but repeated glyphosate applications likely negated any benefits of disking for forbs in my study as did subsequent switchgrass establishment efforts. Severe disturbance (i.e. removal of all understory vegetation) greatly affects herbaceous vegetation (forbs) and only some herbaceous species are able to recolonize (Roberts 2004). Considering chemical and mechanical establishment methods resulted in removal of most (in some cases all) vegetation in IC interbeds, it is likely that these disturbances were persistent enough to delay recolonization.

Graminoid biomass production was similar between IC and PINE stands in all years. This was expected, as graminoid responses to disking and glyphosate are equivocal and taxa dependent (Horsely 1990, Bozzo et al. 1992, Carver et al. 2001). Additional disturbance (herbicide and disking) in 2012 to facilitate reseeding switchgrass likely resulted in similarities in graminoid biomass production in IC and PINE. Differences in graminoid biomass production remained similar even after switchgrass was established in 2013. Although these results seem counterintuitive, they are reflective of large variance because only 1 of 4 IC plots had well-established switchgrass during 2013 sampling. Also, switchgrass was present in two of four PINE plots producing an estimate of 14 kg/ha for PINE. Switchgrass presence in PINE plots was likely due to pre-established switchgrass or propagation of introduced seed stock by human or wildlife transport, but presence of native switchgrass was possible. It was unlikely that switchgrass in PINE plots was a result of transport via mechanical equipment considering plots were sampled ≥50 m from plot edge and no equipment was used in PINE plots during switchgrass seeding.

Overall, biomass production was affected more in interbeds compared to stand level and pine bed estimates between IC and PINE. My expectations that additional site preparation would result in greater biomass removal initially held; biomass production was much less in IC interbeds compared to IC pine beds. This trend continued in 2013 with switchgrass biomass excluded from estimates, but similarity in total biomass further supports that switchgrass biomass did not affect total biomass production at the stand level or specific treatment areas (interbeds).

Like total biomass, forb biomass in IC interbeds was greatly reduced during 2012, but was similar to PINE in 2013, suggesting that biomass production of forbs were not affected post switchgrass establishment. Jones et al. (2009) revealed that forb forage biomass production was less in year 2 when stands received a second broadcast application of herbicide compared to stands receiving broadcast applications in year 1 only (150 kg/ha compared to 211 kg/ha). Although these results are focused on forb forages and not all forbs, it is still likely that repeated applications of glyphosate to interbeds is responsible for reductions in total forb biomass reductions in my study in 2012. Furthermore, Jones et al. (2009) found that broadcast applications reduced forb biomass by 89% compared to banded applications during year 1. This further supports my conclusion that glyphosate applications in 2011 and 2012 were the primary influence on decreased production of forbs during establishment, as opposed to switchgrass presence, considering switchgrass biomass was minimal in most IC plots.

I suspect that initial reductions in subshrub biomass in 2012 and both subshrub and woody biomass in 2013 in IC interbeds was a direct cause of repeated glyphosate applications in 2011 and 2012. Effects of chemical site preparation tend to be more prominent on woody plant species immediately following application and until canopy closure (Jones et al. 2012, Campbell et al. *in press*). Also, in plots where switchgrass biomass was prominent, switchgrass likely displaced subshrubs and woody species. Parrish and Fike (2005) noted that switchgrass seeded in herbicide-killed sod germinated and sprouted quickly, ultimately outcompeting other plant species during establishment. This ability for switchgrass to outcompete other species may have resulted in displacement of other species in interbeds of plots with established switchgrass.

Biomass production in IC and PINE pine beds were similar, therefore I conclude that establishment methods did not affect pine bed biomass. However, biomass production may decline as pines begin to shade out pine beds in subsequent years (Jones et al. 2009). In looking at biomass estimates from year 1 to year 5 in Jones et al. (2009), it seems that biomass (regardless of treatment) peaks following site preparation and then begins to decline 3-5 years following site preparation. Stands used in my study will likely not experience shading effects as early as stands used in Jones et al. (2009) considering tree spacing was much wider in my stands (1.5 m by 6.1 m compared to 3.0 m by 2.1 of Jones et al.). Canopy closure in stands with tree spacing of 3.0 m by 2.1 m begins around year 6 post-establishment (Jones et al. 2012, Campbell et al., *in press*), whereas canopy closure in stands with 1.5 m by 6.1 m tree spacing does not occur until 9-10 years post-establishment or even later considering commercial thinning occurs at approximately 11 years post-establishment (Darren Miller Weyerhaeuser Company, *personal communication*).

Deer Forage Biomass

Summer diets of deer are comprised mostly of forbs (McCaffery et al. 1974, Gee et al. 2011), and intensively managed pine stands can produce abundant forb forage biomass under certain management practices (Edwards et al. 2004, Jones et al. 2009, Mixon et al. 2009, and Iglay et al. 2010b). The negative effect on forb forage biomass production within switchgrass interbeds during year 1 and 2 of my study was likely more than would be expected had there been no need for a second year of herbicide application and switchgrass planting. This additional application of herbicide made my treatment similar to the most intensive herbicide application studied by Jones et al. (2009), but they also found that by the third growing season forb forage biomass no longer differed between 1- and 2-year herbicide application treatments.

I expect that forb forage biomass production will increase in IC compared to PINE due to annual harvests promoting new growth during early- to mid-summer, which will likely provide increased availability of younger, more nutritious and palatable forages in interbeds. Past research reveals that repetitive mowing increased light availability which increased forb abundance and root and shoot biomass (Williams et al. 2007). Although Williams et al. (2007) implemented a much more frequent mowing regime in their study areas, a single mowing (i.e. switchgrass harvest) may increase forb abundance and biomass production resulting in greater available forage and increased foraging opportunity for deer. Intercropping in pine stands that are at least 5 years old (with same row spacing as in my study) produced greater species richness and coverage of forbs three years after switchgrass establishment (Iglay et al. 2012). Past research has also found that fall cattle (*Bos taurus*) grazing can increase foraging habitat for elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) by removal of standing dead plant material providing easier access to young, nutritious forages the following summer (Taylor et al. 2004). Switchgrass mowing and baling would remove standing dead plant material and may increase accessibility to forage plants (Stewart et al. 2000).

Further research is needed to better understand how intercropping switchgrass affects deer foraging environments in young, open-canopied plantations. Although my analysis found effects of intercropping on forage production, forage quality was not assessed. Forage quality varies greatly among forbs, grasses, and browse, so both biomass and composition of available forage influences ability of any given area to support nutritional requirements of deer, and comparisons of nutritional value may differ substantially from strict biomass estimates (Jones et al. 2009). Spacing of crop trees may also extend the period interbed spaces are able to produce peak levels of forage biomass, due to the longer open-canopy period. Compared with conventionally managed stands, forage species composition and productivity may be altered by annual mowing.

Monitoring should continue to determine influence of these factors and how intercropped plantations might contribute to a landscape-scale management strategy for deer.

Management Implication

Initial switchgrass establishment reduced total biomass and biomass of moderate- and high-use deer forages, but my data suggests that these reductions do not persist once switchgrass is fully established, much like other site preparation treatments in intensively managed pine stands. Stand level reductions occurred only in 2012 when a second year of site preparation occurred to facilitate reseeding switchgrass due to low germination in 2011 (Darren Miller, Weyerhaeuser Company, *personal communication*). If retreatment had not occurred, biomass production of these forages may have remained similar in both IC and PINE stands.

Incorporating switchgrass intercropping into a pine management system will decrease deer forage quantity during the establishment phase. Further work is needed to quantify how much and for how long these changes will impact nutritional carrying capacity for deer. Considering the importance of summer forages to deer, particularly forbs (McCaffery et al. 1974, Gee et al. 2011), it is likely that IC stands will be less desirable to deer and this effect should be considered prior to making this land management choice. However, adding a dominant native warm season grass component to these intensively managed stands may benefit deer by providing important bedding cover (Grovenburg et al. 2010) and annual switchgrass harvests holds potential to increase accessibility (Stewart et al. 2010).

Table 3.1 Total biomass of plant classes and deer forage classes by treatment and year.

	Year	IC	PINE	*P*-value
Plant Class Biomass				
Total Biomass	2011	580 (155)	784 (128)	1.000
	2012	1284 (113)	2267 (236)	0.093*
	2013	2506 (417)	2618 (395)	1.000
Forbs	2011	328 (129)	514 (38)	0.988
	2012	602 (144)	1033 (115)	0.188
	2013	488 (127)	649 (81)	0.997
Graminoids	2011	74 (16)	164 (74)	1.000
	2012	270 (37)	573 (64)	0.806
	2013	775 (285)	735 (71)	1.000
Subshrubs	2011	40 (14)	37 (23)	1.000
	2012	151 (80)	265 (50)	0.776
	2013	402 (129)	418 (54)	1.000
Woody	2011	137 (67)	69 (26)	1.000
	2012	253 (57)	396 (147)	0.998
	2013	303 (51)	801 (287)	0.189
Switchgrass	2011	1 (1)	0 (0)	1.000
	2012	7 (7)	0 (0)	1.000
	2013	537 (400)	14 (10)	0.445
Deer Forage Biomass				
Moderate- and High-use Forages	2011	446 (127)	583 (48)	1.000
	2012	872 (149)	1670 (154)	0.019*
	2013	1290 (122)	1558 (207)	0.967
Low- and No-use Forages	2011	126 (34)	151 (67)	1.000
	2012	393 (132)	587 (124)	0.996
	2013	674 (177)	1024 (194)	0.695
Browse	2011	117 (53)	80 (26)	1.000
	2012	188 (41)	441 (103)	0.165
	2013	495 (116)	686 (117)	0.519
Forb Forages	2011	307 (127)	458 (36)	1.000
	2012	522 (157)	1015 (111)	0.090*
	2013	475 (125)	616 (78)	0.999

Table 3.1 (Continued)

Grass Forages	2011	22 (7)	45 (19)	1.000
	2012	162 (29)	215 (37)	1.000
	2013	319 (104)	256 (44)	0.999

Total (pine beds + interbeds) stand biomass (mean ± 1 SE in kg/ha) of plant classes and deer forage classes in switchgrass intercropped (IC) and traditionally managed pine (PINE) plantations in Kemper Co., MS during July 2011-2013. Biomass production of total biomass (all plant classes + switchgrass), individual plant classes (forbs, graminoids, subshrubs, woody), switchgrass, moderate- and high-use deer forages, and individual forage class is presented. Statistical tests were based on Sidak adjusted *P*-values of differences of least-squared means and were considered significant at $\alpha < 0.10$. *P*-values* represents significant interactions.

Table 3.2 Interbed biomass of plant classes and deer forage classes by treatment and year.

	Year	IC	PINE	*P*-value
Plant Guild Biomass				
Total Interbed Biomass	2012	113 (26)	2484 (399)	0.003*
	2013	2572 (627)	2952 (497)	0.964
Forbs	2012	41 (12)	1027 (249)	0.006*
	2013	422 (96)	816 (181)	0.501
Graminoids	2012	44 (19)	760 (42)	0.713
	2013	2032 (718)	871 (91)	0.231
Subshrubs	2012	12 (12)	304 (101)	0.044*
	2013	76 (18)	430 (82)	0.014*
Woody	2012	16 (12)	393 (163)	0.464
	2013	42 (19)	835 (278)	0.023*
Switchgrass	2012	10 (10)	0 (0)	1.000
	2013	1074 (801)	29 (20)	0.458
Deer Forage Biomass				
Moderate- and High-use Forages	2012	77 (20)	1822 (309)	0.002*
	2013	898 (114)	1952 (333)	0.040*
Low- and No-use Forages	2012	22 (11)	653 (156)	0.109
	2013	594 (217)	949 (193)	0.633
Browse	2012	10 (9)	487 (120)	0.078*
	2013	101 (24)	846 (206)	0.006*
Forb Forages	2012	37 (13)	1013 (245)	0.006*
	2013	413 (94)	775 (182)	0.580
Grass Forages	2012	31 (20)	322 (22)	0.054*
	2013	384 (110)	330 (68)	0.994

Interbed biomass (mean ± 1 SE in kg/ha) of plant classes and deer forage classes in switchgrass intercropped (IC) and traditionally managed pine (PINE) plantations in Kemper Co., MS July 2011-2013. Biomass production of total biomass (all plant classes + switchgrass), individual plant classes (forbs, graminoids, subshrubs, woody), switchgrass, moderate- and high-use deer forages, and individual forage class is presented. Statistical tests were based on Sidak adjusted *P*-values of differences of least-squared means and were considered significant at $\alpha < 0.10$. *P*-values* represents significant interactions.

Table 3.3 Pine bed biomass of plant guilds and deer forage classes by treatment and year.

	Year	IC	PINE	*P*-value
Plant Guild Biomass				
Total Pine Bed Biomass	2012	2387 (224)	2113 (191)	0.945
	2013	2440 (228)	2298 (397)	0.998
Forbs	2012	1144 (269)	1033 (115)	1.000
	2013	554 (188)	500 (23)	1.000
Graminoids	2012	496 (72)	425 (100)	0.999
	2013	592 (257)	627 (128)	1.000
Subshrubs	2012	290 (150)	229 (23)	1.000
	2013	728 (254)	407 (112)	0.435
Woody	2012	457 (106)	357 (148)	0.999
	2013	565 (113)	764 (313)	0.961
Switchgrass	2011	0 (0)	0 (0)	1.000
	2012	<1 (0)	0 (0)	0.668
Deer Forage Biomass				
Moderate- and High-use Forages	2012	1673 (281)	1614 (179)	1.000
	2013	1682 (241)	1192 (145)	0.590
Low- and No-use Forages	2012	693 (209)	492 (109)	0.941
	2013	753 (169)	1085 (276)	0.649
Deer Browse	2012	381 (87)	406 (104)	1.000
	2013	890 (226)	538 (85)	0.076
Forb Forages	2012	1020 (314)	1086 (193)	1.000
	2013	537 (188)	474 (24)	1.000
Grass Forages	2012	272 (41)	122 (49)	0.606
	2013	255 (100)	179 (65)	0.970

Pine bed biomass (mean ± 1 SE in kg/ha) of plant classes and deer forage classes in switchgrass intercropped (IC) and traditionally managed pine (PINE) plantations in Kemper Co., MS July 2011-2013. Biomass production of total biomass (all plant classes + switchgrass), individual plant classes (forbs, graminoids, subshrubs, woody), switchgrass, moderate- and high-use deer forages, and individual forage class is presented. Statistical tests were based on Sidak adjusted *P*-values of differences of least-squared means and were considered significant at $\alpha < 0.10$. *P*-values* represents significant interactions.

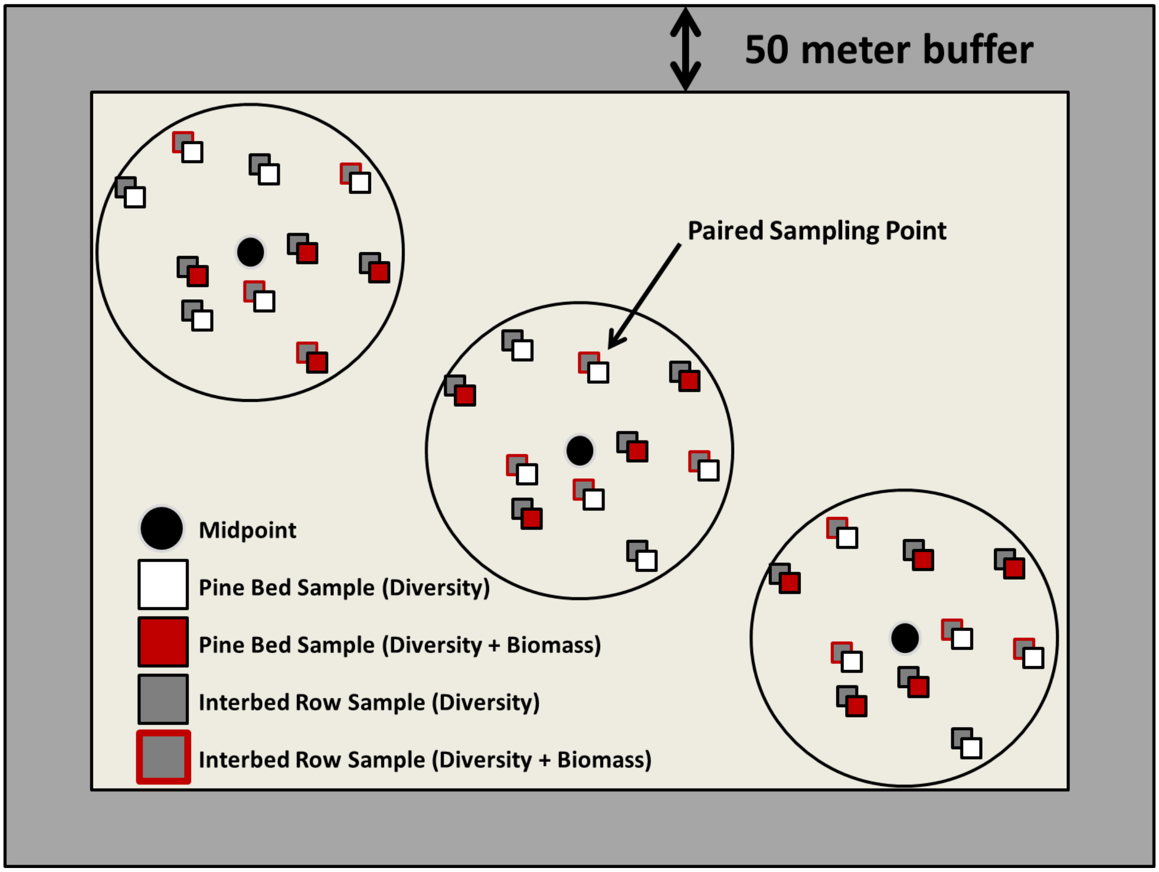

Figure 3.1 Sampling design for biomass collection and species diversity

See Chapter II for each experimental plot.

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APPENDIX A

PLANT SPECIES LIST, FIGURE PORTRAYING LAYOUT OF INTERCROPPED PLOT, AND FIGURE OF SAMPLE DESIGN

Table A.1 Plant species detected during biomass and diversity sampling.

Family	Scientific Name	Common Name	Use	Detected	Plant Class
Aceraceae	*Acer rubrum*	red maple	H	BOTH	W
Anacardiaceae	*Toxicodendron radicans*	eastern poison-ivy	H	BOTH	S
Apocynaceae	*Apocynum cannabinum*	Indianhemp	H	BOTH	W
Araliaceae	*Aralia spinosa*	devil's walking stick	H	BOTH	W
Asteraceae	*Ambrosia artemisiifolia*	common ragweed	H	BOTH	F
Asteraceae	*Bidens aristosa*	bearded beggarticks	H	BOTH	F
Asteraceae	*Conyza canadensis*	Canadian horseweed	H	BOTH	F
Asteraceae	*Coreopsis major*	greater tickseed	H	BOTH	F
Asteraceae	*Eupatorium perfoliatum*	common boneset	H	BOTH	F
Asteraceae	*Eupatorium rotundifolium*	roundleaf thoroughwort	H	BOTH	F
Asteraceae	*Eupatorium serotinum*	lateflowering thoroughwort	H	BOTH	F
Asteraceae	*Iva annua*	annual marsh elder	H	BOTH	F
Asteraceae	*Lactuca canadensis*	wild lettuce	H	BOTH	F
Asteraceae	*Rudbeckia hirta*	blackeyed Susan	H	BOTH	F
Asteraceae	*Solidago gigantea*	giant goldenrod	H	BIO	F
Asteraceae	*Solidago odora*	anisescented goldenrod	H	BOTH	F
Asteraceae	*Symphyotrichum pilosum*	hairy white oldfield aster	H	BOTH	F
Clusiaceae	*Hypericum gentianoides*	orangegrass	H	BOTH	F
Clusiaceae	*Hypericum hypericoides*	St. Andrew's cross	H	BOTH	W
Commelinaceae	*Tradescantia ohiensis*	bluejacket	H	BOTH	F
Commelinaceae	*Tradescantia virginiana*	Virginia spiderwort	H	BOTH	F
Convolvulaceae	*Ipomoea pandurata*	man of the earth	H	BOTH	F

Table A.1 (Continued)

Cornaceae	*Nyssa sylvatica*	blackgum	H	BOTH	W
Dioscoreaceae	*Dioscorea villosa*	wild yam	H	BOTH	F
Euphorbiaceae	*Acalypha gracilens*	three-seeded mercury	H	BOTH	F
Euphorbiaceae	*Euphorbia corollata*	flowering spurge	H	BOTH	F
Fabaceae	*Clitoria mariana*	Atlantic pigeonwings	H	BOTH	F
Fabaceae	*Desmodium ciliare*	hairy small-leaf ticktrefoil	H	BOTH	F
Fabaceae	*Desmodium strictum*	pine barren ticktrefoil	H	BOTH	F
Fabaceae	*Dioclea multiflora*	Boykin's clusterpea	H	BOTH	W
Fabaceae	*Kummerowia striata*	Japanese clover	H	BOTH	F
Fabaceae	*Lespedeza repens*	creeping lespedeza	H	BOTH	F
Fabaceae	*Vicia caroliniana*	Carolina vetch	H	BIO	F
Grossulariaceae	*Itea virginica*	Virginia sweetspire	H	BOTH	W
Lamiaceae	*Pycnanthemum albescens*	whiteleaf mountainmint	H	BIO	F
Onagraceae	*Ludwigia alternifolia*	seedbox	H	BOTH	F
Onagraceae	*Ludwigia hirtella*	spindleroot	H	BOTH	F
Phytolaccaceae	*Phytolacca americana*	American pokeweed	H	BOTH	F
Poaceae	*Dichanthelium laxiflorum*	openflower rosette grass	H	BOTH	G
Poaceae	*Digitaria ciliaris*	southern crabgrass	H	BOTH	G
Poaceae	*Digitaria sanguinalis*	hairy crabgrass	H	BOTH	G
Poaceae	*Panicum anceps*	beaked panicgrass	H	BOTH	G
Rhamnaceae	*Berchemia scandens*	Alabama supplejack	H	BOTH	W
Rosaceae	*Rubus argutus*	sawtooth blackberry	H	BOTH	S
Rosaceae	*Rubus flagellaris*	northern dewberry	H	BOTH	S
Rosaceae	*Rubus trivialis*	southern dewberry	H	BOTH	S

Table A.1 (Continued)

Rubiaceae	*Cephalanthus occidentalis*	common buttonbush	H	BOTH	W
Rubiaceae	*Diodia virginiana*	Virginia buttonweed	H	BOTH	F
Rubiaceae	*Houstonia purpurea*	Venus' pride	H	BIO	F
Smilacaceae	*Smilax bona-nox*	saw greenbrier	H	BOTH	W
Smilacaceae	*Smilax glauca*	cat greenbrier	H	BOTH	W
Smilacaceae	*Smilax rotundifolia*	roundleaf greenbrier	H	BOTH	W
Solanaceae	*Solanum americanum*	American black nightshade	H	BOTH	F
Ulmaceae	*Ulmus alata*	winged elm	H	BOTH	W
Verbenaceae	*Callicarpa americana*	American beautyberry	H	BOTH	W
Vitaceae	*Vitis rotundifolia*	muscadine	H	BOTH	W
Acanthaceae	*Ruellia caroliniensis*	Carolina wild petunia	M	BIO	F
Anacardiaceae	*Rhus glabra*	smooth sumac	M	BIO	W
Apiaceae	*Eryngium yuccifolium*	button eryngo	M	BOTH	F
Apocynaceae	*Trachelospermum difforme*	climbing dogbane	M	BOTH	W
Asclepiadaceae	*Asclepias variegata*	redring milkweed	M	BOTH	F
Asteraceae	*Baccharis halimifolia*	eastern baccharis	M	BOTH	W
Asteraceae	*Erechtites hieraciifolius*	American burnweed	M	BOTH	F
Asteraceae	*Erigeron annuus*	eastern daisy fleabane	M	BOTH	F
Asteraceae	*Eupatorium capillifolium*	dogfennel	M	BOTH	F
Asteraceae	*Helenium autumnale*	common sneezeweed	M	BOTH	F
Asteraceae	*Helianthus angustifolius*	swamp sunflower	M	BOTH	F
Asteraceae	*Mikania scandens*	climbing hempvine	M	BOTH	F
Asteraceae	*Pluchea camphorata*	camphor pluchea	M	BOTH	F
Asteraceae	*Pyrrhopappus carolinianus*	Carolina desert-chicory	M	BOTH	F

Table A.1 (Continued)

Asteraceae	*Solidago canadensis*	Canada goldenrod	M	BOTH	F
Asteraceae	*Vernonia gigantea*	giant ironweed	M	BOTH	F
Bignoniaceae	*Bignonia capreolata*	crossvine	M	BOTH	W
Bignoniaceae	*Campsis radicans*	trumpet creeper	M	BOTH	W
Boraginaceae	*Heliotropium indicum*	Indian heliotrope	M	BOTH	F
Buddlejaceae	*Polypremum procumbens*	juniper leaf	M	BOTH	F
Caprifoliaceae	*Lonicera japonica*	Japanese honeysuckle	M	BOTH	W
Caprifoliaceae	*Sambucus nigra*	black elderberry	M	BOTH	W
Ericaceae	*Vaccinium stamineum*	deerberry	M	BOTH	W
Euphorbiaceae	*Croton capitatus*	hogwort	M	BOTH	F
Fabaceae	*Desmodium canescens*	hoary ticktrefoil	M	BOTH	F
Fabaceae	*Gleditsia triacanthos*	honeylocust	M	BOTH	F
Fabaceae	*Lespedeza cuneata*	sericea lespedeza	M	BOTH	F
Fabaceae	*Vicia sativa*	garden vetch	M	BOTH	F
Lamiaceae	*Monarda fistulosa*	wild bergamot	M	BOTH	F
Lamiaceae	*Prunella vulgaris*	common selfheal	M	BOTH	F
Lamiaceae	*Scutelaria integrifolia*	helmet flower	M	BOTH	F
Malvaceae	*Sida spinosa*	prickly fanpetals	M	BOTH	F
Melastomataceae	*Rhexia mariana*	Maryland meadowbeauty	M	BOTH	F
Moraceae	*Morus rubra*	red mulberry	M	BOTH	W
Oleaceae	*Fraxinus pennsylvanica*	green ash	M	BIO	W
Oxalidaceae	*Oxalis dillenii*	slender yellow woodsorrel	M	BOTH	F
Passifloraceae	*Passiflora lutea*	yellow passionflower	M	BOTH	F
Poaceae	*Dichanthelium dichotomum*	cypress panicgrass	M	BOTH	G

Table A.1 (Continued)

Poaceae	*Dichanthelium scoparium*	velvet panicum	M	BOTH	G
Poaceae	*Elymus virginicus*	Virginia wildrye	M	BOTH	G
Poaceae	*Eragrostis spectabilis*	purple lovegrass	M	BOTH	G
Poaceae	*Leersia oryzoides*	rice cutgrass	M	BOTH	G
Poaceae	*Panicum dichotomiflorum*	fall panicgrass	M	BOTH	G
Poaceae	*Panicum virgatum*	switchgrass	M	BOTH	G
Poaceae	*Paspalum dilatatum*	dallisgrass	M	BOTH	G
Polemoniaceae	*Phlox pilosa*	downy phlox	M	BOTH	F
Polygonaceae	*Polygonum hydropiperoides*	swamp smartweed	M	BOTH	F
Rosaceae	*Potentilla simplex*	common cinquefoil	M	BOTH	F
Rubiaceae	*Diodia teres*	poorjoe	M	BOTH	F
Rubiaceae	*Galium aparine*	stickywilly	M	BOTH	F
Scrophulariaceae	*Mecardonia acuminata*	axilflower	M	BOTH	F
Solanaceae	*Physalis virginiana*	Virginia groundcherry	M	BOTH	F
Solanaceae	*Solanum carolinense*	Carolina horsenettle	M	BOTH	F
Verbenaceae	*Verbena brasiliensis*	Brazilian vervain	M	BOTH	F
Violaceae	*Viola sororia*	common blue violet	M	BOTH	F
Vitaceae	*Vitis aestivalis*	summer grape	M	BOTH	W
Anacardiaceae	*Rhus copallinum*	winged sumac	L	BOTH	W
Asteraceae	*Gamochaeta purpurea*	spoonleaf purple everlasting	L	BOTH	F
Asteraceae	*Pseudognaphalium obtusifolium*	rabbit-tobacco	L	BOTH	F
Cupressaceae	*Juniperus virginiana*	eastern redcedar	L	BOTH	W
Cyperaceae	*Carex annectens*	yellowfruit sedge	L	BOTH	G
Cyperaceae	*Carex complanata*	hirsute sedge	L	BOTH	G

Table A.1 (Continued)

Cyperaceae	*Carex glaucodea*	blue sedge	L	BOTH	G
Cyperaceae	*Carex longii*	Long's sedge	L	BOTH	G
Cyperaceae	*Cyperus echinatus*	globe flatsedge	L	BOTH	G
Cyperaceae	*Cyperus erythrorhizos*	redroot flatsedge	L	BOTH	G
Cyperaceae	*Cyperus pseudovegetus*	marsh flatsedge	L	BOTH	G
Cyperaceae	*Eleocharis obtusa*	blunt spikerush	L	BOTH	G
Cyperaceae	*Scirpus cyperinus*	woolgrass	L	BOTH	G
Cyperaceae	*Scleria ciliata*	fringed nutrush	L	BOTH	G
Cyperaceae	*Scleria triglomerata*	whip nutrush	L	BOTH	G
Ebenaceae	*Diospyros virginiana*	common persimmon	L	BOTH	W
Fabaceae	*Desmodium rotundifolium*	prostrate ticktrefoil	L	BOTH	F
Fagaceae	*Quercus stellata*	post oak	L	BOTH	W
Geraniaceae	*Geranium carolinianum*	Carolina geranium	L	BOTH	W
Geraniaceae	*Geranium dissectum*	cutleaf geranium	L	BOTH	F
Hamamelidaceae	*Liquidambar styraciflua*	sweetgum	L	BOTH	F
Hippocastanaceae	*Aesculus pavia*	red buckeye	L	BOTH	W
Juncaceae	*Juncus coriaceus*	leathery rush	L	BOTH	G
Juncaceae	*Juncus effusus*	common rush	L	BOTH	G
Lamiaceae	*Pycnanthemum tenuifolium*	narrowleaf mountainmint	L	BOTH	F
Onagraceae	*Ludwigia palustris*	marsh seedbox	L	BOTH	F
Oxalidaceae	*Oxalis stricta*	common yellow woodsorrel	L	BOTH	F
Oxalidaceae	*Oxalis violacea*	violet woodsorrel	L	BOTH	F
Passifloraceae	*Passiflora incarnata*	purple passionflower	L	BOTH	F
Poaceae	*Andropogon glomeratus*	bushy bluestem	L	BOTH	G

Table A.1 (Continued)

Poaceae	*Andropogon virginicus*	broomsedge bluestem	L	BOTH	G
Poaceae	*Chasmanthium latifolium*	Indian woodoats	L	BOTH	G
Poaceae	*Chasmanthium sessiliflorum*	longleaf woodoats	L	BOTH	G
Poaceae	*Cynodon dactylon*	Bermudagrass	L	BIO	G
Poaceae	*Dichanthelium aciculare*	needleleaf rosette grass	L	BOTH	G
Poaceae	*Dichanthelium acuminatum*	tapered rosette grass	L	BOTH	G
Poaceae	*Dichanthelium commutatum*	variable panicgrass	L	BOTH	G
Poaceae	*Echinochloa crus-galli*	barnyardgrass	L	BOTH	G
Poaceae	*Paspalum laeve*	field paspalum	L	BIO	G
Poaceae	*Paspalum urvillei*	Vasey's grass	L	BOTH	G
Poaceae	*Saccharum alopecuroides*	silver plumegrass	L	BOTH	G
Violaceae	*Viola triloba*	three-lobe violet	L	BOTH	F
Vitaceae	*Ampelopsis arborea*	peppervine	L	BOTH	W
Vitaceae	*Parthenocissus quinquefolia*	Virginia creeper	L	BOTH	W
Asteraceae	*Heterotheca subaxillaris*	camphorweed	NONE	BIO	F
Malvaceae	*Hibiscus moscheutos*	crimsoneyed rosemallow	NONE	BOTH	F
Acanthaceae	*Ruellia strepens*	limestone wild petunia	NR	BOTH	F
Apiaceae	*Eryngium prostratum*	creeping eryngo	NR	BOTH	F
Asteraceae	*Cirsium horridulum*	yellow thistle	NR	BOTH	F
Asteraceae	*Eupatorium album*	white thoroughwort	NR	BIO	F
Asteraceae	*Helianthus divaricatus*	woodland sunflower	NR	BOH	F
Asteraceae	*Krigia virginica*	Virginia dwarfdandelion	NR	BOTH	F
Clusiaceae	*Hypericum prolificum*	shrubby St. Johnswort	NR	BOTH	W
Clusiaceae	*Hypericum punctatum*	spotted St. Johnswort	NR	BOTH	F

Table A.1 (Continued)

Convolvulaceae	*Convolvulus arvensis*	field bindweed	NR	BOTH	F
Convolvulaceae	*Jacquemontia tamnifolia*	hairy clustervine	NR	BOTH	F
Cucurbitaceae	*Melothria pendula*	Guadeloupe cucumber	NR	BOTH	F
Cyperaceae	*Rhynchospora corniculata*	shortbristle horned beaksedge	NR	BOTH	G
Cyperaceae	*Rhynchospora globularis*	globe beaksedge	NR	BOTH	G
Euphorbiaceae	*Chamaesyce maculata*	small spotted sandmat	NR	BOTH	F
Fabaceae	*Crotalaria sagittalis*	arrowhead rattlebox	NR	BOTH	F
Fabaceae	*Trifolium carolinianum*	Carolina clover	NR	BOTH	F
Juncaceae	*Juncus acuminatus*	tapertip rush	NR	BIO	G
Juncaceae	*Juncus diffusissimus*	slimpod rush	NR	BOTH	G
Juncaceae	*Juncus marginatus*	grassleaf rush	NR	BOTH	G
Juncaceae	*Juncus scirpoides*	needlepod rush	NR	BOTH	G
Juncaceae	*Juncus tenuis*	poverty rush	NR	BOTH	G
Poaceae	*Dichanthelium sp.*	panicgrass	NR	BOTH	G
Poaceae	*Leptochloa sp.*	sprangletop	NR	BIO	G
Poaceae	*Setaria pumila*	yellow foxtail	NR	BOTH	G
Poaceae	*Sporobolus junceus*	pineywoods dropseed	NR	BIO	G
Polygalaceae	*Polygala sanguinea*	purple milkwort	NR	BOTH	F
Polygonaceae	*Polygonum amphibium*	water knotweed	NR	BOTH	F
Ranunculaceae	*Clematis virginiana*	devil's darning needles	NR	BOTH	W
Rosaceae	*Rosa multiflora*	multiflora rose	NR	BIO	W
Scrophulariaceae	*Agalinis purpurea*	purple false foxglove	NR	BOTH	F
Verbenaceae	*Verbena rigida*	tuberous vervain	NR	BOTH	F
Anacardiaceae	*Toxicodendron pubescens*	Atlantic poison oak		DIV	

Table A.1 (Continued)

Asclepiadaceae	*Asclepias tuberosa*	butterfly milkweed	DIV
Asteraceae	*Verbesina virginica*	white crownbeard	DIV
Campanulaceae	*Lobelia puberula*	downy lobelia	DIV
Campanulaceae	*Lobelia spicata*	palespike lobelia	DIV
Campanulaceae	*Triodanis biflora*	small Venus' looking-glass	DIV
Caprifoliaceae	*Lonicera sempervirens*	trumpet honeysuckle	DIV
Caryophyllaceae	*Minuartia patula*	pitcher's stitchwort	DIV
Convolvulaceae	*Ipomoea purpurea*	tall morning-glory	DIV
Cornaceae	*Cornus drummondii*	roughleaf dogwood	DIV
Cyperaceae	*Carex lurida*	shallow sedge	DIV
Cyperaceae	*Cyperus esculentus*	yellow nutsedge	DIV
Cyperaceae	*Cyperus odoratus*	fragrant flatsedge	DIV
Dennstaedtiaceae	*Pteridium aquilinum*	western brackenfern	DIV
Ericaceae	*Gaylussacia dumosa*	dwarf huckleberry	DIV
Euphorbiaceae	*Euphorbia pubentissima*	false flowering spurge	DIV
Fabaceae	*Apios americana*	groundnut	DIV
Fabaceae	*Desmodium laevigatum*	smooth ticktrefoil	DIV
Fabaceae	*Lespedeza procumbens*	trailing lespedeza	DIV
Fabaceae	*Lespedeza virginica*	slender lespedeza	DIV
Fagaceae	*Quercus falcata*	southern red oak	DIV
Fagaceae	*Quercus nigra*	water oak	DIV
Fagaceae	*Quercus phellos*	willow oak	DIV
Fagaceae	*Quercus velutina*	black oak	DIV
Gentianaceae	*Sabatia angularis*	rosepink	DIV

Table A.1 (Continued)

Haemodoraceae	*Lachnanthes caroliana*	Carolina redroot	DIV
Juglandaceae	*Carya ovalis*	red hickory	DIV
Juglandaceae	*Carya ovata*	shagbark hickory	DIV
Juglandaceae	*Carya pallida*	sand hickroy	DIV
Juncaceae	*Juncus longii*	Long's rush	DIV
Lamiaceae	*Salvia lyrata*	lyreleaf sage	DIV
Liliaceae	*Allium sp.*	onion	DIV
Lygodiaceae	*Lygodium japonicum*	Japanese climbing fern	DIV
Magnoliaceae	*Liriodendron tulipifera*	tuliptree	DIV
Oleaceae	*Fraxinus pennsylvanica*	green ash	DIV
Oleaceae	*Ligustrum sinense*	Chinese privet	DIV
Plantaginaceae	*Plantago aristata*	largebracted plantain	DIV
Plantaginaceae	*Plantago major*	common plantain	DIV
Poaceae	*Andropogon gerardii*	big bluestem	DIV
Poaceae	*Bouteloua curtipendula*	sideoats grama	DIV
Poaceae	*Lolium perenne*	perennial ryegrass	DIV
Poaceae	*Paspalum notatum*	bahiagrass	DIV
Poaceae	*Saccharum giganteum*	sugarcane plumegrass	DIV
Poaceae	*Steinchisma hians*	gaping grass	DIV
Polygonaceae	*Rumex crispus*	curly dock	DIV
Rosaceae	*Crataegus sp.*	hawthorn	DIV
Rubiaceae	*Galium sp.*	bedstraw	DIV
Rubiaceae	*Galium tinctorium*	stiff marsh bedstraw	DIV
Rubiaceae	*Stenaria nigricans*	diamond-flowers	DIV

Table A.1 (Continued)

Scrophulariaceae	*Verbascum thapsus*	common mullein	DIV
Ulmaceae	*Ulmus rubra*	slippery elm	DIV

Plant species detected in biomass and diversity sampling in intensively managed pine stand controls, intercropped plots, and switchgrass monocultures in Kemper Co., MS May-Aug, 2011-2013. Plant species are categorized by forage rank (use) during summer: H = High-use, M = Moderate-use, L = Low-use, NONE = No forage value, NR = Forage value not reported (Warren and Hurst 1981, Miller and Miller 1999, Gee et al. 2011) and plant class: F = forbs, G = graminoids, S = subshrubs, W = woody trees, shrubs, and vines (USDA 2014). Species are also ranked by method in which they were detected: BOTH = detected during biomass and diversity sampling, BIO = detected only during biomass sampling, DIV = detected only during diversity sampling. Species that were detected only during diversity sampling were not provided a forage rank or plant class since neither were used in diversity analyses (see Chapter II).

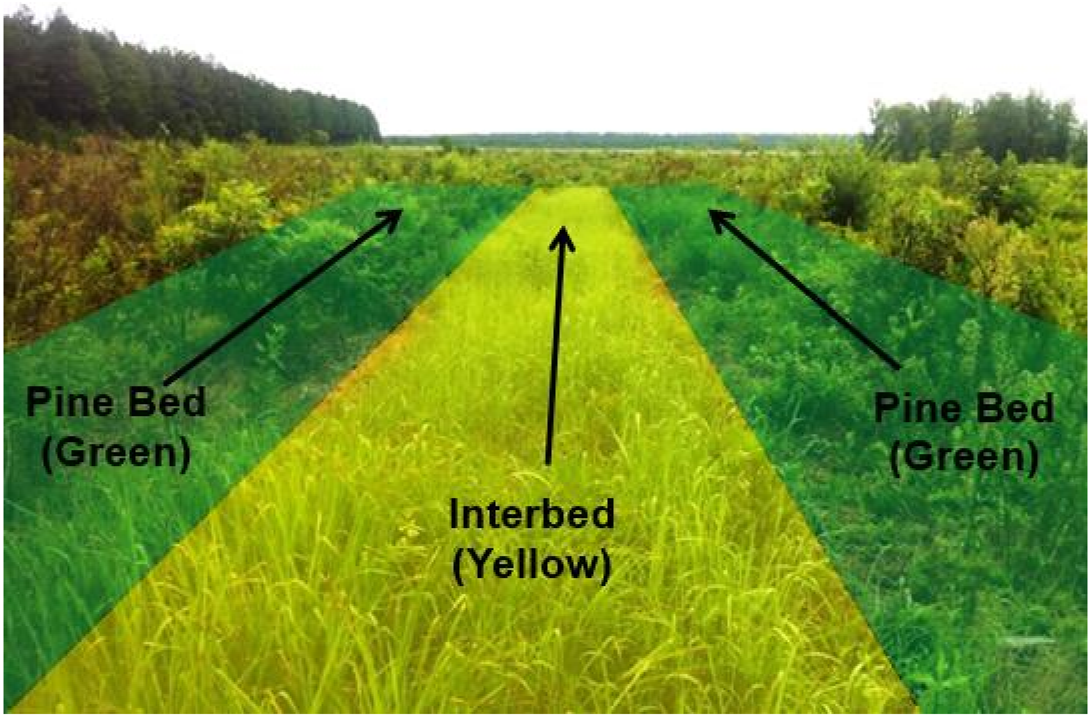

Figure A.1 Layout of switchgrass intercropped plot.