INFLUENCES OF ELEVATION ON OVERSTORY SPECIES COMPOSITION IN AN OLD-GROWTH BOTTOMLAND HARDWOOD-LOBLOLLY PINE FOREST IN SOUTHERN ARKANSAS

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Abstract—Elevation was quantified in a 16.2-ha southern Arkansas bottomland forest using surveying equipment and survey-grade GPS units. Six 500-m2 plots were established in each of three 0.5-m elevation classes. Species and d.b.h. were determined for all trees ≥ 9.1-cm d.b.h. Species importance values were calculated by plot. Twenty-four environmental characteristics were collected on site, as were soil physical, soil moisture, and soil chemical factors in the summer of 2002. The Kruskal-Wallis test of group comparisons was used for direct gradient analysis, and nonmetric-multidimensional scaling (NMS) was used for indirect gradient analysis. The direct gradient analysis identified that 30 percent of overstory species and 70 percent of environmental variables significantly differed by elevation. NMS revealed that elevation and a host of other variables were correlated to species occurrence.

INTRODUCTION

Researchers have given considerable attention to the distribution of plant communities within bottomland hardwood forests (e.g., Bell 1974; Gemborys and Hodgkins 1971; Nixon and others 1977; Titus 1990). However, studies seldom relate plant distributions to environmental conditions, and even fewer have investigated these relationships in old-growth forests (Robertson and others 1978). The Lost Forty is an old-growth bottomland hardwood-loblolly pine (*Pinus taeda* L.) forest in southern Arkansas. It offers a unique opportunity to study if and how overstory plant communities are influenced by changes in environmental conditions. Our study's objectives are to quantify elevation and environmental characteristics of the Lost Forty and to characterize overstory vegetative communities and their relationships to environmental conditions.

METHODS

The Lost Forty is located in Calhoun County, Arkansas. Dominant overstory vegetation consists of loblolly pine, sweetgum (*Liquidambar stryaciflua* L.), and oaks (*Quercus* spp.). Some trees are as large as 120-cm d.b.h. and 46-m tall with ages of more than 200 years. Wolf Creek, the largest of the small streams that meander through the area, is generally dry during the summer and autumn (June-October) and floods during the winter and spring. The soils are comprised of Guyton silt loams (frequently flooded) and Ruston fine sandy loams with 1-3 percent slopes (Gill and others 1980).

Over 1,800 X, Y, Z coordinates were established across the area using a GTS Topcon® 6000 Series Total Station. Coordinates were interpolated across the tract using ArcView® 3.2 Spatial Analyst to create a digital elevation model with a cell size of 1.5 m. The interpolation identified five 0.5-m elevation classes: ≤ 27.7, > 27.7–28.2, > 28.2–28.7, > 28.7–29.2, and > 29.2 m. However, the highest and lowest classes constituted only small portions of the tract (about 5 percent), and thus they were eliminated from the analysis. Consequently, six 500-m^2 plots were randomly located in each of the three elevation classes. Random X and Y coordinates were selected for tentative plot location, and then all interior 1.5 m^2 cells within the tentative plot were evaluated to see if they fell within the designated elevation class. If they did, the plot location was accepted; if they did not, the plot was rotated 45 degrees, and the new set of cells was evaluated. If no rotations qualified, new X and Y coordinates were selected and evaluated. This procedure was continued until six plots were randomly selected for each elevation class.

All trees ≥ 9.1 cm d.b.h. within the plots were identified by species and measured for d.b.h. in August 2002. Data were also collected on soil moisture (in May, July, and September), site and stand factors (elevation, cover of forest floor litter, and canopy cover), soil physical factors (bulk density and texture), and soil chemical factors (pH, electrical conductivity, organic matter, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and Na). All soil data were collected from 0-30 cm in depth.

Species importance values (IV) were calculated for each plot. Importance values was the sum of relative density, basal area, and frequency of occurrence and was expressed as a percentage. Because most vegetation data were not normally distributed, the Kruskal-Wallis test of group comparison (SAS 1989) was used to test for differences in species IV among elevation classes. Nonmetric-multidimesional scaling (NMS), a commonly used ordination technique in plant ecology (McCune and Grace 2002), was used to explore and examine patterns of species composition. Prior to ordination, species occurring on less than 5 percent of the plots were eliminated from the data. The NMS ordination used Sorenson (Bray-Curtis) distance measure, 400 iterations, random starting points, and 40 runs.

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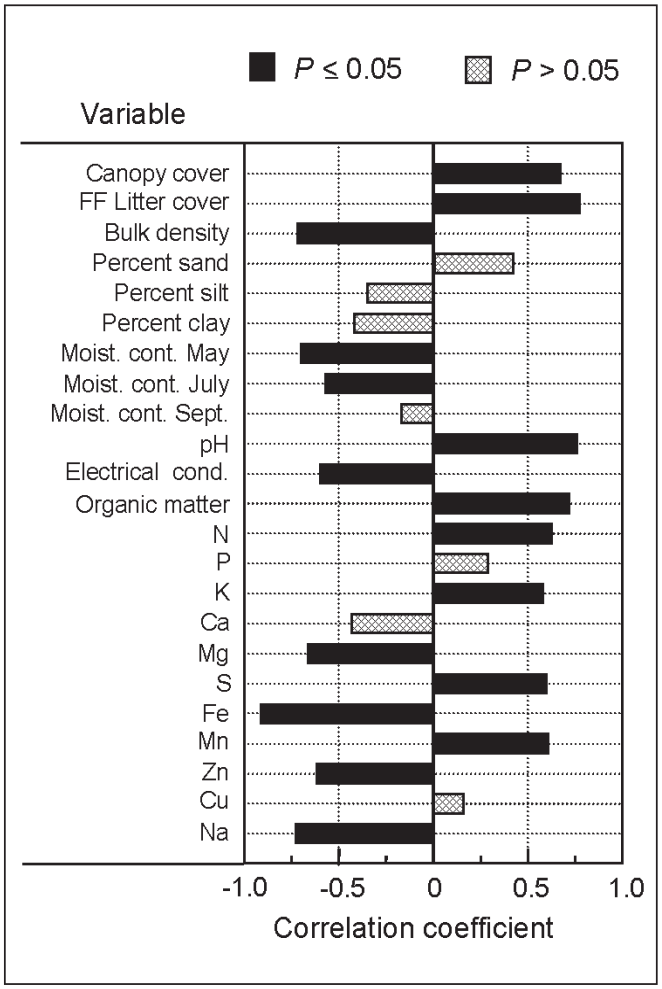

Figure 1—Correlation between elevation and other environmental variables at the Lost Forty, an old-growth bottomland forest in southern Arkansas.

RESULTS AND DISCUSSION

Elevation had a significant ($P \leq 0.05$) correlation with 16 of 23 variables (fig. 1). Variables with the strongest correlations included Fe (-0.91), forest floor litter cover (+0.77), and pH (+0.76). One-half of the significant correlations were positive, while the rest were negative. Variables with positive coefficients increased with elevation, while those with negative coefficients decreased. Only 30 percent of the variables were not significantly correlated with elevation.

Results indicated that 7 of 23 species identified in the overstory significantly differed by elevation (table 1). The IV for blackgum (*Nyssa sylvatica* Marsh.) was a maximum in the low class, and its IV decreased as elevation increased. In contrast, American basswood (*Tilia americana* L.), eastern hophornbeam (*Ostrya virginiana* K. Koch.), and American holly (*Ilex opaca* Ait.) were most common in the high class and were very uncommon in the low class. Red maple (*Acer rubrum* L.) and American hornbeam (*Carpinus caroliniana* Walt.) were at their maximum IV in the mid-elevation class. Sweetgum was an important species in all elevation classes but was at its lowest IV for the mid class.

We used NMS to produce abstract axes that arranged the Lost Forty vegetation samples in relation to each other. Axis 1 in the resulting ordination explained 74 percent in the variation, while Axis 2 explained an additional 12 percent (86 percent in total). The distance between points along the axes was an expression of the degree of similarity in species composition (fig. 2). Species such as American basswood, eastern hophornbeam, winged elm (*Ulmus alata* Michx.), flowering dogwood (*Cornus florida* L.), and sassafras [*Sassafras albidum* (Nutt.) Nees.] were clustered on the right side of the graph, which was indicative of higher elevations. In contrast, willow oak (*Quercus phellos* L.), bald cypress [*Taxodium distichum* (L.) Rich.], and persimmon (*Diospyros virginiana* L.) were clustered on the left side of the graph, which represented the lower elevations.

Ten environmental variables were strongly related with Axis 1; these included elevation (r = +0.92), Fe (r = -0.82), bulk density (r = -0.76), forest floor litter cover (r = 0.72), and May soil moisture (r = -0.71). In contrast, only percent silt (r = +0.60) and percent clay (r = -0.48) appeared to be strongly related with Axis 2. Thus, Axis 1 appeared to be a reflection of elevation and its host of associated variables, while Axis 2 appeared to be a reflection of soil texture.

Table 1—Direct gradient analysis of IV (percent) of overstory species by elevation class in the Lost Forty, an old-growth bottomland forest in southern Arkansas

Species[a]	Elevation class			P
	Low	Mid	High	
American basswood	0.0	0.0	6.2	0.035
American holly	0.6	17.6	23.7	0.002
American hornbeam	11.8	19.7	3.1	0.020
Blackgum	19.5	10.9	3.1	0.016
Eastern hophornbeam	0.0	0.0	14.4	0.001
Red maple	2.1	6.2	0.0	0.049
Sweetgum	25.7	17.6	23.7	0.002

[a] Limited to species with significant differences ($P \leq 0.05$).

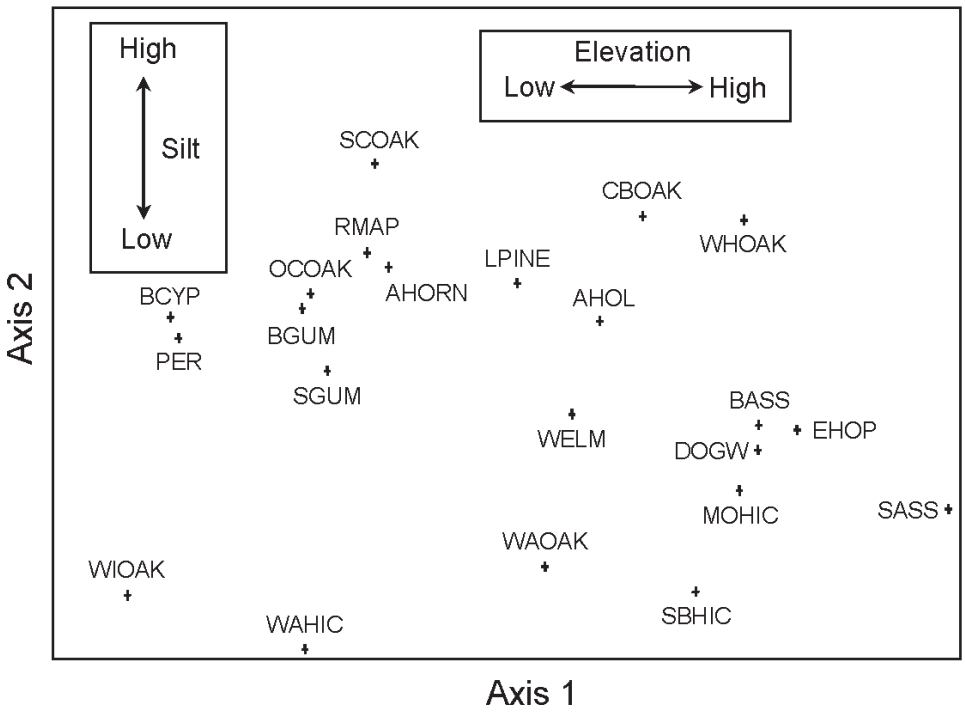

Figure 2—NMS ordination of overstory species composition in the Lost Forty, an old-growth bottomland forest in southern Arkansas. Abbreviations are: AHOL = American holly, AHORN = American hornbeam, BASS = American basswood, BCYP = bald cypress, BGUM = blackgum, CBOAK = cherrybark oak (*Quercus pagoda* Raf.), DOGW = flowering dogwood, EHOP = eastern hophornbeam, LPINE = loblolly pine, MOHIC = mockernut hickory (*Carya tomentosa* Nutt.), PER = persimmon, OCOAK = overcup oak (*Quercus lyrata* Walt.), RMAP = red maple, SASS = sassafras, SBHIC = shagbark hickory (*Carya ovata* K. Koch.), SCOAK = swamp chestnut oak (*Quercus michauxii* Nutt.), SGUM = sweetgum, WAHIC = water hickory (*Carya aquatica* (Michx. f.) Britton), WAOAK = water oak (*Quercus nigra* L.), WELM = winged elm, WHOAK = white oak (*Quercus alba* L.), and WIOAK = willow oak.

CONCLUSIONS

Within the Lost Forty, differences of only 1.5 m in elevation represented diverse landforms—ridges, flats, and transitional zones. Differences in relief, drainage, and depositional patterns resulted in pronounced soil variation. Significant differences in species composition and environmental variables were identified in three 0.5-m elevation classes. Elevation exerts its influences on species composition by affecting soil properties (chemical, physical, and moisture content) and flooding characteristics (frequency, intensity, and duration). For example, we found that forest floor litter was scoured by flooding at lower elevations, which could affect soil organic matter and associated properties. The ability to accurately and efficiently create a detailed topographic map allowed us to sample narrow elevation classes and consequently to identify strong environmental and compositional relationships. We also collected data on understory and ground flora, which are currently being analyzed; these results will provide information on the factors affecting the establishment of plant species. Results from this study suggest that differences in vegetation were primarily the result of subtle variations in elevation. Restoration or management of these forests should carefully consider these microtopographical influences.

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