RELATIONSHIP BETWEEN HERBACEOUS LAYER, STAND, AND SITE VARIABLES IN THE BANKHEAD NATIONAL FOREST, ALABAMA

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Abstract—We studied herbaceous layer richness, diversity and cover in stands on the southern Cumberland Plateau. The stands are mixed pine-hardwoods dominated by 25-40-year-old planted loblolly pine (*Pinus taeda* L.). Scheduled future treatments combining thinning and fire are designed to restore the hardwood component, particularly oak (*Quercus* spp.) and hickory (*Carya* spp.) species, and to increase herbaceous diversity. We related pretreatment herbaceous layer (vegetation < 1.4 m height) richness, diversity, and cover to basal area and site variables on 125 plots in 25 stands. Our models showed significant but weak relationships. Slope, broadleaf litter cover, and basal area accounted for 14 percent of the herbaceous layer richness. Models for species diversity and cover had lower coefficients of determination. The measured stand and site variables were not reliable predictors of pretreatment herbaceous layer variation.

INTRODUCTION

Floral diversity of temperate forests in eastern North America is highest in the herbaceous layer (classified as vegetation < 1-2 m in different sources) (Braun 1950, Gilliam and Roberts 2003). Composition of the herbaceous layer is also influenced by stand conditions, which are often modified by silvicultural treatments and natural disturbance events (Royo and Carson 2006). Concerns about biodiversity loss have caused forest managers to use silvicultural practices that promote biodiversity and alter species composition (Burton and others 1992).

Future silvicultural activities on the William B. Bankhead National Forest (BNF) are also designed with biodiversity in mind, mostly in response to recent outbreaks of southern pine beetle (*Dendroctonus frontalis* Zimm) and in an effort to restore stands on ridge tops currently dominated by planted loblolly pine (*Pinus taeda* L.) to oak (*Quercus* spp.)–hickory (*Carya* spp.), and mixed hardwood. The desired future community has been found to hold the highest diversity in the herbaceous layer (Monk and others 1969) and ought to be characterized before silvicultural treatments begin.

Past studies relating herbaceous layer data to environmental variables report that slope and especially aspect (Clanton 1953, McCarthy and others 1987), in addition to soil moisture (Wayman and North 2007), tend to have the strongest influence on richness, diversity, and cover in the herbaceous layer. Small and McCarthy (2002) suggest that topographical variation and ecosystem properties be well-studied along with disturbance responses. In the central hardwoods region and the southern Cumberland region, there remains a need for in depth herbaceous layer studies given the wide variety of results and lack of consistent findings on herbaceous layer dynamics (Gilliam and Roberts 2003).

Our study objectives were to 1) quantify herbaceous layer species richness, diversity, and cover; 2) determine their relationships to pretreatment basal area and site variables (slope, aspect, broadleaf litter, pine leaf litter, and moisture); and 3) establish baseline characterization of the plant communities of the ridge tops in the BNF. This work is a part of a multidisciplinary forest ecosystem response study to nine silvicultural treatments. Our null hypotheses were that site and stand variables would not be significant predictors of species richness, diversity, and cover in the herbaceous layer.

METHODS

Study Area

The study took place in the Bankhead National Forest (BNF) on the southern Cumberland Plateau (N 34°19' W087°21') in Lawrence, Winston, and Franklin counties in northwest AL. Study stands are all located on or near ridge tops of the plateau and are composed of mixed pine-hardwoods (approximately 75 and 25 percent of the basal area, respectively) dominated by planted loblolly pine. Approximate stand ages range from 25 to 40 years. Average total basal area in each stand is 38 m^2/ha ± 10 SD (range 18-67). Precipitation is approximately 145 cm per year (Sipsey Fork near Grayson, AL, USGS Station 02450250). Soil pH ranged from 4.5 to 5.8 (Dillon 2006). The soils were sandy Ultisols on limestone bedrock, well drained, and permeable Typic Hapludults (Smalley 1982). Elevation ranges from 219 to 300 m. Scheduled silvicultural treatments are nine combinations of three levels of low intensity dormant season prescription burns—frequent (3 to 5 years), infrequent (8 to 10 years), and control (no burn), and three levels of partial overstory removal, which is a free thinning to favor the hardwoods—heavy thin (residual basal area 11 m^2/ha), light thin (residual basal area 17 m^2/ha) and control (no thin). Treatments will be replicated four times. Post-treatment herbaceous layer sampling is planned and will be carried out three times during the growing season.

Herbaceous Layer Sampling

All vegetation < 1.4 m in height was sampled in 25 of the 36 stands selected for future treatment at the BNF. The other 11 stands had already been treated at the time of the sampling.

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Citation for proceedings: Stanturf, John A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

Herbaceous layer vegetation plots were situated within five permanently marked, concentric circular nested 0.08-ha woody vegetation plots in each stand. Imposed upon each of the woody vegetation plots were 4 subplots, each 4-m^2, to measure herbaceous layer vegetation. The area sampled in each of the 125 plots totaled 16 m^2. Cover was determined by ocular estimates to the nearest 1 percent and totaled 100 percent since overlap was uncommon. All vascular plants were identified to species whenever possible. Specific nomenclature follows that of Radford and others (1968).

Stand and Site Variables

All trees with diameter at breast height (d.b.h., 1.37 m above ground) greater than 3.8 cm were used to calculate basal area in each of five 0.01-ha circular plots, nested within the 0.08-ha plots. At each subplot, area not covered by live vegetation or other ground variables (e.g. rock, bare soil, tree bole, etc.) was categorized as either pine litter or broadleaf litter. Broadleaf and pine litter cover were also used as predictor site variables in this study because of the different physical, chemical, and biotic influences they have on the soil and distribution of plant species (Facelli and Pickett 1991). However, they were not included as predictor variables in the model for plant cover because of collinearity between the two variables. Slope and aspect were collected from the center of each plot. Aspect was transformed to a northness (cos[Aspect]) and eastness (sin[Aspect]) component where a value of 1 for northness represented due north and -1 represented due south. Likewise, a value of 1 for eastness represented due east and -1 represented due west. The moisture index (MI) used in this study was generated in ArcGIS (ESRI, Redlands, CA, USA) with a digital elevation model (10-m resolution) using the ratio of slope to specific watershed area (Beven and Kirby 1979):

$$MI = \ln(WA/tg(\beta)) \quad (1)$$

where WA is the watershed area of the pixel and $tg(\beta)$ is the local slope. A mean of this index was generated for each plot.

Data Analysis

Diversity was represented by the Shannon-Wiener index (H') calculated with the formula (Magurran 1988):

$$H' = -\Sigma \ p_i \ln p_i \quad (2)$$

where p_i is the proportion of all individuals in sample that belongs to the *i*th species.

Species richness was the number of species in each sample unit (i.e., the plot). Multiple linear regression analysis with stepwise variable selection was used to relate herbaceous layer cover, richness (number of species - S'), and diversity (H') to basal area and site variables using SAS V. 9.1.3 (SAS 2005). Each plot was treated as a sample (n = 125). Because each of the plots is 33 to 498 m apart ($\overline{X}$ = 197 ± 105 SD), we treated them as independent from one another.

RESULTS AND DISCUSSION

Average pretreatment stand-scale (averaged for all 5 plots per stand) herbaceous layer cover was 32 percent, species richness was 57, and Shannon-Wiener Index (H') was 2.74. Across all 25 stands, we found 165 vascular species, 127 genera, and 62 families. This is similar to findings on dry mixed hardwood and pine-hardwood stands in the Southern Appalachians where species richness was less than 200 (Clinton and Vose 2000, Elliot and Knoepp 2005). Fifteen of the most frequently occurring vine, herbaceous, and graminoid species, five from each of three different life forms, included species that also represent much of the relatively sparse cover that exist on these sites (table 1). Slope varied from 0 to 19.9 degrees ($\overline{X}$ = 7.9) and aspect varied considerably across all 25 stands and within any given stand (table 2).

We found herbaceous layer species richness to have significant negative association with the predictor variables broadleaf litter cover and slope, but positive association with basal area (table 3). The overall model was highly significant (p-value < 0.01), but the model accounted for only 14 percent of the total variance in the data (table 3). The independent variables slope and eastness were significant predictors of species diversity (model P = 0.06), while slope and mean moisture index were significant predictors of vascular plant cover (model P = 0.02). However, the models R^2 were low, 5 and 6 percent, respectively (table 3). The parameter estimates indicated that a change in the mean moisture index value would result in much larger response in vascular plant cover than changes in the slope. The negative association between cover and moisture index also suggests that there is higher cover of vascular plants on drier sites. The low fit of the models indicate that that the relationship between the dependent and independent variables may be non-linear or that other variables that we did not measure have stronger influence on richness, diversity, and cover.

Pretreatment herbaceous layer richness and diversity were low in the studied stands at the BNF most likely because of the closed canopy, low light conditions, and limited moisture on the plateau ridge tops. Although there were a number of variables in the model that were significant, basal area and the measured site variables did not account for much of the variance in herbaceous layer richness, diversity, and cover at the plot level. Other variables not considered, such as burn history (Joyce and Baker 1986) and land use (Flinn and Velland 2005) are likely contributing to variation in the herbaceous layer and will have to be taken into account in future analysis.

Thinning, dormant season prescribed burning, and combinations of thinning and burning in a randomized complete block design will be applied to the stands. This study will establish the baseline data upon which to investigate long-term response to silvicultural practices in these plant communities. We expect that stronger relationships between herbaceous layer vegetation and environmental variables will emerge after the treatments and that richness, diversity, and cover will increase post-treatment as has recently been found in other studies from the region (Hutchinson and others 2005, Zenner and other 2006).

Table 1—Five most frequently occurring species of 3 life forms in 25 mixed pine-hardwood stands at the Bankhead National Forest, AL (listed alphabetically for each life form)

Life Form	Scientific Name	Common Name	Cover	Frequency
			----- *percent* -----	
Vines	*Berchemia scandens* (Hill) K.Koch	Supplejack	1.8	38
	Gelsemium sempervirens (L.) Ait.	Yellow jessamine	1.2	31
	Smilax rotundifolia L.	Roundleaf greenbrier	2.0	98
	Rhus radicans L.	Poison ivy	3.2	75
	Vitis rotundifolia Mich.	Muscadine	8.5	93
Herbaceous	*Chimaphila maculata* (L.) Pursh	Pipsissewa	0.2	54
	Lespedeza procumbens Mich.	Creeping bush clover	1.0	9
	Mitchella repens L.	Partridge berry	2.9	13
	Polystichum acrostichoides (Mich.) Schott	Christmas fern	2.5	14
	Solidago arguta Ait.	Atlantic goldenrod	0.6	26
Graminoids	*Carex picta* Steud. *	Boott's sedge	3.5	38
	Danthonia spicata (L.) Beauvois	Poverty oat-grass	0.5	6
	Scleria oligantha Mich.	Nut rush	0.7	15
	Stipa avenacea L.	Needlegrass	1.4	60
	Uniola sessiflora Poir.	Spanglegrass	2.1	12

* not found in Radford and others (1968); accepted by ITIS (Integrated Taxonomic Information System)

Table 2—Mean, standard error, minimum, and maximum for variables from 125 plots that were used in the analysis

Variable	Mean	Standard Deviation	Minimum	Maximum
Independent				
Slope (°)	7.8	4.1	0.5	19.9
Eastness	-0.12	0.67	-1.0	1.0
Northness	-0.09	0.73	-1.0	1.0
Basal area (m^2/ha on 0.01 ha plot)	38.0	10.0	18.2	67.9
Pine litter cover (%)	38.2	13.4	7.5	68.4
Broadleaf litter cover (%)	25.0	9.2	9.2	56.3
Moisture Index	0.003	0.001	<0.001	0.008
Dependent				
Species richness (S')	11.1	3.0	5.0	20.5
Species diversity (H')	1.56	0.27	0.93	2.20
Cover (%)	33.0	15.9	4.8	71.0

Table 3—Selected predictor variables, parameter estimates, and overall model P-value and R^2 for multiple linear regression using the stepwise variable selection. The predictor variables were chosen from among the stand and site variables

Dependent and predictor variable	Parameter Est.	Standard Error	P-value	Model P-value	Model R^2
Species Richness (S'):					
Intercept	13.15	1.32	<0.01		
Broadleaf litter cover	-0.05	0.02	0.01	<0.01	0.14
Slope	-0.16	0.06	0.01		
Basal area (0.01 ha plot)	0.04	0.03	0.15		
Species Diversity (H'):					
Intercept	1.65	0.06	<0.01		
Slope	-0.01	0.01	0.06	0.06	0.05
Eastness	0.07	0.04	0.08		
Vascular Plant Cover (%):					
Intercept	43.90	4.27	<0.01		
Slope	-0.70	0.35	0.05	0.02	0.06
Mean moisture index	-2051.48	1191.07	0.09		

Such relationships and increases should be captured as we study the initial impacts of the silvicultural treatments on herbaceous layer dynamics.

ACKNOWLEDGMENTS

Research support was provided by National Science Foundation, CREST-Center for Ecosystems Assessment, Award No. 0420541. Additional support came from the Center for Forestry, Ecology, and Wildlife; Department of Plant and Soil Science, Alabama A&M University; USDA Forest Service, Southern Research Station, Ecology and Management of Southern Appalachian Hardwoods Research Work Unit. We would also like to thank our partners from the USDA Forest Service William B. Bankhead National Forest for providing logistical and technical support throughout the study and the Bankhead Liaison Panel. Dawn Lemke and Yong Wang from Alabama A&M University provided technical and statistical advice, respectively.

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