To the Graduate Council:

I am submitting herewith a thesis written by Marcus Alan Lashley entitled Deer forage available following silvicultural treatments in upland hardwood forests and warm-season plantings. I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

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Deer forage available following silvicultural treatments in upland hardwood forests and warm-season plantings

A thesis presented
for the
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Marcus Alan Lashley
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Dedication

I dedicate this to my parents who influenced the passion that I have developed for the outdoors and wildlife management and for their support throughout my life.

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Preface

I evaluated the effects of various silvicultural treatments and warm-season food plot plantings on white-tailed deer forage availability. Chapter 1 contains background information, while Chapter 2 has been formatted to meet requirements specified by the Journal of Wildlife Management.

Abstract

Thinning, herbicide release, and prescribed fire have been used to increase forage availability in pine forests for white-tailed deer, rivaling that available in warm-season food plots. Related data are lacking for hardwood forests. I measured forage availability following 7 silvicultural treatments, including controls (C), forest regeneration methods, and Timber Stand Improvement practices in 4 upland mixed hardwood stands, July–September 2007 and 2008. I also measured forage availability in 4 paired warm-season food plots, including soybeans, lablab, and iron-and-clay cowpeas, July–September 2007, and three varieties of soybeans, July–October 2008. I compared nutritional carrying capacity (NCC) of selected species and species from the literature at 3 crude protein nutritional constraints (diet) between forest treatments and food plot plantings. For both years of the study, retention cut with fire (RF) and shelterwood with fire (SF) tended to have the greatest NCC, regardless of species list or diet constraint. Understory triclopyr applications killed woody species following retention cut with herbicide, but relative biomass contribution of woody and herbaceous species returned to original levels two years post treatment. Herbicide applications did not increase NCC. Production of forage plantings exceeded forest treatments in 2007, but RF production was similar to 4.6 and 5.6 soybeans in 2008. Lablab, cowpeas, and later-maturing varieties of soybeans maintained production longer than the early-maturing soybean. Lablab and late-maturing soybeans were the most cost effective plantings. Forage plantings were inexpensive compared to forest treatments (excluding shelterwood) in the short-term, but RF was comparable when using species from the literature after 2 years, and becomes more cost effective after 4 years. I encourage landowners interested in increasing available nutrition for white-tailed deer to manage upland hardwood forests using

canopy reduction and prescribed fire. When coupled with population reduction, food plots can be an important management practice where deer exceed NCC.

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I. FOREST MANAGEMENT FOR WILDLIFE

Dense populations of white-tailed deer modify forest ecosystems (Webster et al. 2005). The influence of deer can negatively impact wildlife that depend on understory strata for food and shelter (Casey and Hein 1983; de Calesta 1994). Some negative impacts include reduction of seed production of understory plants (Willard and McKell 1978), impedance on regeneration of commercial species (Tilghman 1989), and reduction of native herbaceous and woody plant covers (Rossell et al. 2007). Intense herbivory of white-tailed deer can also increase the occurrence of unpalatable species, such as garlic mustard (*Alliaria petiolata*) and japangrass (*Microstegium vemineum*), which are capable of forming extensive mono-specific colonies in understories (Webster et al. 2005) and encourage development of non-browse or browse-tolerant species at the expense of those sensitive to browsing (Anderson and Katz 1993).

The extirpation of large predators in the southeastern United States has allowed white-tailed deer populations to grow rapidly (Terborgh et al. 2001). Tennessee is no exception with deer populations reaching all-time highs in 2005 (Tennessee Wildl. Res. Ag. 2005). Increasing deer populations coupled with wildfire suppression has resulted in habitat deterioration across much of the Southeast (Dickson 2001). More than half of Tennessee is forested and 80% of forested land in Tennessee is privately owned (Sweitzer 2000). Approximately 10% of private landowners in Tennessee actively manage their forests (Sweitzer 2000). In unmanaged forest, prolific keystone herbivores, such as white-tailed deer, can easily exceed nutritional carrying capacity (NCC) and alter the structure and composition of the plant community (Terborgh et al. 2001).

In order to protect the health of many wildlife species, including white-tailed deer, from adverse effects of chronic over-browsing, deer populations must be maintained below NCC. Active herd management coupled with active habitat management best accomplishes this.

Many forest management strategies have been evaluated relative to forage availability and quality for white-tailed deer, including forest regeneration methods, such as clearcutting and shelterwood harvest, and Timber Stand Improvement (TSI) practices, such as thinning, prescribed burning, understory fertilization, and understory herbicide applications.

In the southern Appalachians, clearcutting has been shown to promote regeneration of fast growing tree species, such as yellow poplar (*Lireodendron tulipifera*), red maple (*Acer rubrum*), and sassafras (*Sassafras albidum*), while stimulating growth of other beneficial species for wildlife, such as grape (*Vitis spp.*), brambles (*Rubus* spp.), and various herbaceous species (Hicks et al. 2004). Several studies in pine (*Pinus* spp.) and hardwood-dominated systems have documented tremendous increases of forage available to deer following clearcutting (Stransky and Halls 1978, Beck and Harlow 1981, Ford et al. 1994). Partial harvest regeneration methods, such as shelterwood harvests, can stimulate a similar response from understory vegetation, depending on the amount of overstory removed (Miller et al. 1999, Peitz et al 1999, Peitz et al. 2001).

Prescribed fire consumes leaf litter and sets back succession, maintaining browse in the reach of deer, while stimulating the seedbank to germinate. Prescribed burning following clearcutting maintains forage availability for approximately three years before decreasing in availability (Stransky and Halls 1978). Availability decreases as plants compete and grow out of the understory strata and the developing midstory shades the understory. In pine systems, one burn 5 years post-harvest may maintain vegetation response up to ten years (Edwards et al.

2004). However, prescribed burning in otherwise unmanaged hardwood stands may have little or no effect on forage quality or production (Wood et al. 1988, Shaw 2008). Even prescribed fire with understory fertilization may not increase NCC in closed-canopy hardwood stands (Shaw 2008). Overstory removal coupled with prescribed fire may not increase nutritional quality, but can increase available nutrition by increasing forage availability (Edwards et al. 2004), and can have long term increases in plant diversity and persistence of grass and forb species following fire (Dyke and Darragh 2007). Lay (1967) reported deer preferred recently burned stands over control stands, foraging in burned stands more than twice as much as controls. This disproportionate use of burned areas was likely a result of structural changes in plant height, which spatially concentrated resources in the understory, making it more efficient for deer to forage in burned areas (Ford et al. 1994).

Canopy disturbance is generally necessary for the understory to respond to prescribed fire (Franklin et al. 2003, Hutchinson et al. 2005, Shaw 2008). Increasing light to the forest floor stimulates increased groundcover. Total biomass production in the understory is heavily correlated with basal area of the overstory (Miller et al. 1999). In hardwood stands, more basal area must be removed for the same increase in light to the forest floor than within pine-dominated stands because the larger leaf surface area blocks more light (Miller et al. 1999). Following a disturbance, such as thinning, the increase in browse production available to deer peaks 3–4 years after thinning (Beck and Harlow 1981; Peitz et al. 2001). Fertilization may extend biomass availability to the fifth year post-treatment (Nelson and Graney 1996). Fertilization in closed-canopy hardwood stands, however, is not cost-effective to increase NCC, even when used in combination with prescribed fire (Shaw 2008).

Herbicide application is commonly used for site preparation when planting pines. Vegetation response varies from site to site and among herbicides used (Miller and Miller 2004). Chamberlain and Miller (2006) found herbicide application with site preparation maintained early successional plant species without reducing forage available for deer in Louisiana. Herbaceous vegetation, legumes, and various forbs dominated herbicide and dormant-season fire treatments, whereas dormant-season fire-only treatments were dominated by woody species (Chamberlain and Miller 2006). Research in pine systems has found herbicide applications following regeneration or TSI can increase forage availability for deer (Copeland 1986; Hurst and Warren 1986; Blake et al. 1987; Hurst and Watkins 1988; McNease and Hurst 1991), but no such data are available in hardwood systems. Herbicides may also suppress undesirable woody vegetation and provide short-term benefits for deer (Witt et al. 1993, Edwards et al. 2004).

Warm-season food plots can increase NCC during the growing season (McDonald and Miller 1995). Increasing NCC may be beneficial as long as deer density is controlled. Allowing the population to increase when providing food plots could be a problem for surrounding habitat. Hehman and Fulbright (1997) suggested using food plots to increase NCC can degrade habitat even further by promoting an increase in deer density and putting more pressure on native forage because food plots did not take the place of native forbs. It is important to realize that while food plots may effectively increase NCC during particular seasons of the year (Miller 2001, Shaw 2008), they often lack other important functions, such as fawning cover.

Edwards et al. (2004) reported canopy reduction in combination with prescribed fire, understory herbicide application, and fertilization in pine stands was a cost effective forest management strategy to increase forage availability for white-tailed deer. They found TSI practices in pine systems rivaled both NCC and cost efficiency of iron-and-clay cowpea (*Vigna* *sinensis*) food plots. They found imazypyr coupled with prescribed fire effectively reduced undesirable woody species and stimulated desirable deer forages, such as *Desmodium* spp., *Smilax* spp., *Vitis* spp., and *Rubus* spp. in the understory. This may be an excellent management strategy in pine stands; however, in hardwood systems, imazapyr should not be used because of soil activity and risks to desirable overstory species (BASF 2007). The use of commercial thinning may also be limited by parcel size and/or poor timber quality. In these situations, non-commercial thinning (such as retention cutting) is an option. Retention cutting is typically a non-commercial operation that kills undesirable species and individuals with poor form or crown class (Smith 1986). Retention cutting can produce similar results to commercial thinning, when other methods of canopy reduction are unavailable. Prior research evaluating the influence of silvicultural treatments on wild turkey habitat found prescribed fire increased woody stem density in the understory strata. Retention cutting with prescribed fire and shelterwood with prescribed fire provided better cover for wild turkeys in the understory than control. Soft mast tended to increase with canopy reduction and fire after the second year post-treatment, and invertebrate biomass was not affected by treatment (Jackson et al. 2007). The effects of these treatments on white-tailed deer forage availability were not evaluated.

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II. DEER FORAGE AVAILABLE FOLLOWING SILVICULTURAL TREATMENTS IN UPLAND HARDWOOD FORESTS AND WARM-SEASON PLANTINGS

Deer Forage Availability Following Silvicultural Treatments in Upland Hardwoods

Abstract

Past research has shown forest regeneration increases forage availability for white-tailed deer (*Odocoileus virginianus*). Recent work showed timber stand improvement in pine forests can increase forage production and rival that of warm-season forage food plots. Related data are not available for hardwood forests. We measured forage availability and calculated nutritional carrying capacity (NCC) using two sets of species at 6, 12, and 14% crude protein mixed diet, following 7 silvicultural treatments, including controls, in 4 mixed upland hardwood stands July–September 2007 and 2008. We compared NCC among forest treatments and within 4 paired warm-season forage food plots. Each food plot contained separate plantings of soybeans (*Glycine max*), lablab (*Lablab purpureus*), and iron-and-clay cowpeas (*Vigna sinensis*) in 2007 and three separate varieties of soybeans (4.6, 5.6, and 7.0 maturity) in 2008. NCC estimates (deer days/hectare) were greatest following canopy reduction with prescribed fire treatments in both years. Understory herbicide application did not affect species composition or NCC one or two years post treatment. Production of forage plantings exceeded that of forest treatments both years with the exception of retention cut with fire in 2008. We encourage land managers to use canopy reducing treatments and prescribed fire to increase available nutrition and improve available cover in upland hardwoods when managing for white-tailed deer. Further, high-quality forage food plots, when coupled with population reduction, can be an important management tool where deer exceed NCC.

Key Words

White-tailed Deer, Forage availability, Timber Stand Improvement, Prescribed Fire, Understory Herbicide application, Silviculture, Retention cut, Shelterwood

Silviculture can have a profound effect on NCC for white-tailed deer (Beck and Harlow 1981, Wood 1988, Miller and Miller 2004, Edwards et al. 2004). Regeneration methods, such as clearcutting and shelterwood harvest, alter the forest canopy, allow increased light to the forest floor, and stimulate increased forage availability. Timber Stand Improvement (TSI) practices, especially thinning, may produce a similar response, depending on the level or intensity of treatment. The increase in browse production available to deer generally peaks 3–4 years after thinning (Beck and Harlow 1981, Peitz et al. 2001). Prescribed fire can be used following canopy reduction to stimulate the understory and increase forage availability for deer (Edwards et al. 2004). Prescribed burning alone, however, may not increase forage availability in closed-canopy stands (Wood et al. 1988, Shaw 2008), though it can influence the plant community and increase plant diversity (Dyke and Darragh 2007).

Extensive research of TSI practices has been conducted within pine-dominated (*Pinus* spp.) systems (Copeland 1986, Peitz et al. 2001, Edwards et al. 2004, Jones et al. 2009). Following thinning, herbicide release, and prescribed fire in loblolly pine (*Pinus taeda*) stands, forage availability for white-tailed deer was similar to that within warm-season food plot plantings (Edwards et al. 2004). Jones et al. (2009) reported herbicide release encouraged better-quality forages and increased forage availability for deer in intensively managed open-canopy pine plantations. Similar data, evaluating the effects of canopy reduction in conjunction with prescribed fire and understory herbicide applications on forage availability for white-tailed deer in hardwood-dominated systems, have not been reported. This information is needed to address the impact of dense white-tailed deer populations in closed-canopy mature hardwood forests, especially where landowners are interested in managing for white-tailed deer among other wildlife species.

We conducted a field experiment that evaluated the effects of overstory reduction (shelterwood, retention cut) in combination with understory disturbance (prescribed fire, herbicide application) on forage production and quality for white-tailed deer. We compared the treatments based on overall forage availability, selected forage availability (species selected by deer), and NCC (based on selected forages). We also compared cost-effectiveness of these treatments to commonly used warm-season food plot plantings.

Study Area

Chuck Swan State Forest and Wildlife Management Area (CSF) encompasses 9,892 hectares (24,444 acres) in Union, Campbell, and Anderson Counties, TN within the Southern Appalachian Ridge and Valley physiographic province. The Tennessee Division of Forestry (TDF) and the Tennessee Wildlife Resources Agency (TWRA) jointly manage CSF.

CSF is 92% forested with the remaining acreage in mowed fields, wildlife food plots, logging decks, and maintained roads. The majority of forested acreage at CSF is oak-hickory with scattered pine (*Pinus* spp.) across the forest. Common overstory trees include white oak (*Quercus alba*), chestnut oak (*Quercus montana*), northern red oak (*Quercus rubra*), black oak (*Quercus velutina*), southern red oak (*Quercus falcata*), scarlet oak (*Quercus coccinea*), mockernut hickory (*Carya tomentosa*), pignut hickory (*Carya glabra*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), yellow poplar (*Liriodendron tulipifera*), blackgum (*Nyssa sylvatica*), and American beech (*Fagus grandifolia*), with scattered shortleaf pine (*Pinus echinata*). In 2003, an infestation of southern pine beetle (*Dendroctonus frontalis*) greatly reduced the pine component from 35% of CSF to less than 1 percent. Sassafras (*Sassafras* *albidum*), dogwood (*Cornus florida*), pawpaw (*Asimina triloba*), and sourwood (*Oxydendrum arboreum*) are common in the midstory. Species common to the understory include greenbrier (*Smilax spp*.), lilies (*Liliaceae spp*.), poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), wild grape (*Vitis spp*.), blackberry (*Rubus spp*.), blueberry (*Vaccinium spp*.), panicgrasses (*Dicanthelium spp*.), and violets (*Viola spp*.). Hardwood stands are managed on an 80-year rotation with clearcutting the primary regeneration method. Sandstone ridges with 15–30% northwest-facing slopes 365–490 meters (1200–1600 feet) in elevation characterize the oak-hickory forest. The majority of the soils on the study area are classified in the Clarksville Fullerton Claiborne association.

Surveys conducted by the TWRA estimate 75 white-tailed deer per square kilometer (30 deer per square mile). Herd management includes a draw hunt system following state regulations. The average annual deer harvest at CSF is 25 deer per square kilometer (9.8 deer per square mile) since 2005 (Tennessee Wildl. Res. Ag. 2009).

Methods

Forest treatments

We used a randomized block design, blocking on stands to minimize variation caused by any site differences. Stands were 9.6 ha (24 acres) each and divided into twelve 0.81-hectare (2-acre) treatment units. We randomly assigned seven treatments to experimental units within each stand. Pre-treatment basal area ranged from 20-24 m^2/ha (90-105 $ft^2/acre$). Treatments included shelterwood (S), shelterwood with fire (SF), retention cut with fire (RF), retention cut with herbicide application (RH), retention cut with herbicide and fire (RHF), fire only (F), and control (C). S, SF, RF, F, and C were replicated twice in each stand. RH and RHF occurred only once in each stand because the herbicide application was made in experimental units that were formerly unburned retention cuts.

S is an even-aged regeneration method characterized by a series of partial commercial harvests. Trees are left in the overstory to shelter regenerating understory and are removed usually 6–8 years after initial harvest (Smith 1986). Four S harvests were completed in each stand, June through July 2001. The objective of the harvests was to reduce basal area to 13 m^2/ha (~60ft^2/acre) and provide shelter for advanced regeneration. Overstory trees are scheduled for harvest in 2010. Wildlife was not a factor in harvest selection. In April 2005, we burned 2 S treatment units in each stand.

Retention cutting usually is a non-commercial operation, killing undesirable overstory species. We completed a retention cut on 4 units in each stand during February 2001. We burned 2 units in each stand during March and early April 2001. Basal area was reduced to 13 m^2/ha (60 ft^2/acre) in treatment units. Trees were retained based on species, form, crown class, and size. White and red oaks were retained for acorn production, and blackgum and black cherry were retained for soft mast production. Scattered American beech was also retained for hard mast production. Red maple, sugar maple, sourwood, and yellow poplar were species commonly killed by girdling and hack-and-squirt using a 1:1 Garlon®-3A/water mixture (5.15 kg a.i./liter, 3lbs a.i./gallon) in the wound. Trees less than 13 cm (5 inches) DBH were cut down and stumps treated with the herbicide mixture. We burned the RF units again April of 2005 and 2007. A backpack-spray crew broadcast 6.6 L/ha (5qt/acre) of Garlon® 4 (6.87 kg a.i./liter; 4lbs a.i./gallon) to the understory of the unburned retention cut units in June 2006. We randomly selected one RH unit per stand and burned (RHF) in April 2007.

We implemented F treatments in February through late March 2001, and in April 2005 and 2007. For all controlled burns, backing fires were set initially and the remainder of the units were burned using strip-heading fires. Relatively low-intensity strip-heading fires generating 15–45 cm (6–18 in.) flame heights were used during all prescribed burns.

Food plot treatments

We used 4 openings, each adjacent to one of the forest stands, similar in slope, aspect, size, and prior land use, for 3 food plot plantings: 4.6 maturation soybeans, iron-and-clay cowpeas, and lablab in June 2007, and 3 varieties of soybeans (4.6, 5.6, and 7.0 maturation) in June 2008. Each field was relatively square, 1.5 to 2 hectares, and surrounded by woods on all sides. We amended sites with ag-lime to adjust pH and fertilized to adjust phosphorus and potassium levels according to soil tests.

Sampling

We randomly placed 3, 1.2m x 1.2m x 1.2m (4ft x 4ft x 4ft) woven-wire panel exclusion cages in each forest treatment unit. We collected all leaf biomass from woody species and entire herbaceous plants (excluding large stems) within cages and within three paired randomly placed un-caged plots, early July through mid-August and late August through September 2007 and 2008. Each cage was moved and randomly placed after each sampling period. Each sampled area was marked to avoid re-sampling a plot.

We randomly placed 4, 0.6m x 0.6m x 1.2m (2ft x 2ft x 4ft) exclusion cages in each food plot planting, and collected all biomass, except for large stems, for caged and un-caged samples July, August, and September 2007 and July, August, September, and October 2008. Each cage was moved and randomly placed after each sampling period. Each sampled area was marked to avoid re-sampling a plot.

Forage analysis

We collected samples of all selected forages within forest treatments in August 2007 and 2008. We collected caged samples of all food plot plantings in each sampling period. We dried all samples to constant mass in an air-flow dryer at 50 Cº, ground them using a 1-millimeter-mesh Wiley mill, and sent them to SURE-TECH™ Laboratories (2435 Kentucky Avenue Indianapolis, IN 46221) for crude protein (CP), neutral detergent fiber, and acid detergent fiber analysis using traditional chemical methods (wet chemistry) in 2007 and 2008. SURE-TECH™ Laboratories is certified by the National Forage Testing Association.

Species Selection

Edwards et al. (2004) and Jones et al. (2009) used past literature to determine which plants to include in NCC analysis. However, previous literature has shown plant selection by deer varies across their range. Thus, we used 50m (164 ft) line transects to determine plant selection by deer at CSF. One transect in each unit was sampled at 3 systematically located plots. Plot centers were located at 10, 25, and 40 meters (33, 82, 131 feet) along the transect, and we recorded all plants, tallying browsed plants by species in a 1.2m x 1.2m x 1.5m (4ft x 4ft x 5ft) plot. After tallying all species and number of stems browsed, we created a selection index.

We also used past literature (Harlow and Hooper 1972, Warren and Hurst 1981) to determine important foods for deer. We used these species to calculate alternate estimates of NCC in addition to our list determined from the browse plots.

Selection Index

We used the Chesson Index to determine species selection (Chesson index; Chesson 1978, 1983). We compared index values for each species to the Index cut-off (0.24 in 2007, 0.26 in 2008) to determine species selection. We determined the preference rating (*n*) by the following:

$$\frac{\text{total browsed stems (per species)}}{\text{total stems}} = n$$

Then we divided *n* by total browsed stems (*N*) to derive the weighted selection value (*r*) as shown in the following:

$$\frac{n}{(N)} = r$$

We divided 1 by the summation of *r* to determine the species selection cut-off number (*X*) as shown in the following:

$$\frac{1}{\sum(r)} = X$$

We divided *n* by the summation of *r* to derive index values by species (*x*) as shown in the following:

$$\frac{n}{\sum(r)} = x$$

Nutritional Carrying Capacity

We used selected species (Table 1) to determine NCC per hectare based on a 6%, 12%, and 14% CP mixed diet (Holter et al. 1979, Verme and Ullrey 1984, Edwards et al. 2004). Holter et al. (1979) documented yearling deer require an average of 6% CP mixed diet for body maintenance, Edwards et al. (2004) used a 12% CP mixed diet to emulate maintenance needs of adult deer, and Verme and Ullrey (1984) found a 14% CP mixed diet would support a lactating doe with one fawn. NCC was calculated using the explicit nutritional constraints model (Hobbs and Swift 1985). We assumed deer eat about 1.36 kg (3 lbs) dry weight of biomass per day (Holter et al. 1979). Since not all of the selected species were greater than 12% and 14% crude protein content, the maximum amount of forage available from the selected species was mixed until the

Table 1. Selected forages (Index Value[a]; Crude Protein %) as determined by selection transects at Chuck Swan State Forest and Wildlife Management Area, TN, USA, August 2007 and 2008.

		(IV)		(CP%)	
Common Name	Species	2007	2008	2007	2008
American Pokeweed	*Phytolacca americana*	0.018	0.109	11.06	29.81
Tick-trefoil	*Desmodium spp.*	0.059	0.059	16.95	20.90
Grape	*Vitis spp.*	0.075	0.090	10.96	20.16
Virginia Creeper	*Parthenocissus quinquefolia*	0.011	0.033	11.23	14.42
Wild Yam	*Dioscorea villosa*	0.078	0.092	10.02	13.76
Blackberry	*Rubus spp.*	0.140	0.048	10.08	13.12
Greenbrier	*Smilax spp.*	0.043	0.080	10.85	12.65
Blackgum	*Nyssa sylvatica*	0.095	0.072	12.61	11.24
Strawberrybush	*Euonymus americana*	0.256	0.130	9.71	11.06
Mapleleaf Viburnum	*Viburnum acerfolium*	0.021	0.034	7.23	7.23
Hogpeanut	*Amphicarpeae bracteata*	0.020	0.038	---[b]	---[b]
Bedstraw	*Gallium spp.*	0.026	0.004	8.55	8.55
Flowering Dogwood	*Cornus florida*	0.039	0.017	8.52	18.05

[a] Index Value cut-off was 0.024 in 2007 and 0.026 in 2008.

[b] Data not collected because species contribution was negligible.

12% and 14% threshold was met. This was then extrapolated into NCC by dividing each treatment total by 1.36 kg (3 lbs), which provided deer days per hectare. Additionally, NCC was calculated using the species list from past literature to compare NCC at each diet constraint (Table 2).

Production

Production was calculated for forest treatments and food plots plantings for comparison. We added the first period of caged production to the production of each additional period (subtracted biomass within uncaged samples from caged samples of additional periods) for an overall production estimate.

Cost Analysis

There were no differences between caged and uncaged plots or periods in the forest treatments in either year of the study. Thus, we assessed cost per kilogram by dividing the total cost of the treatment by the average amount of total and selected dry matter forage available. Cost per kg for the forest treatments was extrapolated over 2 years using the same cost with combined means from both years because treatment cost was not recurring. We calculated cost per kilogram for total forage available, selected species from the selection transects, and selected species according to past literature. Food plots were assessed by dividing production by the cost incurred from planting. Food plot plantings were a recurring cost because forages were annuals, so each year of production was assessed separately.

Any cost incurred by implementing a treatment, such as man-hours, cost of herbicide and application, or prescribed burning, were included. There were no costs associated with C or shelterwood treatments. The F treatment cost $37.00 per ha, which include man-hours, tractor-hours, and fuel. The RF treatment cost $294.00 per ha, including man-hours ($8.00/hr), herbicide

Table 2. Forages important to white-tailed deer (Harlow and Hooper 1972, Warren and Hurst 1981) at Chuck Swan State Forest and Wildlife Management Area, TN, USA, August 2007 and 2008.

Common Name	Species	CP%	
		2007	2008
Yellow Poplar	*Lireodendron tulipifera*	10.60	12.46
Sourwood	*Oxydendron arboreum*	9.48	11.54
Japanese Honeysuckle[a]	*Lonicera japonica*	12.86	12.86
Blueberry	*Vaccinium spp.*	7.76	9.21
Blackberry	*Rubus spp.*	10.08	13.12
Maples	*Acer spp.*	7.81	10.87
Oaks	*Quercus spp.*	10.20	18.56
Flowering Dogwood	*Cornus florida*	8.52	18.05
Strawberrybush	*Euonymus americana*	9.71	11.06
Greenbrier	*Smilax spp.*	10.85	12.65
Grape	*Vitis spp.*	10.96	20.16
Mapleleaf Viburnum[a]	*Viburnum acerfolium*	7.24	7.24
Sumac[a]	*Rhus spp.*	10.34	10.34
Poison Ivy[a]	*Toxicodendron radicans*	10.52	10.52
Sassafras	*Sassafras albidum*	11.34	13.78
Bedstraw[a]	*Gallium spp.*	8.55	8.55
American Pokeweed	*Phytolacca americana*	11.06	29.81
Tick-trefoil	*Desmodium spp.*	16.95	20.90
Virginia Creeper	*Parthenocissus quinquefolia*	11.23	14.42
Hogpeanut	*Amphicarpeae bracteata*	---[b]	---[b]
Wild Yam	*Dioscorea villosa*	10.02	13.76
Blackgum	*Nyssa sylvatica*	12.61	11.24

[a] Data only collected in 2007.

[b] Data not collected because species contribution was negligible.

($98.00/ha to treat cut stems), and cost of prescribed fire ($37.00/ha). The RH treatment cost $652.00 per ha, including man-hours, herbicide, and broadcast application of herbicide ($198.00/ha). The RHF treatment cost $689.00 per ha, including man-hours, herbicide, and prescribed fire. Forage plantings were assessed similarly, taking into account costs for soil testing ($5.00/field), seed ($148.00/ha for soybeans, $203.00/ha for cowpeas, $178.00 for lablab), lime and fertilizer ($178.00/ha), preemergence imazethapyr application ($44.00/ha), and tractor-/man-hours ($74.00/ha).

DATA ANALYSIS

For forest treatments, we conducted a mixed-model ANOVA using SAS 9.13 (SAS Institute, Cary, NC). The experiment was a randomized block design with incomplete replication in each stand. RH and RHF were the only treatments that were not replicated in each stand. We used the Tukey's Honestly Significant Difference multiple comparison test to compare means at $\alpha = 0.05$. The fixed effects were year, sampling period, treatment, and cage. Random effects included stand and stand*treatment. We used the square root transformation to correct for non-normality in 2007 and 2008 ($W = 0.83$, $W = 0.86$). In both years, periods and caged and un-caged samples were pooled to calculate means after initial tests showed no differences ($P = 0.943$, $P = 0.895$).

For food plot plantings, we conducted a mixed-model ANOVA using SAS 9.13. The experiment was a randomized block design with replication in each field. The fixed effects were year, sampling period, species, and cage. Random effects included site and species*site. The data were normal both years ($W = 0.94$, $W = 0.98$). Caged and un-caged samples were different in 2007 ($P = 0.032$) and similar in 2008 ($P = 0.713$); therefore, they were not pooled.

RESULTS

Forest Treatments

Total forage

Total forage available in RF and SF treatments exceeded that in C in 2007. In 2008, total forage available in RF and SF exceeded that in all other treatments, and S and F treatments contained more forage than C (Table 3).

Selected species at CSF

In 2007, there was more forage from selected species in RF than control. SF, S, RH and F treatments did not differ from C, while there was less forage in RHF than C. In 2008, there was more selected forage in RF and SF than in all other treatments (Table 4).

Selected species from literature

Forage available from species included in Harlow and Hooper (1972) and Warren and Hurst (1981) was greater in RF and SF treatments than all other treatments during 2007. In 2008, RF produced more forage than all other treatments except SF. SF, S, and F also produced more forage than C (Table 5).

Nutritional Carrying Capacity

NCC decreased as the CP% constraint was raised. NCC was greater when species from the literature were used in comparison to selected species because more species were included. Regardless of species used or CP% constraint, RF supported a larger NCC than all other treatments, except SF, throughout the study. When species from the literature are considered, F supported a larger NCC than C during 2008, regardless of CP% constraint (Tables 6, 7, and 8).

Table 3. Total forage available (kg/ha; SE) following silvicultural treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Year[a]					
Treatment[b]	2007			2008		
C	193	(53)	DEF	129	(22)	F
F	222	(38)	DEF	375	(62)	CDE
S	366	(54)	CDE	334	(57)	CDE
SF	581	(90)	BC	722	(113)	AB
RF	711	(90)	AB	940	(120)	A
RH	152	(49)	EF	326	(92)	CDEF
RHF	467	(326)	BCD	329	(84)	CDEF

[a] Treatment effect significant (F=12.61, P<0.0001, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[b] C, F, S, SF, RF, RH, RHF (N=4).

Table 4. Selected forage[a] available (kg/ha; SE) following silvicultural treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Year[b]	
Treatment[c]	2007	2008
C	27 (8) FGH	32 (9) F
F	29 (8) EFGH	50 (9) CDE
S	57 (9) DEFGH	57 (13) CDE
SF	121 (29) CDEF	111 (20) AB
RF	141 (42) CD	164 (40) A
RH	20 (13) GH	39 (18) EF
RHF	7 (2) H	51 (14) CDEF

[a] Species determined from selection transects.

[b] Treatment effect significant (F=6.56 , P<0.0001, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[c] C, F, S, SF, RF, RH, RHF (N=4).

Table 5. Forage available from Harlow and Hooper (1972) and Warren and Hurst (1981) (kg/ha; SE) following silvicultural treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Year[a]	
Treatment[b]	2007	2008
C	150 (33) DE	103 (20) E
F	212 (31) CD	337 (47) BC
S	274 (52) C	259 (51) C
SF	496 (72) B	651 (79) AB
RF	591 (74) AB	844 (91) A
RH	110 (30) E	163 (44) DE
RHF	105 (43) E	130 (41) DE

[a] Treatment effect significant (F=7.23, P<0.0001, DF= 1,78). Means with the same letter are not different (*P*<0.05).

[b] C, F, S, SF, RF, RH, RHF (N=4).

Table 6. Nutritional carrying capacity (deer days/ha; SE) following silvicultural treatments at 6% Crude Protein nutritional constraint at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

		Year	
	Treatment[a]	2007	2008
Selected Species[bc]	C	27 (7) DE	33 (8) D
	F	32 (8) D	47 (9) CD
	S	54 (13) CD	52 (13) CD
	SF	145 (44) AB	103 (21) AB
	RF	125 (57) AB	180 (53) A
	RH	27 (14) DEF	37 (8) D
	RHF	8 (5) F	44 (8) CD
Species from Literature[d]	C	139 (31) EF	97 (19) F
	F	194 (29) EF	312 (42) DE
	S	255 (49) EF	191 (48) EF
	SF	459 (67) CD	603 (72) B
	RF	548 (69) BC	886 (83) A
	RH	100 (28) EF	152 (41) EF
	RHF	97 (41) EF	120 (38) EF

[a] C, F, S, SF, RF, RH, RHF (N=4).

[b] Species determined from selection transects.

[c] Treatment effect for selected species significant (F=3.07, *P*=0.0256, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[d] Species from Harlow and Hooper (1972), and Warren and Hurst (1981). Treatment effect for species from literature significant (F=15.24, *P*<0.0001, DF= 1,78). Means with the same letter are not different (*P*<0.05).

Table 7. Nutritional carrying capacity (deer days/ha; SE) following silvicultural treatments at 12% Crude Protein nutritional constraint at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

		Year	
	Treatment[a]	2007	2008
Selected Species[bc]	C	18 (8) DE	33 (8) CDE
	F	23 (9) CDE	44 (6) C
	S	27 (12) CDE	52 (9) C
	SF	68 (33) CD	102 (14) AB
	RF	93 (33) BC	174 (40) A
	RH	13 (10) DE	37 (11) CDE
	RHF	3 (1) E	44 (10) C
Species from Literature[d]	C	32 (13) E	97 (19) D
	F	71 (31) DE	308 (38) C
	S	54 (27) DE	229 (44) C
	SF	130 (53) D	598 (71) B
	RF	194 (90) CD	886 (83) A
	RH	37 (29) E	139 (42) DE
	RHF	8 (4) F	116 (33) DE

[a] C, F, S, SF, RF, RH, RHF (N=4).

[b] Species determined from selection transects.

[c] Treatment effect for selected species significant (F=9.48, P<0.0001, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[d] Species from Harlow and Hooper (1972), and Warren and Hurst (1981).Treatment effect for species from literature significant (F=17.96, P<0.0001, DF= 1,78). Means with the same letter are not different (*P*<0.05).

Table 8. Nutritional carrying capacity (deer days/ha; SE) following silvicultural treatments at 14% Crude Protein nutritional constraint at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

		Year	
	Treatment[a]	2007	2008
Selected Species[bc]	C	12 (7) D	30 (10) CD
	F	17 (10) CD	33 (14) CD
	S	9 (6) DE	33 (12) CD
	SF	18 (10) CD	79 (22) AB
	RF	47 (24) BC	152 (64) A
	RH	20 (14) CDE	33 (18) CD
	RHF	1 (1) E	42 (9) CD
Species from Literature[d]	C	18 (12) FG	87 (21) D
	F	30 (14) F	217 (44) BC
	S	20 (11) F	151 (43) C
	SF	30 (13) EF	486 (103) A
	RF	79 (43) CDE	712 (126) A
	RH	21 (18) EFG	74 (27) D
	RHF	2 (2) G	87 (22) CD

[a] C, F, S, SF, RF, RH, RHF (N=4).

[b] Species determined from selection transects.

[c] Treatment effect for selected species significant (F=3.02, *P*=0.0275, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[d] Species from Harlow and Hooper (1972), and Warren and Hurst (1981).Treatment effect for species from literature significant (F=13.93, *P*<0.0001, DF= 1,78). Means with the same letter are not different (*P*<0.05).

Warm-season Food plots

Production of all planted warm-season forages produced thousands of pounds of forage in both years of the study (Tables 9 and 10). Production of iron-and-clay cowpeas and lablab persisted longer than soybeans in 2007. Caged estimates were greater than uncaged estimates for soybeans and lablab in August. There was no difference in deer use among forages in other months during 2007. In 2008, late-maturing soybeans persisted longer than 4.6 maturity soybeans. There was no difference in deer use among soybean varieties**.**

Forest Treatments vs. Food plots

Total production in food plot plantings exceeded production of all forest treatments in 2007. In 2008, 7.0 soybean production exceeded production of all forest treatments (Table 11). 4.6 and 5.6 soybeans production was similar to RF and greater than other forest treatments.

Cost Analysis

Shelterwood harvests provided income; thus, they were very economical. RH and RHF were least economical, regardless of species list used (Table 12). RF and F were more economical to implement and cost per kilogram of production was lower than treatments including understory herbicide application. The cost per kilogram of forage available in the lablab was more economical than, cowpeas, and the 4.6, 5.6, and 7.0 soybeans. RF was similar in cost/kg of forage produced to food plots if considering species from the literature.

DISCUSSION

Canopy reduction in combination with prescribed fire increased forage availability for white-tailed deer over all other treatments at CSF. Increased availability of selected forages also led to increased NCC, regardless of CP% constraint. Prescribed fire alone increased availability of species noted in the literature during the second year of sampling. NCC following S harvest still

Table 9. Forage availability (kg/ha; SE) following 3 commonly planted warm-season plantings at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007.

Month		Planting[a] Soybeans	Cowpeas	Lablab
July	caged	771 (200) B	1608 (299) A	344 (47) B
	uncaged	645 (361) B	2376 (1099) A	469 (104) B
August	caged	3200 (325) AB	3443 (147) AB	4836 (623) A
	uncaged	2303 (327) C	2447 (216) BC	2782 (271) BC
September	caged	633 (242) DE	2305 (393) BC	4036 (389) A
	uncaged	575 (246) E	1424 (255) CD	2747 (242) ABC

[a] Treatment effect significant (F=5.12, *P*=0.018, DF= 1,50). Means separated between forages within month. Means with same letter are not different (P<0.05).

[b] Soybeans, cowpeas, and lablab (N=4).

Table 10. Forage availability (kg/ha; SE) following 3 commonly planted warm-season plantings at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–October 2008.

Month		Soybean Planting[a] 4.6	5.6	7.0
July	caged	272 (101) A	379 (206) A	551 (286) A
	uncaged	184 (84) A	190 (115) A	170 (103) A
August	caged	1897 (375) A	2351 (463) A	2175 (323) A
	uncaged	1757 (258) A	1883 (344) A	2045 (386) A
September	caged	1872 (184) B	3392 (459) A	2993 (255) A
	uncaged	1796 (351) B	2895 (497) A	3092 (570) A
October	caged	17 (33) C	995 (349) AB	1385 (472) A
	uncaged	13 (27) C	819 (314) B	756 (194) B

[a] Treatment effect significant (F=4.66, *P*=0.022, DF= 1,50). Means separated between forages within month. Means with same letter are not different (P<0.05).

[b] 4.6 Soybeans, 5.6 soybeans, and 7.0 soybeans (N=4).

Table 11. Production (kg/ha; SE) following treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July - September 2007 and 2008.

	Year	
Treatment[a b]	2007	2008
C	199(48) E	169(38) E
F	271(69) E	510(56) DE
S	437(54) E	497(55) DE
SF	804(93) DE	1009(102) DE
RF	729(108) DE	1173(104) CDE
RH	156(55) E	660(83) DE
RHF	674(325) E	376(95) E
Lablab	5309(249) A	--- ---
Cowpeas	2381(361) ABC	--- ---
4.6 Soybean	2959(252) ABC	1869(158) BC
5.6 Soybean	--- ---	3604(306) ABC
7.0 Soybean	--- ---	3797(288) AB

[a] Treatment effect significant (F=16.72, P=0.0008, DF=1,17). Means with the same letter are not different (*P*<0.05).

[b] C, F, S, SF, RF, RH, RHF, Lablab, Cowpeas, Soybeans (N=4).

Table 12. Cost per kilogram of forage available following silvicultural treatments and food plantings at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Cost per Kilogram[a]		
Treatment[b]	Total Forage	Selected Forage[c]	Literature[d]
C[e]	---	---	---
F	\$0.04	\$0.42	\$0.07
S[e]	---	---	---
SF[e]	---	---	---
RF	\$0.15	\$0.86	\$0.18
RH	\$0.75	\$6.04	\$1.32
RHF	\$0.46	\$6.73	\$1.35
Lablab	\$0.10	---	---
Cowpeas	\$0.23	---	---
Soybeans (4.6)[f]	\$0.20	---	---
Soybeans (5.6)	\$0.13	---	---
Soybeans (7.0)	\$0.13	---	---

[a] Forage available divided by cost of treatment.

[b] Cost of forest treatments based on 2 years of data collection. Food plot plantings were an annual cost.

[c] Species determined from selection transects.

[d] Species from Harlow and Hooper (1972) and Warren and Hurst (1981).

[e] No cost associated with control or shelterwood harvests.

[f] Cost was same in 2007 and 2008.

exceeded that within C seven years post-harvest. However, periodic prescribed fire following canopy reduction continued to disturb the understory and maintain a larger NCC.

Damaging overstory hardwoods with fire is often a concern among forest managers. We used low-intensity early growing-season fire at CSF to consume the litter layer and set back succession without damaging valuable overstory species. Precautionary measures were taken by removing any large debris from the base of desirable trees prior to burning. Previous research has shown heat maintained in burning large debris adjacent to the base of a tree may damage the cambium and consequently decrease timber value or even kill the tree (Brose and Van Lear 1999).

Our data suggest fire alone can increase NCC, but this effect was most likely influenced by multiple prescribed fires with a relatively short fire-return interval. Wood (1988) found one dormant-season prescribed fire did not increase forage availability in the following 3 growing seasons in closed-canopy stands. Shaw (2008) detected a small increase in NCC following 1 dormant-season fire in closed-canopy hardwoods.

We predicted repeated prescribed burning, as well as understory broadcast applications of triclopyr, would reduce woody composition and increase herbaceous composition of the understory. However, woody regeneration accounted for more than half the available forage in all treatments (Table 13). Although available herbaceous forage increased following treatments that included fire and herbicide, relative woody composition remained large. Edwards et al. (2004) and Jones et al. (2009) found imazapyr reduced undesirable woody growth and stimulated more desirable herbaceous forage for deer. However, imazapyr is not recommended for use in hardwoods because of soil activity and potential risk to valuable overstory species (BASF 2007).

Table 13. Percent composition of total forage available (kg/ha) following silvicultural treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2008.

	Total Biomass	Herbaceous[a]		Trees[b]		Shrubs[c]		Other[d]	
Treatment	Kg	kg	(%)	Kg	(%)	kg	(%)	kg	(%)
C	117	21	(18)	67	(57)	9	(8)	20	(17)
F	298	42	(14)	221	(74)	24	(8)	12	(4)
S	265	40	(15)	180	(68)	19	(7)	27	(10)
SF	574	52	(9)	453	(79)	34	(6)	40	(7)
RF	747	90	(12)	545	(73)	45	(6)	67	(9)
RH	129	18	(14)	88	(68)	14	(11)	9	(7)
RHF	131	26	(20)	85	(65)	8	(6)	12	(9)

[a] *Desmodium* spp., *Phytolacca americana*, *Carex* spp., *Eupatorium* spp., *Liliaceae* spp., *Lespedeza* spp., < 5% other.

[b] Woody species include *Liriodendron tulipifera*, *Quercus* spp., *Acer* spp., *Oxydendron arboreum*, *Sassafras albidum*, *Nyssa sylvatica*, < 5% other.

[c] Shrubs include *Vaccinium* spp., *Frangula caroliniana*, *Rhus* spp., *Euonymus americanus*, < 5% other.

[d] Other include *Smilax* spp., *Parthenocissus quinquefolia*, *Rubus* spp., *Vitis* spp., *Dioscorea villosa*, *Lonicera japonica*, < 5% other.

Triclopyr, which has no residual soil activity, is safe to apply under hardwoods (Dow Agro-Sciences 2005). Triclopyr effectively killed woody species in the understory and developing midstory of RH and RHF. However, with no soil activity, woody species, such as red maple, sassafras, and yellow poplar, quickly reestablished from seed during the two growing seasons following herbicide application. Other work has shown applications of soil-active herbicides alter plant composition and increase forage available for deer in pine systems (Copeland 1986, Hurst and Warren 1986, Blake et al. 1987, Hurst and Watkins 1988, McNease and Hurst 1991, Witt et al. 1993, Chamberlain and Miller 2006). However, our data suggested an understory application of triclopyr is not effective in decreasing undesirable woody species composition or increasing NCC in upland hardwoods.

Consideration for species composition obviously is important when evaluating forage availability for deer because increased biomass does not necessarily equate to increased NCC. For example, burnweed (*Erechtites hieracifolia*), which was not eaten by white-tailed deer, accounted for the majority of total forage available in RHF in 2007.

We used two species lists to estimate NCC because we felt the list of species selected at CSF may have under represented NCC, given the relatively low deer density. The species list from the literature was probably more accurate in determining the deer density that could actually be supported.

Forage quality is another important consideration when evaluating NCC. And our data show it is important to calculate forage quality each year; estimates from previous years may not be accurate for any given year. The difference in forage quality between 2007 and 2008 was likely a result of drought. East Tennessee experienced the worst drought on record in 2007 followed by normal rainfall in 2008 (National Oceanic and Atmospheric Administration 2008). NCC was influenced by forage quality between years at both 12% and 14% CP constraints. Most of the plants selected were below these constraints in 2007 and above both in 2008. Forage availability was similar across years in all treatments, but because of lower forage quality, an unproportionally low NCC was estimated in 2007.

In 2007, data collected suggested significant use of all food plot plantings by white-tailed deer in August, and cowpeas and lablab in September. However, the vining nature of lablab and cowpeas may have lead to increased biomass collected within the exclusion cages. Thus, we planted three varieties of soybeans in 2008. Regardless, forage availability in all warm-season plantings exceeded that in all forest treatments during both years of the study, with the exception of RF, which was similar to early maturing soybeans in 2008. It is important to note these data are applicable to the growing season only. Additional evaluation is needed to address NCC during the dormant season.

Shelterwood regeneration harvests are economical and appropriate if the stand is ready to regenerate or if trees intended for removal are merchantable. Costs associated with retention cutting may be sizable initially, but cost per kilogram decreased considerably over time, and rivaled that of warm-season forage food plots after only 2 years (when considering species from literature). The warm-season food plots provided thousands of kilograms of high-quality forage per hectare and the cost per kilogram for each of the plantings was relatively low in comparison to forest treatments. However, the cost associated with planting annual forage plots recurs each year.

MANAGEMENT IMPLICATIONS

Where increased forage availability is desirable for white-tailed deer in closed-canopy upland hardwoods, we recommend canopy reduction followed by periodic prescribed fire. Landowners should evaluate available forage, species composition, stand type, age, and quality when considering management options. If the stand is ready to regenerate, or at least has merchantable timber, landowners may consider a regeneration harvest, such as shelterwood.

Otherwise, retention cutting may be used to open the canopy and stimulate forage production. Regardless of treatment, trees should be retained based on wildlife benefit (e.g., oaks and other mast producers) as well as crown class, size, shape, and form. Vegetation response will vary among sites and will dictate fire-return interval. Our data clearly show periodic low-intensity prescribed fire can be used in upland hardwood stands to maintain early successional plant growth and available forage. A 3- to 5-year fire return interval will maintain forage availability, soft mast production, and provide attractive fawning cover. Warm-season food plots may be used to relieve native vegetation of excessive browsing when populations exceed NCC. However, an appropriate annual doe harvest is required to reduce deer density and allow plant communities to recover.

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Appendix

Table 14. Total forage available (lbs/ac; SE) following silvicultural treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008**.**

	Year[a]	
Treatment[b]	2007	2008
C	172 (47) DEF	116 (20) F
F	198 (34) DEF	335 (56) CDE
S	327 (48) CDE	298 (51) CDE
SF	519 (80) BC	645 (102) AB
RF	635 (80) AB	839 (107) A
RH	136 (44) EF	291 (83) CDEF
RHF	417 (291) BCD	294 (76) CDEF

[a] Treatment effect significant (F=12.61, *P*<0.0001, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[b] C, F, S, SF , RF, RH, RHF (N=4).

Table 15. Selected forage available (lbs/ac; SE) following silvicultural treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Year[a]	
Treatment[b]	2007	2008
C	24 (7) FGH	29 (8) F
F	26 (7) EFGH	45 (8) CDE
S	51 (8) DEFGH	51 (11) CDE
SF	109 (26) CDEF	100 (18) AB
RF	127 (38) CD	147 (36) A
RH	18 (12) GH	35 (16) EF
RHF	6 (2) H	41 (13) CDEF

[a] Treatment effect significant (F=6.56 , *P*<0.0001, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[b] C, F, S, SF, RF, RH, RHF (N=4).

Table 16. Forage available from Harlow and Hooper (1972) and Warren and Hurst (1981) (lbs/ac; SE) following silvicultural treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Year[a]	
Treatment[b]	2007	2008
C	134 (30) DE	93 (18) E
F	189 (28) CD	301 (42) BC
S	245 (47) C	231 (46) C
SF	443 (65) B	581 (71) AB
RF	528 (67) AB	754 (81) A
RH	98 (27) E	146 (40) DE
RHF	94 (39) E	115 (37) DE

[a] Treatment effect significant (F=7.23, *P*<0.0001, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[b] C, F, S, SF, RF, RH, RHF (N=4).

Table 17. Nutritional carrying capacity (deer days/ac; SE) following silvicultural treatments at 6% Crude Protein nutritional constraint at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

		Year	
	Treatment[a]	2007	2008
Selected Species[bc]	C	24 (6) DE	30 (8) D
	F	29 (7) D	42 (9) CD
	S	49 (13) CD	47 (12) CD
	SF	130 (39) AB	93 (19) AB
	RF	113 (51) AB	160 (48) A
	RH	24 (16) DEF	33 (7) D
	RHF	7 (4) F	39 (7) CD
Species from Literature[d]	C	124 (28) EF	87 (17) F
	F	174 (26) EF	279 (38) DE
	S	227 (44) EF	215 (43) EF
	SF	410 (60) CD	538 (65) B
	RF	489 (62) BC	791 (75) A
	RH	90 (25) EF	135 (37) EF
	RHF	87 (37) EF	107 (34) EF

[a] C, F, S, SF, RF, RH, RHF (N=4).

[b] Species determined from selection transects

[c] Treatment effect for selected species significant (F=3.07, *P*=0.0256, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[d] Species from Harlow and Hooper (1972), and Warren and Hurst (1981). Treatment effect for species from literature significant (F=15.24, *P*<0.0001, DF= 1,78). Means with the same letter are not different (*P*<0.05).

Table 18. Nutritional carrying capacity (deer days/ac; SE) following silvicultural treatments at 12% Crude Protein nutritional constraint at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

		Year	
	Treatment[a]	2007	2008
Selected Species [bc]	C	16 (7) DE	30 (9) CDE
	F	21 (8) CDE	40 (7) C
	S	24 (11) CDE	47 (10) C
	SF	61 (30) CD	91 (16) AB
	RF	84 (30) BC	156 (36) A
	RH	12 (9) DE	33 (10) CDE
	RHF	3 (1) E	39 (8) C
Species from Literature[d]	C	29 (15) E	87 (17) D
	F	64 (28) DE	274 (34) C
	S	49 (24) DE	204 (40) C
	SF	116 (48) D	534 (64) B
	RF	173 (81) CD	791 (75) A
	RH	33 (26) E	125 (38) DE
	RHF	8 (4) F	104 (30) DE

[a] C, F, S, SF, RF, RH, RHF (N=4).

[b] Species determined from selection transects.

[c] Treatment effect for selected species significant (F=9.48, P<0.0001, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[d] Species from Harlow and Hooper (1972), and Warren and Hurst (1981).Treatment effect for species from literature significant (F=17.96 , *P*<0.0001, DF= 1,78). Means with the same letter are not different (*P*<0.05).

Table 19. Nutritional carrying capacity (deer days/ac; SE) following silvicultural treatments at 14% Crude Protein nutritional constraint at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

		Year	
	Treatment[a]	2007	2008
Selected Species[bc]	C	11 (6) D	27 (9) CD
	F	19 (9) CD	33 (13) CD
	S	8 (6) DE	30 (11) CD
	SF	16 (9) CD	71 (20) AB
	RF	42 (22) BC	135 (58) A
	RH	18 (13) CDE	30 (16) CD
	RHF	1 (1) E	35 (8) CD
Species from Literature[d]	C	16 (11) FG	78 (19) D
	F	27 (13) F	194 (40) BC
	S	18 (10) F	135 (39) C
	SF	27 (12) EF	434 (93) A
	RF	71 (39) CDE	636 (113) A
	RH	19 (16) EFG	67 (24) D
	RHF	2 (2) G	78 (20) CD

[a] C, F, S, SF, RF, RH, RHF (N=4).

[b] Species determined from selection transects.

[c] Treatment effect for selected species significant (F=3.02, *P*=0.0275, DF= 1,80). Means with the same letter are not different (*P*<0.05).

[d] Species from Harlow and Hooper (1972), and Warren and Hurst (1981).Treatment effect for species from literature significant (F=13.93, *P*<0.0001, DF= 1,78). Means with the same letter are not different (*P*<0.05).

Table 20. Forage availability (lbs/ac; SE) following 3 commonly planted warm-season plantings at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007.

		Planting[a]		
Month		Soybeans	Cowpeas	Lablab
July	caged	688 (179) B	1436 (267) A	307 (42) B
	uncaged	576 (322) B	2121 (981) A	419 (94) B
August	caged	2857 (290) AB	3074 (147) AB	4318 (556) A
	uncaged	2056 (292) C	2185 (193) BC	2484 (242) BC
September	caged	565 (216) DE	2058 (351) BC	3604 (347) A
	uncaged	513 (220) E	1271 (228) CD	2453 (216) ABC

[a] Treatment effect significant (F=5.12, *P*=0.018, DF= 1,50). Means separated between forages within month. Means with same letter are not different (P<0.05).

[b] Soybeans, cowpeas, and lablab (N=4)

Table 21. Forage availability (lbs/ac; SE) following 3 commonly planted warm-season plantings at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–October 2008.

		Soybean Planting[a]		
Month		4.6	5.6	7.0
July	caged	243 (91) A	338 (184) A	492 (256) A
	uncaged	164 (76) A	170 (104) A	152 (92) A
August	caged	1694 (335) A	2099 (413) A	1942 (288) A
	uncaged	1569 (230) A	1681 (307) A	1826 (345) A
September	caged	1671 (164) B	3029 (410) A	3353 (228) A
	uncaged	1604 (313) B	2585 (444) A	2761 (509) A
October	caged	15 (30) C	888 (312) AB	1237 (421) A
	uncaged	12 (24) C	731 (280) B	675 (173) B

[a] Treatment effect significant (F=4.66, *P*=0.022, DF= 1,50). Means separated between forages within month. Means with same letter are not different (P<0.05).

[b] 4.6 soybeans, 5.6 soybeans, and 7.0 soybeans (N=4)

Table 22.Production (lbs/ac; SE) following treatments at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Year	
Treatment[a b]	2007	2008
C	178(43) E	151(34) E
F	242(62) E	455(50) DE
S	390(48) E	444(49) DE
SF	718(83) DE	901(91) DE
RF	651(96) DE	1047(93) CDE
RH	139(49) E	589(74) DE
RHF	602(290) E	336(85) E
Lablab	4740(222) A	--- ---
Cowpeas	2126(322) ABC	--- ---
4.6 Soybean	2642(225) ABC	1669(141) BC
5.6 Soybean	--- ---	3218(273) ABC
7.0 Soybean	--- ---	3390(257) AB

[a] Treatment effect significant (F=16.72, *P*=0.0008, DF=1,17). Means with the same letter are not different (*P*<0.05).

[b] C, F, S, SF, RF, RH, RHF, Lablab, Cowpeas, Soybeans (N=4).

Table 23. Cost per Pound of forage available following silvicultural treatments and food plantings at Chuck Swan State Forest and Wildlife Management Area, TN, USA, July–September 2007 and 2008.

	Cost per Pound[a]		
Treatment[b]	Total Forage	Selected Forage[c]	Literature[d]
C[e]	---	---	---
F	\$0.03	\$0.21	\$0.03
S[e]	---	---	---
SF[e]	---	---	---
RF	\$0.08	\$0.43	\$0.09
RH	\$0.38	\$3.06	\$0.67
RHF	\$0.23	\$3.42	\$0.69
Lablab	\$0.04	---	---
Cowpeas	\$0.10	---	---
Soybeans (4.6)[f]	\$0.08	---	---
Soybeans (5.6)	\$0.05	---	---
Soybeans (7.0)	\$0.05	---	---

[a] Forage available divided by cost of treatment.

[b] Forest treatments 2 years of forage data, food plot plantings is an annual cost.

[c] Species derived from selection transects.

[d] Species from Harlow and Hooper (1972), and Warren and Hurst (1981).

[e] No cost associated with control or shelterwood harvests.

[f] Cost was same in 2007 and 2008.

VITA

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