CORRELATION OF FOREST CHARACTERISTICS WITH WHITE-TAILED DEER FORAGE

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Abstract: Significant ($P<0.05$) correlation coefficients were obtained by relating various forest characteristics to amounts of selected (succulent, new-growth) forage from plants utilized by white-tailed deer (*Odocoileus virginianus*) in mixed pine-hardwood forests. Forage from forbs and grasses was inversely related to most characteristics pertaining to basal area, age, dbh, height, and number of layers. Forage from vines was not significantly correlated with any forest characteristic. Forage from woody plants was directly related to hardwood density, age, dbh, and basal area. Stepwise multiple regression analyses were performed and only the forage from forbs was significantly correlated ($r^2=0.586$) with a single forest characteristic. Four additional characteristics raised the R^2 to 0.716. Correlations for grass, vine, woody and total deer forage were too low to provide any confidence that deer forage could be predicted on the basis of forest measurements.

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The production of forage for white-tailed deer is dependent upon forest characteristics (Halls 1970, Blair and Brunett 1977). Forest resource managers would like to estimate deer forage adequately by measuring 1 or 2 forest characteristics (Schuster and Halls 1963, Halls and Schuster 1965, Wiggers et al. 1978).

Mississippi has about 6.7 million ha of forested land and a deer population of at least 750,000. The most prevalent forest type is the mixed pine-hardwood forest, which is increasing in acreage (Murphy 1978, Wolters et al. 1977). This study was conducted to determine if deer forage abundance was correlated with stand characteristics in the mixed pine-hardwood forest.

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METHODS

Four forested tracts in the flatwoods of the Upper Coastal Plain of Mississippi were sampled. The interior flatwoods has acid soils, annual precipitation ranges from 127-152 cm, and the frost-free period averages 215 days (Pettry 1977).

Dominant trees were loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*), post oak (*Quercus stellata*), southern red oak (*Q. falcata*), sweetgum (*Liquidambar styraciflua*) and other hardwood species. Stands were natural, second-growth forests that had not been recently burned, cut, or grazed (Table 1).

Within each stand, 12 circular plots (0.08 ha) were established along a randomly selected transect. Plot centers were systematically located at 102 m intervals along the transect. A plot was rejected if atypical conditions, such as an old home site, were found and another plot was substituted. No plot was accepted closer than 102 m to an opening. Data from the 48 unstratified plots were combined for analyses.

TABLE 1. Stand characteristics for the 4 mixed pine-hardwood forests sampled, Interior Flatwoods, northcentral Mississippi.

Size of tract (ha)	Average site index pine (m)	Average no. layers	Average age[a] Hdw. (years)	Average age[a] Pine (years)	Average basal area[b] Hdw. (m^2/ha)	Average basal area[b] Pine (m^2/ha)	Average dbh[c] Hardwood Tot. (cm)	Average dbh[c] Hardwood Mer. (cm)	Average dbh[c] Pine Tot. (cm)	Average dbh[c] Pine Mer. (cm)	Average density[d] Hdw. (stems/ha)	Average density[d] Pine (stems/ha)	Average density[d] Total (stems/ha)
51	24	3.9	86	44	14	13	12	33	14	33	1,290	864	2,154
65	25	4.8	106	99	12	17	10	41	39	42	1,876	81	1,960
14	28	4.2	82	60	24	11	9	27	32	39	1,366	272	1,640
133	25	4.6	79	41	15	13	8	37	21	31	2,021	393	2,441

[a]Dominant and codominant for pine, dominant for hardwood.
[b]Total stems > 11.4 cm dbh.
[c]Tot. = total dbh, total stems >1.4 cm dbh; Mer. = merchantable, stems >20.3 cm dbh.
[d]Total stems <1.4 cm dbh.

Data collected from each 0.08 ha plot included: 1. Basal area of pine and hardwood, determined by 10 factor prism. 2. Pine and hardwood age, determined by boring 1 dominant and 1 codominant tree for loblolly and/or shortleaf pine and 2 dominant hardwoods. 3. Number of layers, obtained by ocular estimate. 4. Heights of all stems >9.1 cm dbh, estimated in 3-m intervals. Some trees were measured to validate estimates. All stems >20.3 cm dbh were estimated using a Suunto. 5. Diameter at breast height, measured for all stems >1.4 cm dbh on a 0.04 ha plot within the 0.08 ha plot. All stems >9.1 cm dbh on a 0.08 ha plot were measured with a diameter tape.

From these data basal area, site index and density were computed. Five variables pertaining to density were created: the number of stems >1.4 cm dbh, number of stems <9.1 cm dbh, number of stems >9.1 cm dbh, number of stems 9.1 to <20.3 cm dbh, and number of stems >20.3 cm dbh.

Ranked-set sampling was used in July-September to estimate deer forage (Halls and Dell 1966, Dell and Clutter 1972). Three circular hoops, 105 cm in diameter (0.89 m^2 in area), were used. Three sets, a set being 1 high, 1 medium, and 1 low ocular estimate of forage present, were taken on each 0.08 ha plot. The sets were placed on the perimeter of a circle 7.62 m from the center of the 0.08 ha plot center.

Forage species utilized by deer in mixed pine-hardwood forests in east-central Mississippi (Warren 1980), were removed up to a height of 1.52 m. Only palatable, green, succulent, new growth parts of the plants were selected. The forage was separated by plant life form (grass, forb, vine, and woody), placed in paper bags, oven-dried at 70 C for 72 hours and weighed. The woody class included succulent twigs and attached green leaves and fruit.

The Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975) was used for analysis. The subprogram PEARSON CORR was used to calculate Pearson correlation coefficients (r) which measure the relationship between interval-level variables. Correlation coefficients compared the 5 classes of deer forage (Total, forb, grass, vine and woody) with 19 forest characteristics. Stepwise multiple regression analyses were also performed using the REGRESSION subprogram of SPSS. The multiple regression analyses related the amount of deer forage to forest characteristics. The forest characteristic that explained the greatest amount in the dependent variable was entered into the equation first. The variable that explained the greatest amount of variance in conjunction with the first variable was entered second, and so on.

RESULTS

Forage from vines (mostly *Rhus radicans, Anisostichus capreolata, Dioclea multiflora, Vitis* spp., *Parthenocissus* sp., and *Smilax* spp.) was not significantly correlated (P>0.05) with any forest characteristic (Table 2).

TABLE 2. Significant (P<0.05) correlation coefficients (r) for various forest characteristics and deer forage abundance, by class, Interior Flatwoods, northcentral, Mississippi.

	Deer Forage Class				
Forest characteristics	Total	Grass	Forb	Vine	Woody
Basal					
Pine	-0.33 c&p[a]	*	*	*	-0.28c
Hardwood	0.26c	*	*	*	0.39c
Total	-0.26p	*	-0.26 p	*	*
Number of Layers	*	-0.26	-0.39	*	*
Site Index					
Pine	-0.26	*	*	*	-0.24
Age					
Pine	*	-0.30	-0.27	*	0.32
Hardwood	*	-0.38	*	*	0.24
Total	*	-0.37	*	*	0.37
Diameter Breast Height					
Average total pine	-0.25	-0.43	-0.50	*	*
Average total hardwood	0.28	*	0.30	*	*
Average pine >20.3 cm dbh.	*	-0.32	-0.27	*	0.24
Average hardwood >20.3	*	*	*	*	*
Height					
Average total pine	*	-0.28	-0.36	*	*
Average total hardwood	*	*	*	*	*
Average total pine >20.3 cm dbh	*	-0.34	-0.41	*	*
Average total hardwood >cm dbh	-0.26	*	-0.43	*	*

[a]Negative symbol means an inverse relationship existed, c = calculated, p = prism.
* Correlation coefficient not significant at the 0.05 level.

Grasses (primarily *Uniola sessiflora, Erianthus* spp. and *Panicum* spp.) were negatively related to number of layers, age, average dbh of pine, and average height of pine.

Forbs (mainly *Aster* spp., *Solidago* spp., *Desmodium* spp., *Eupatorium* spp., *Viola* spp., *Vicia* spp., *Elephantopus* spp., *Clitoria mariana*, and *Euphorbia corollata*) were negatively related to total basal area, number of layers, pine age, average dbh of pine, average height of pine and average height of hardwoods >20.3 cm dbh.

Forage from woody plants (mainly *Prunus* spp., *Crataegus* spp., *Ulmus* spp., *Ilex* spp., *Fraxinus* spp., *Vaccinium* spp., *Cornus florida*, *Acer rubrum*, *Nyssa sylvatica*, *Hypericum* spp., and *Callicarpa americanum*) was directly related to basal area of hardwood, age, and average dbh of pine >20.3 cm dbh while being inversely related to basal area of pine and site index.

Total forage was inversely correlated with basal area of pine, total basal area, site index, average dbh of pine and average dbh of hardwoods >20.3 cm dbh, and directly correlated with hardwood basal area and average dbh of all hardwoods. The average dbh of all pines was inversely related to total, forb, and grass forage.

Vines were not significantly correlated with any of the 5 variables pertaining to density (stems/ha) (Table 3). Pine density was directly related to grass and forb forage. Total deer forage was also directly related to the 2 smallest pine stem sizes. Total forage was inversely related to pine density (stems >20.3 cm), but was directly related to hardwood density of the same density class. Forbs declined as density of hardwood stems (both >1.4 and <9.1 cm) increased. Woody forage was inversely related to pine density in the 3 smallest size classes. Woody forage was directly related to the 3 largest hardwood density size classes.

TABLE 3. Significant (P<0.05) correlation coefficients (r) for various stand density measurements and deer forage abundance, by class, Interior Flatwoods, northcentral, Mississippi.

	Deer Forage Class				
Stand Density	Total	Grass	Forb	Vine	Woody
All Stems >1.4 cm dbh					
Pine	0.28[a]	0.41	0.68	*	-0.24
Hardwood	*	*	-0.36	*	*
Those Stems <9.1 cm dbh					
Pine	0.43	0.36	0.76	*	*
Hardwood	*	*	-0.36	*	*
All Stems >9.1 cm dbh					
Pine	*	0.29	0.27	*	-0.35
Hardwood	*	*	*	*	0.34
Those Stems 9.1 to <20.3 cm dbh					
Pine	*	0.33	0.44	*	-0.27
Hardwood	*	*	*	*	0.25
All Stems >20.3 cm dbh					
Pine	-0.34	*	*	*	-0.27
Hardwood	0.30	*	*	*	0.26

[a]Negative symbol means an inverse relationship existed.
* Correlation coefficient not significant at the 0.05 level.

Nineteen forest stand characteristics were used in the stepwise multiple regression analyses. However, only the first 5 characteristics that entered the analysis will be presented. A low correlation (r^2=0.312) was obtained for forage from woody plants and the 5 forest characteristics. Four of the characteristics pertained to hardwoods (basal area, height, density, age). The fifth characteristic was pine age (Table 4).

TABLE 4. Relationships between pine-hardwood forest characteristics and forage from woody plants, vines and grasses.

Forest characteristics	R^2	R^2 change
Woody plants		
hardwood basal area (cal.)[a]	.151	.151
average pine age	.230	.079
average total hardwood height, stems > cm dbh	.261	.031
hardwood density, stems >20.3 cm dbh	.295	.034
average hardwood age	.312	.018
Vines		
hardwood density, stems >20.3 cm dbh	.030	.030
hardwood density, stems <9.1 cm dbh	.057	.027
number of layers	.080	.024
average pine age	.106	.025
pine density, stems >9.1 cm dbh	.134	.029
Grasses		
average total pine dbh	.185	.185
average hardwood age	.315	.130
pine basal area (prism)	.399	.083
average total pine height, stems >9.1 cm dbh	.423	.025
average total pine height[b] stems >20.3 cm dbh	.456	.032

[a]Basal area was calculated, not from prism method.
[b]Caution, multicollinearity may have occured.

Forage from vines was weakly correlated (r^2=0.134) with the 5 stand characteristics. The variables chosen were hardwood and pine density, pine age, and number of layers.

Forage from grasses was not strongly correlated (r^2=0.456) with the 5 variables that entered the equation. Four of the variables dealt with pine (average dbh, basal area, and average height). Hardwood age was the other variable that entered the equation.

Forage from forbs showed a strong correlation with forest characteristics (r^2=0.716) (Table 5). Pine density (stems <9.1 cm dbh) accounted for 59% of the variation. Hardwood height and dbh, pine basal area, and number of layers were the other variables that entered the equation.

Total deer forage was not strongly correlated with forest characteristics (r^2=0.462). Four of the 5 variables pertained to pine (density, basal area, and height) and the fifth variable was hardwood height.

DISCUSSION

Correlation coefficients relating forest characteristics to deer forage suggest that the forest-wildlife manager can predict trends in the amount of deer forage given certain stand conditions in the mixed pine-hardwood forests of east-central Mississippi. The amount of forage from grasses and forbs can be expected to decline as average age, dbh,

TABLE 5. Relationships between pine-hardwood forest characteristics and forage from forbs and total forage.

Forest characteristic	R^2	R^2 change
Forbs		
pine density, stems <9.1 cm dbh	.586	.586
average total hardwood height, stems >20.3 cm dbh	.651	.066
pine basal area (prism)	.680	.029
number of layers	.703	.023
average hardwood dbh, stems >20.3 cm dbh	.716	.013
Total Forage		
pine density, stems <9.1 cm dbh	.183	.183
pine basal area (cal.)[a]	.242	.059
average total hardwood height, stems >20.3 cm dbh	.300	.058
average total pine height, stems >9.1 cm dbh	.352	.051
average total pine height[b], stems >20.3 cm dbh	.462	.111

[a]Basal area was calculated, not from prism method.
[b]Caution, multicollinearity may have occurred.

basal area, height, and number of layers increase. The amount of forage from vines does not significantly correlate with any forest stand characteristic measured in this study. Forage from woody plants generally increased as the hardwood component of the stands increased. Forage from woody plants was inversely correlated with pine density.

The mixed pine-hardwood forest is a highly variable forest and high R^2 values, relating forest characteristics to forage abundance from known deer food plants should not be expected. Wiggers et al. (1978) found no significant regressions for predicting production of known deer food plants from overstory measurements. The best correlation found in this study was with forage from forbs, which are important deer food plants in some habitats of the South (Blair and Brunett 1977, Warren 1980.)

Basal area has been correlated with total herbage, grass, browse and forb production (Halls and Schuster 1965, Blair and Enghardt 1976, Myers 1977). However, any given basal area can be "packaged" in many different combinatons of stem dbh and species. No doubt basal area affects forage production, but it did not explain much of the variation in deer forage in the mixed pine-hardwood forest type in the flatwoods of east-central Mississippi. Wiggers et al. (1978) explained 94% of the variation in total forage production, all annual growth of all species, with basal area of large stems. However, a wide range of stands was used, including data-sets from pine plantations, age 0-5 years, with zero basal area.

Forest cover has been used to explain variation in forage (Rhodes 1952, Ehrenreich and Crosby 1960, Schuster and Halls 1963, Halls and Schuster 1965). Cover was not measured in the present study because an accurate, objective method of measuring cover in a multilayered forest was not found. Cover is a result of a combination of all or most of the forest characteristics measured. Therefore the independent variables can be correlated among themselves and multi-collinearity would exist (Neter and Wasserman 1974).

Based on these results it appears that there is no simple, fast and reliable method to predict the amount of forage produced by plants utilized by deer on the basis of forest measurements in the mixed pine-hardwood forest in the flatwoods of Mississippi (Leopold 1979).

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