Effects of Row Spacing and Debris Distribution on Deer Forage and Carrying Capacity in Newly Established Loblolly-pine Plantations in Louisiana

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Abstract: Intensively managed loblolly pine (*Pinus taeda)* forests are common in the southeastern United States and critical to providing fiber for global wood supply needs. There are concerns regarding possible effects of stand establishment treatments on plant communities, particularly availability and quality of browse for white-tailed deer (*Odocoileus virginianus)*. We quantified response of non-pine vegetation productivity at either narrow (4.3 m) or wide (6.1 m) row spacing combined with either piled or scattered woody debris following clearcut harvest in Louisiana. We examined total (kg/ha) and preferred forage production and used crude protein percentages of preferred forage to estimate carrying capacity, based on lactation requirements, in each treatment ($n = 16$ replicates) for years 4–5-post treatment (2009–2010). We documented 95 genera or species of plants including 36 preferred forage species. Total forage production did not differ among years or between row spacing or type of debris distribution. Production of preferred forage increased from 2009 to 2010 and was reflective of increasing species diversity among vegetation communities. We found woody and semi-woody (i.e. shrubs, *Rubus* spp.) forage production to be greater in stands with scattered debris distribution. Lactation-level carrying capacity estimates were greatest in stands with a combination of narrower row spacing and scattered debris distribution. Increased production of semi-woody and woody browse in scattered debris may increase deer carrying capacity. However, an increased woody component can shorten the period of greatest plant diversity which occurs between establishment and canopy closure.

Key words: carrying capacity, forest management, intensive forestry, Louisiana, *Odocoileus virginianus*, *Pinus taeda*, silviculture, site preparation, stand establishment, white-tailed deer

Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 66:133–139

The southeastern United States is composed of approximately 12 million ha of pine plantation (Ince 2001). The forest products industry is economically important in the Southeast, particularly Louisiana, where greater than 48% of land is used for timber production (Clement and Vlosky 2008). To meet increasing wood supply demands, forest managers have adopted more intensive management regimes to increase timber productivity. Intensive forest management involves management of even-aged stands and results in short rotation length. Mechanical and chemical site preparation techniques are used to facilitate planting and increase the speed and quality of loblolly pine growth (Glover and Zutter 1993, Gresham 2002).

Increasing interest in sustainable forest management necessitates an understanding of how site preparation techniques affect wildlife and plant communities. Site preparation increases timber yield, but has varying effects on development and composition of the understory (Carnus et al. 2006). Many wildlife species are associated with understory conditions within pine plantation, particularly early seral stages (Askins 2001, Huntly and Inouye 1987), including white-tailed deer (*Odocoileus virginianus*; hereafter, deer; Litvaitis 2001). Deer are an important economic and recreational resource in Louisiana and considered by many to be a keystone herbivore relative to forest understory vegetation (Waller and Alverson 1997, Greenwald et al. 2008). Moreover, it is common practice for commercial forest landowners to lease land for sport hunting, primarily deer hunting (Jones et al. 2004).

The considerable interest in deer throughout the Southeast, coupled with the known relationship between deer carrying capacity and vegetation quality (Jones et al. 2009), warrants research to explore effects of stand establishment techniques on deer forage. Research examining effects of stand establishment on deer forage and carrying capacity is advancing, but is limited to primarily the effects of chemical or few mechanical treatments (e.g., prescribed fire [Chamberlain and Miller 2006, Iglay et al. 2010b]). In particular, information on effects of row spacing and distribution of logging debris on forage quality for deer is lacking. Logging debris influences microhabitat and availability of nutrients to plants (Harmon et al. 1986), and distribution of debris can affect seed germination of forage species (Van Lear 1993). Different row spacings are assumed to create differences in canopy cover which may temporally and spatially affect vegetation succession and plant communities within plantations. Additionally, the period between planting and canopy closure provides abundant deer forage (Askins 2001, Fuller and Gill 2001), and impacts to this window of time due to silvicultural treatments needs to be understood. Therefore, we examined effects of stand establishment with experimental row spacing and distribution of logging debris on forage abundance and nutritional carrying capacity for deer.

Methods

Study Area

We quantified abundance of deer forage plants in four, early rotation, loblolly pine plantations of approximately 60.7 ha each. Each study site ($n = 4$) was owned by Weyerhaeuser Company, harvested using clear cutting during 2005, and replanted in winter 2006. Two study sites were located in north-central Louisiana (Winn and Jackson parishes) and two in southeast Louisiana (Tangipahoa and Washington parishes). Mean annual rainfall 2009–2011 ranged from 150.62–163.10 cm and average January low and July high temperatures were 0.5–3.3 and 33 C, respectively (National Oceanic and Atmosphere Administration 2011). Elevation ranged from 30 to 77 m above sea level. All sites were >20 years old prior to harvest. Spacing of trees within rows was held constant and seed beds were elevated after shearing. All sites received a banded application of Arsenal AC (48 ml/ha, BASF Corp. Research Triangle Park, North Carolina) and Oust Extra (30 ml/ha, DuPont Crop Protection, Wilmington, Delaware) within the first growing season for weed control. Sites received a hardwood release treatment of Arsenal AC (143 ml/ha) in years 2 or 3 post-planting. The site located in Tangipahoa Parish received the hardwood release treatment in the fall prior to 2010 sampling following standard operating procedures for substantial woody growth of non-pine species. All sites received similar chemical site preparation and we assumed effects on plant communities were similar among locations. The sites were predominantly upland pine ecosystems with interspersed stream management zones (SMZs) and soil types ranged from fine sandy loams to very fine sandy loams (Natural Resources Conservation Service 2011). Dominant woody and semi-woody species generally included loblolly pine, red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), black cherry (*Prunus serotina*), and blackberry (*Rubus* spp.). Dominant grasses included bluestems (*Andropogon* spp.), rosette grasses (*Dicanthelium* spp.), and paspalum grasses (*Paspalum* spp; Miller and Miller 1999, USDA Plants Database 2011).

Data Collection and Analysis

We established four 10.1-ha stands ($n = 16$) within each study site and randomly assigned a treatment combination. Treatments included two row spacing widths (4.3 m and 6.1 m) and two debris distributions (scattered and piled). Scattered debris distribution consisted of scattering logging debris in rows throughout the stand, whereas piled distribution involved piling debris into five large piles located throughout the stand. The resulting design represented a randomized complete block design consisting of four experimental stands within each of four study sites.

We used standard methods for estimating deer forage which involved collecting vegetation data annually during June and July 2009 and 2010 (representing years four and five in the stand rotation). We placed 10 1-m^2, Daubenmire frames at equal distance on a diagonal transect across each stand ($n = 16$; Daubenmire 1959). We clipped all succulent plant material ≤1.5 m above ground and identified species/genera (hereafter, species), and composed a list of potential moderate and high quality deer forages (Miller and Miller 1999, Moreland 2005). We kept clippings frozen until they were oven-dried at a temperature of 70 C for 72 hours (Chamberlain and Miller 2006), and measured dry-weight biomass to the nearest gram and determined total production (kg/ha) for all species ($n = 95$) and preferred forage species ($n = 36$). We selected five forage species for individual analysis because of their abundance on the study sites or recorded importance to deer in Louisiana (brambles [*Rubus* spp.], ragweed [*Ambrosia* spp.], goldenrod [*Solidago* spp.], greenbriar [*Smilax* spp.], and wild grape [*Vitis* spp.]; Moreland 2005).

Three samples of each preferred forage species ($n = 36$) were analyzed by the Southeast Research Station operated by the Louisiana State University Agricultural Center for crude protein (CP) on a dry matter basis using the Kjeldahl procedure (Jurgens 2002). We report all nutritional values on a dry matter basis (kg/ha). We estimated carrying capacity (deer-days/ha) using the explicit nutritional constraints model (Hobbs and Swift 1985), assuming a daily dry matter intake of 1,360 g (Edwards et al. 2004), which is within the range of intake rates of deer in the southern United States (Asleson et al. 1996, Campbell and Hewitt 2005). For each stand, we calculated a measure of nutritional carrying capacity (CC) based on lactation demands for CP. Because our sites contained adequate biomass to meet maintenance requirements (6% CP) in all stands, we set target diet quality at 14% CP to support a lactating female with one fawn (Verme and Ullrey 1984, Asleson et al. 1996). Lactating females experience the greatest nutritional demands among adult deer during the growing season (Jacobson et al. 1979), therefore lactation level requirements should be sufficient to support antler growth in males (Asleson et al. 1996). Although secondary compounds, such as condensed proteins, have potential effects on protein digestibility (Hanley et al. 1992), we assumed CP content of forage species accurately compared relative plant quality among treatments.

We used mean response of each variable across transects for two years, with stands as experimental units ($n = 16$), to quantify response variables. We used repeated measures, mixed model analysis of variance (ANOVA) to test for main effects of year, treatment, and year by treatment interactions on total forage production, production of preferred forage species, production of the five individual species abundant on our study sites, and 14% CP CC estimates (PROC MIXED; SAS Institute 2009). We specified year as a repeated measure with subject equal to site × row × debris and treated site as a random variable to account for geographical differences and variation in timing of herbicide application. For each analysis, we selected the covariance structure using Akaike's Information Criterion corrected for small sample size. If significant year effects occurred, we used least-squared means with Bonferonni corrections for multiple comparisons. We tested the null hypothesis that 14% CP CC estimates and forage production for total, preferred, and five individual forage species did not differ between years or treatments. We used 0.05 as the alpha level for all statistical tests.

Results

Mean total biomass of plants sampled in 2009 and 2010 was 14,239 ± 34 kg/ha and 12,313 ± 39 kg/ha, respectively. Species with the greatest biomass included goldenrod (3,784 kg/ha), brambles (3,370 kg/ha), bluestems (2,757 kg/ha), and rosette grass (1,933 kg/ha). There were no year × treatment interactions for any comparisons. Total forage biomass did not differ between treatments or among years (Table 1). Preferred forage biomass differed among years but not among treatments (Table 1). Preferred forage was greater in 2010 (551.94 kg/ha ± 70.63) than 2009 (390.60 kg/ha ± 55.88; $t_{21} = -2.80$; $P = 0.012$). Biomass of ragweed was affected by distribution of logging debris but not by row spacing or year (Table 1). We found greater biomass of ragweed on sites with piled debris (48.85 kg/ha ± 36.00) than scattered (6.76 kg/ha ± 4.74). Biomass of goldenrod differed by year but not by treatment, with greater biomass in 2010 (184.50 kg/ha ± 69.25) than 2009 (32.23 kg/ha ± 5.47; $t_{21} = -2.53$; $P = 0.019$; Table 1). Biomass of brambles was affected by distribution of debris but not row spacing or year (Table 1), with greater biomass in scattered (114.92 kg/ha ± 19.32) than piled debris (7.82 kg/ha ± 5.47). Biomass of *Vitis* spp. was greater in stands with scattered (14.33 kg/ha ± 8.12) than piled debris (1.08 kg/ha ± 0.93), but was not affected by row spacing or year (Table 1).

Table 1. Effects of treatments and year on total forage biomass (kg/ha) and total biomass (kg/ha) of selected preferred deer forage and selected plant species (kg/ha) important to deer in loblolly pine plantations in north and southeastern Louisiana, 2009–2010.

Variable	Effect[a]	*F*-value	*P*-value
Total forage	Row[b]	2.43	0.134
	Debris[c]	0.36	0.554
	Year	0.29	0.312
Preferred forage	Row	2.64	0.119
	Debris	2.4	0.136
	Year	7.82	0.011
Ragweed	Row	0.14	0.712
	Debris	4.85	0.039
	Year	0.28	0.600
Greenbriar	Row	1.86	0.187
	Debris	1.41	0.248
	Year	0.2	0.660
Goldenrod	Row	0.24	0.629
	Debris	0.26	0.614
	Year	6.4	0.020
Brambles	Row	0.37	0.550
	Debris	5.03	0.036
	Year	0.33	0.232
Vitis spp.	Row	0.55	0.465
	Debris	5.73	0.026
	Year	0.15	0.703

a. Degrees freedom (numerator, denominator) are 1, 21
b. Row spacing treatments (4.3 m and 6.1 m)
c. Debris treatments (piled and scattered)

Crude protein values for 36 species of preferred deer forage ranged from 2.47% to 16.34% (Table 2). Lactation-level CC estimates ranged from 0.12 deer-days/ha to 360 deer-days/ha and differed between row and debris combination, but not among row spacing ($F_{1,21} = 0.01$; $P = 0.918$), debris distribution ($F_{1,21} = 4.19$; $P = 0.053$) or years ($F_{1,21} = 1.38$; $P = 0.253$; Table 3). We found CC to be greater in stands with 4.3 m row spacing with scattered debris (89.91 deer-days/ha ± 13.23) than those with piled debris (73.82 deer-days/ha ± 43.85; $F = 6.28$; $P = 0.021$).

Discussion

Lactation-level CC estimates were greater in stands with a combination of 4.3 m spacing and scattered debris distribution. Notably, a coinciding study found scattering debris increased woody and semi-woody vegetation including production of brambles and *Vitis* spp. throughout our study sites (Grace et al. 2011). Additionally, biomass of these species was greater in scattered debris in our study. Logging debris can provide favorable conditions for rapid regeneration of woody growth (Van Lear 1993). Although the narrower row spacing within the combination of 4.3-m row spacing may have contributed to conditions favorable for woody growth, we suspect increased CC estimates in this treatment combination were a result of increased woody and semi-woody growth due to scattering debris. However, it is important to recognize that wider row spacing generally delays canopy closure, extending the

Table 2. Mean total biomass (kg/ha) of total and preferred forage, and biomass (kg/ha) and crude protein (CP, %) of forage species used for lactation-level (14% CP) white-tailed deer carrying capacity estimates in intensively managed loblolly pine plantations treated with mechanical site preparation techniques in north and southeastern Louisiana, 2009–2010.

	Biomass						
Species	**4.3 m**	**6.1 m**	**Piled**	**Scattered**	**2009**	**2010**	**CP**
Aster (*Asteraceae* spp.)	277.9	278.2	355.8	200.3	528.3	27.9	5.6
American beautyberry (*Callicarpa americana*)	125.0	784.5	452.6	456.9	334.0	575.5	8.6
Boneset (*Eupatorium leucolepis*)	174.7	270.4	283.8	161.4	264.5	180.6	9.4
Bracken fern (*Pteridium aquilinum*)	52.2	10.6	10.6	52.2	0.0	62.8	7.2
Brambles (*Rubus* spp.)	1795.7	1573.5	1530.4	1838.7	1772.7	1596.5	12.5
Butterfly pea (*Clitoria mariana*)	4.7	0.4	3.5	1.7	3.9	1.3	9.1
Chinese privet (*Ligustrum sinense*)	0.0	11.3	11.3	0.0	11.3	0.0	4.5
Common ragweed (*Ambrosia artemisiifolia*)	150.4	659.4	701.6	108.2	720.5	89.3	11.0
Daisy fleabane (*Erigeron strigosus*)	0.0	3.3	3.3	0.0	0.0	3.3	10.3
Deerberry (*Vaccinium stamineum*)	43.5	12.9	9.3	47.2	28.4	28.0	9.1
Goldenrod (*Solidago* spp.)	976.6	2507.0	2678.2	805.4	531.7	2951.9	8.5
Grape (*Vitis* spp.)	151.9	94.7	17.3	229.2	55.9	191.0	5.7
Greenbriar (*Smilax* spp.)	233.2	169.6	191.3	210.9	179.6	223.3	8.1
Japanese honeysuckle (*Lonicera japonica*)	3.9	10.4	1.1	13.3	10.3	4.0	11.9
Meadowbeauty (*Rhexia virginica*)	22.6	1.3	22.6	1.3	0.0	24.0	6.4
Oaks (*Quercus* spp.)	0.0	13.7	0.0	13.7	13.7	0.0	8.6
Partridge pea (*Chamaecrista* spp.)	0.4	2.0	0.0	2.3	1.9	0.5	16.3
Pencil flower (*Stylosanthus biflora*)	0.2	0.7	0.7	0.2	0.8	0.1	10.1
Persimmon (*Diospyrus virginiana*)	119.7	0.0	119.7	0.0	60.7	59.0	5.8
Red maple (*Acer rubrum*)	108.7	101.7	4.7	205.7	20.5	189.9	10.6
Rosette grass (*Dicanthelium* spp.)	825.5	1107.6	1267.2	665.8	675.1	1257.9	8.6
Rush (*Juncus* spp.)	185.9	240.1	327.7	98.3	274.4	151.6	8.9
Smooth tickclover (*Desmodium laevigatum*)	18.3	51.0	19.8	49.5	14.1	55.2	10.0
Spurred butterfly pea (*Callicarpa americana*)	3.4	3.9	5.4	2.0	5.7	1.6	13.0
Swamp sunflower (*Helianthus angustifolius*)	511.2	488.3	598.8	400.6	353.9	645.6	8.1
Trailing lespedeza (*Lespedeza procumbens*)	9.1	85.1	10.2	84.1	56.0	38.2	12.5
Virginia buttonweed (*Diodia virginiana*)	25.4	33.4	31.1	27.8	0.0	58.8	10.0
White titi (*Cyrilla racemiflora*)	0	9.3	0.0	9.3	9.3	0.0	13.7
Winged sumac (*Rhus copallinum*)	108.7	101.7	4.7	205.7	20.5	189.9	10.6
Witch hazel (*Hamamelis virginiana*)	0	63.0	22.3	40.7	40.7	22.3	9.5
Yaupon (*Ilex vomitoria*)	52.2	54.2	18.4	88.0	35.5	70.9	5.3
Yellow jessamine (*Gelsemium sempervirens*)	47.6	79.9	72.1	55.4	55.0	72.5	10.7
Yellow woodsorrel (*Oxalis stricta*)	0.2	1.4	1.1	0.5	0.0	1.6	12.4

Table 3. Mean nutritional carrying capacity (deer-days/ha with appropriate standard error) based on a mean diet quality of 14% crude protein in 4–5-year-old loblolly pine plantations in north and southeastern Louisiana, 2009–2010.

	Treatment			
Year	**4.3 m**	**6.1 m**	**Piled debris**[a]	**Scattered debris**[b]
2009	85.31 ± 41.44	73.50 ± 41.49	88.64 ± 47.51	70.16 ± 34.16
2010	78.42 ± 41.49	67.92 ± 10.76	49.22 ± 15.20	97.12 ± 11.15

a. Debris distributed in five large piles throughout stand
b. Debris scattered throughout the stand between seed rows

more diverse early-seral stages (Dickson 1982, Melchoirs 1991). Furthermore, Lane et al. (2011) suggested wider row spacing may be beneficial for wildlife species such as songbirds, but results of that study did not allow specific examination of row spacing. Further research examining commercial pine yields and successional changes associated with wider spacing will aid in determining whether it is a desired approach.

Presumably, we would expect greater CC estimates in stands with treatments involving wider row spacing or piled debris distribution given that suppressing woody growth is known to promote a herbaceous understory and increase preferred deer forage and CC estimates (Peitz et al. 1999, Carnus et al. 2006, Iglay et al. 2010a). In our study, woody and semi-woody species contributed to 88% of CC estimates due to their high production and moderate CP content. Contribution of forage grasses and forbs was limited by their low CP content. Unlike similar studies conducted in more fertile soil regions of the Southeast (e.g., Mixon et al. 2008, Jones et al. 2009, Iglay et al. 2010a), we documented fewer total forage species and fewer species with >14% CP. Campbell (2011) estimated

CC in the Lower Coastal Plain of Mississippi using biomass and nutritional parameters from 78 forage species ranging from 3.4%–19.4% CP, compared to only 36 preferred forage species found throughout our study with a maximum of 16.34% CP. The explicit nutritional constraints model estimates maximum number of deer that can obtain a diet of 14% CP based on the primary assumption that herbivores will select higher quality forage items in preference to lower ones (Hobbs and Swift 1985). Estimates rely on determining proportion of biomass of forage species that can be mixed to achieve the target diet quality, using higher quality forage species and mixing lower quality species until nutritional requirements are met. We found extreme variation in ranges of CC, which can be attributed to certain estimates being based on a mixture of only a few, high protein forages in very low amounts. A lack of forage species with >14% CP limited CC estimates in stands where target diet quality was met by high protein forages in low abundance (e.g., *Chamaecrista* spp., 16.34% CP). Carrying capacity estimates in stands based on a mixture of species with moderate protein levels and very high production (e.g., *Rubus* spp., 12.46% CP) were higher. Presumably, stands in which estimates were based on low amounts of high quality forage (e.g., *Chamaecrista* spp.), despite an abundance of brambles, should support greater CC than estimated given that it is unlikely deer will limit foraging on species if additional forage species are abundant.

Woody and semi-woody plant species, including greenbriar, brambles, blueberry (*Vaccinium* spp.), and wild grape are considered to be among the most, if not the most, important forage groups for deer throughout the Southeast (Harlow and Guynn 1987, Moreland 2005). The contributions of brambles and other semi-woody species to CC estimates in our study support this consideration. Specifically, brambles have been found to dominate bite counts, and fecal and stomach samples from deer in young loblolly-pine plantations of Louisiana and eastern Texas (Lay 1965, Thill 1984). They are a valuable forage species in recently established pine plantations, providing foliage from early spring to late fall (Miller and Miller 1999, Askins 2001). Spring and summer forages promote body growth, meet lactation demands, and replenish fat stores necessary for winter survival (Wallmo et al. 1977, Moen 1978). Although Imazapyr is known to drastically reduce and control broadleaf herbs and woody species, brambles are relatively resistant to the treatment (Iglay 2010, Lane et al. 2011) and we can assume release treatments conducted after planting likely only minimally affected CC estimates and biomass of preferred species in our analyses. Early plant succession following stand establishment is often characterized by a quick recovery of vegetation with increasing species richness and diversity throughout the initial two–three years post planting (Miller et al. 1995, Baker and Hunter 2002, Miller and Chamberlain 2008). Deer carrying capacity in neighboring Mississippi pine forests has been found to correspond with species richness and diversity, declining drastically as plant communities become more similar and pine canopy increases (Jones et al. 2009, Campbell 2011). We assumed carrying capacity estimates on our study sites corresponded with peaking species diversity and richness estimates in years 4 and 5 post-establishment found by Grace et al. (2011). Therefore, increasing biomass of dominant species such as brambles and goldenrod through the first five years post-planting undoubtedly benefits deer and suggests that preferred forage may increase beyond the initial two–three years post-planting as reported in other studies (Hurst and Warren 1980, Felix et al. 1986).

Management Implications

Balancing greater timber yields and quality of deer habitat will continue to grow in importance given the vast area of timber plantations and frequency with which these forests are leased for hunting. Our findings illustrate that scattering debris throughout new plantations, rather than piling in specific locales, increase semi-woody vines and lactation-level CC estimates, particularly within narrower row spacing. The importance of semi-woody vines to deer diets in Louisiana suggests that a scattered debris distribution may be highly beneficial to deer carrying capacity. However, an increased woody component could come at the cost of decreased time to canopy closure and a shorter-lived, less diverse understory (Baker and Hunter 2002).

Acknowledgments

Funding and support were provided by Weyerhaeuser Company, the School of Renewable Natural Resources at Louisiana State University (LSU), and the LSU Agricultural Center.

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