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NATURAL REPRODUCTION ON UPLAND SITES IN THE CUMBERLAND MOUNTAINS OF TENNESSEE

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ABSTRACT

Reproduction was observed on 199 sample plots and composition and density were related to soil and site characteristics as well as overstory species. Some species were restricted to north or south exposures, but two of the most common species, chestnut oak and red maple, were relatively evenly distributed. Sweetgum, bitternut hickory and beech reproduce abundantly by root sprouts; these three species also had the highest intraspecific overstory-understory correlation coefficients for densites. Neither yellow-poplar nor red maple showed any significant relationship between densities of overstory and understory. Five site variables, thickness of the A horizon, slope direction, percent slope, slope position and the pH of the soil were found to be significantly correlated wtih species density in the understory. However, only a small proportion of the variation in desities of individual species could be accounted for by multiple regression equations.

A Continuous Forest Inventory (CFI) was established in 1962 to aid in the management of the University forests in the Cumberland Mountains. In addition to standard mensurational data, information was obtained for a large number of site characteristics. Regeneration data from the original survey indicated that most of the understory was made up of undesirable species. Due to the large variation in species composition among sites additional study to determine the relationship between site and species composition was initiated in 1965.

STUDY AREA

One part of the University forest, Wilson Mountain in Morgan County, was selected for this study. Wilson Mountain is at the southern end of the Cumberland Mountain section of the Appalachian Plateau Province described by Fenneman (1938). The soils, all derived from sandstone and shale, have been mapped as members of the Muskingum series which here have a grayish-brown silt loam A horizon and yellowish-brown silty clay loam B horizon. The mean annual temperature is 55° F, but summer temperatures as high as 102° F have been recorded. In general, the mean annual precipitation of 55 inches is well distributed throughout the year with least amounts occurring in the autumn.

The Wilson Mountain tract, containing 1,202 acres, was deeded to the University in 1937. Timber has been sold both before and after this time, but lumbering on a large scale was halted in 1949. The only known fire in the study area occurred in 1953 and it was restricted to the northwest end of the mountain. The CFI data obtained in 1962 indicate that the sawtimber volume was 4,073 board feet and the pulpwood volume 288 cubic feet per acre, much better than the average for the county.

METHODS

Transects were established from the base (elevation 1360-1400) to the top of Wilson Mountain (elevation 2260 feet) both on ridges and in draws on northeast and southwest exposures. Twenty transects were established, five each on ridges and in draws on each exposure. On each transact an average of ten sample plots were established; these were separated by distances allowing 80-100 feet rise in elevation. No plots were located within 100 feet of road and strip mine areas (1600 and 1800-1900 contours). In all, 199 sample locations were selected, 102 on the northeast exposure and 97 on the southwest exposure.

At each location two concentric circular plots were established. On 1/5-acre plots, trees larger than 5 inches d.b.h. were counted by species. On 1/100-acre plots reproduction with stems smaller than 5 inches d.b.h. and taller than 3 feet was counted by species. No distinction was made between seedlings and seedling sprouts; if a group of sprouts indicated growth from a common base, only the largest sprout was counted.

Reproduction was counted by four height classes: 3-10, 10-20, 20-30 and 30-40 feet. However, height classes did not prove to be a significant factor in the initial analysis so all sizes were pooled for further statistical treatment. Sixty-eight percent of the reproduction was in the 3 to 10 foot class, while 17, 8 and 7 percent were in the three successive classes.

Data were analyzed by IBM 7040 computer using programs prepared by The University of Tennessee Computing Center. Statistical analysis included nested analysis of variance, correlation, and linear (simple) and stepwise multiple regression.

COMPOSITION AND DENSITY OF UNDERSTORY

Species composition of the understory was expressed as frequency (percent of plots on which a species occurred) relative to exposure and topography (Table I). Few species were uniformly distributed; seventeen were found only on north or south-facing exposures, eight were restricted to draws and four to ridges.

Yellow buckeye and umbrella magnolia appear to be restricted to the cool north draws while blackjack oak is found only on the hot, dry, south ridges. Under-

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story trees of American hornbeam, bitternut hickory, American chestnut and Carolina buckthorn were found only on north exposures, both ridges and draws, while winged elm was restricted to ridges and draws on the south exposures. No reproduction of beech or white pine was found in the south draws while mulberry was absent from south ridges. On north exposures, no shortleaf pine was found on the ridges or scarlet oak in the draws.

The mean number of understory trees for the sampled area was 2,500 per acre. The lowest density was found on south ridges (2,000 trees per acre) and the highest on north draws (3,200 trees per acre). The greater number of trees on north exposures is probably due to the better soil moisture conditions which enhance survival of such shade tolerant understory species as dogwood. When the densities of species which may develop into overstory trees are compared between exposures it is found that 73 percent of those on south exposure but only 55 percent of those on north exposure are potential timber trees. Thus, there are about the same number of potential timber trees present as reproduction on both exposures.

Following adjustment for understory species there remain about 1,500 stems of timber species reproduction per acre. However, the number varies greatly among the main timber species (Table II). More than half of this reproduction is accounted for by three relatively undesirable species; chestnut oak, red maple and blackgum. In comparison the most desirable reproduction consisting of shortleaf pine, white pine, northern red oak, white oak, black oak, yellow-poplar, sweetgum and white ash accounts for about 30 percent of all potential timber trees. On an average, there are 470 desirable trees per acre which may be classified as advance reproduction.

Two of the most common less desirable species, chestnut oak and red maple, are relatively evenly distributed on both exposures and in draws and on ridges. Most of the blackgum occurs on the dry south ridges where it makes up almost one third of all reproduction, while it is almost absent in the cool moist north draws.

TABLE 1. FREQUENCY OF UNDERSTORY TREE SPECIES BY EXPOSURE AND TOPOGRAPHY[a]

Scientific Name[b]	North Ridge	North Draw	South Ridge	South Draw	Total Area	Common Name
Acer rubrum	73	78	77	63	71	Red maple
Cornus florida	76	89	43	65	66	Flowering dogwood
Quercus prinus	54	52	57	67	57	Chestnut oak
Nyssa sylvatica	52	41	78	65	56	Blackgum
Oxydendrum arboreum	55	24	57	46	46	Sourwood
Carya glabra	39	37	41	50	41	Pignut hickory
Fraxinus americana	23	67	2	33	30	White ash
Quercus rubra	29	33	26	33	30	Northern red oak
Robinia pseudoacacia	13	11	43	48	28	Black locust
Prunus serotina	21	30	6	52	27	Black cherry
Quercus alba	13	13	29	48	24	White oak
Quercus velutina	18	2	43	30	23	Black oak
Carya ovalis	21	30	10	9	18	Sweet pignut hickory
Liriodendron tulipifera	20	28	4	17	17	Yellow-poplar
Sassafras albidum	23	30	4	2	15	Sassafras
Quercus coccinea	20	0	26	11	15	Scarlet oak
Liquidambar styraciflua	7	24	12	15	14	Sweetgum
Carya tomentosa	11	4	16	17	12	Mockernut hickory
Amelanchier arborea	9	22	10	2	10	Downy serviceberry
Fagus grandifolia	16	20	2	0	10	American beech
Pinus strobus	25	2	8	0	9	Eastern white pine
Castanea dentata	13	17	0	0	8	American chestnut
Ulmus alata	0	0	4	26	7	Winged elm
Pinus echinata	0	4	18	2	7	Shortleaf pine
Carya cordiformis	11	11	0	0	6	Bitternut hickory
Morus alba	7	13	0	2	6	White mulberry
Carpinus caroliniana	4	17	0	0	5	American hornbeam
Rhamnus caroliniana	7	11	0	0	5	Carolina buckthorn
Aesculus octandra	0	16	0	0	4	Yellow buckeye
Magnolia tripetala	0	13	0	0	3	Umbrella magnolia
Betula lenta	0	7	0	2	2	Sweet birch
Quercus marilandica	0	0	8	0	2	Blackjack oak

[a]Percent of plots on which species occurred.
[b]Additional species found had frequencies of less than two percent in the total area: Acer saccharum, Diospyros virginiana, Magnolia acuminate, Quercus stellata, Carya ovata, Juglans nigra, Tilia heterophylla, Tsuga canadensis, Ulmus americana.

TABLE II. DISTRIBUTION OF REPRODUCTION OF SELECTED SPECIES RELATED TO EXPOSURE AND TOPOGRAPHY

Species	Mean Number Per Acre	Percent of Total Number			
		North Ridge	North Draw	South Ridge	South Draw
Shortleaf pine	31	0	50	47	3
Eastern white pine	26	88	4	8	0
Northern red oak	60	33	32	14	21
Scarlet oak	25	47	2	39	12
White oak	70	22	5	27	46
Black oak	41	29	1	48	22
Chestnut oak	255	25	32	20	23
Red maple	254	33	27	21	19
Yellow-poplar	55	51	27	2	20
Sweetgum	68	4	46	20	30
Blackgum	292	17	6	53	24
White ash	119	17	67	0	16
Sweet pignut hickory	40	51	32	12	5
Mockernut hickory	18	26	6	40	28
American beech	41	26	72	2	0
Pignut hickory	92	32	22	29	17

Desirable species were observed on all sites, but several species had very uneven distribution. Most of the white pine and yellow-poplar reproduction was concentrated on north ridges. White oak was common in the south draws, but almost absent in north draws. Black oak also was seldom found in the north draws while it was common on south ridges. Large numbers of sweetgum and white ash in reproductive stages were observed in north draws; however, sweetgum density was low on north ridges while white ash density was low on south ridges.

Effects of exposure and topography on density of the various species were tested by analysis of variance. Density of white pine, white oak, red maple, yellow-poplar, blackgum and pignut hickory was significantly different (at the 5 percent level) between exposures. Topographic effects were not as pronounced; density of only white pine and pignut hickory was significantly different between ridges and draws.

Overstory-Understory Correlation

The significant intraspecific correlation coefficients (Table III) for species such as white oak, sweetgum, bitternut hickory and beech suggest a relationship between reproduction and an overstory seed source. However, it is well known (Fowells 1965) that sweetgum, bitternut hickory and beech reproduce abundantly from older trees by root sprouts. These three species also have the highest overstory-understory correlation coefficients for absolute densities indicating that, when an overstory of these species is present, vegetative reproduction may be of major importance in determining the density of reproduction.

TABLE III. HIGHLY SIGNIFICANT CORRELATIONS BETWEEN ABSOLUTE DENSITIES OF OVERSTORY AND UNDERSTORY SPECIES

Species	Simple Correlation Coefficients (r)
Eastern white pine	.28
Scarlet oak	.20
White oak	.48
Chestnut oak	.26
Sweetgum	.61
Blackgum	.20
Sweet pignut hickory	.27
Mockernut hickory	.29
Bitternut hickory	.50
American beech	.57

Neither yellow-poplar (intolerant) nor red maple (tolerant) showed any significant intraspecific relationship between densities of overstory and understory. Vegetative reproduction of the two species is vigorous from stumps (Fowells 1965) but root sprouts are not common. The reproduction of these two species is probably of seed origin since no significant cutting had occurred in the study area for many years, and both produce large amounts of seed which are carried by wind for considerable distances.

The lack of significant correlation between overstory and understory density of desirable species such as

TABLE IV. HIGHLY SIGNIFICANT SIMPLE CORRELATION COEFFICIENTS FOR SOIL-SITE VARIABLES AND UNDERSTORY DENSITY

Species	Soil-site Variables				
	A-thickness	Slope Direction	Slope %	Slope Position	pH
Eastern white pine		-.19	-.19		
Northern red oak		-.16			
Scarlet oak	.20				-.19
White oak				-.25	
Black oak	.21	.20			-.25
Chestnut oak			.20		
Yellow-poplar		-.19			
Sweetgum			-.29	.33	
Blackgum	.27	.37			-.29
Sweet pignut hickory		-.19			
Bitternut hickory	-.22				.20
American beech		-.21	-.36	.29	

shortleaf pine, northern red oak, black oak, and yellow-poplar indicates that conditions other than proximity to a source of reproducing overstory trees may be of great importance for the establishment of abundant reproduction. Tryon and Carvell (1958) found that although there was some agreement with amount of white oak in the overstory and the number of white oak seedlings no close relationship existed. They point out (Carvell and Tryon 1961) that only through favorable environmental conditions can oak seedlings persist and build up advance reproduction; one important environmental factor is percent of sunlight or the interaction of percent of sunlight with exposure. No direct measurement of insolation was made in the study of Wilson Mountain, but observations on canopy closure, and density and basal area of overstory stems were recorded. However, no significant simple correlations were found between any of these variables and density of a species in reproductive stages.

The total density of all species in the understory was positively related to the presence of northern red oak, red maple, yellow-poplar and sweet pignut hickory in the overstory; while a negative relationship was found between total understory density and overstory density of shortleaf pine, scarlet oak, black oak, and chestnut oak. These relationships, however, are primarily the result of site; the overstory species related to high total density in the understory were all most abundant on north slopes while the overstory species related to low understory density were found on dry south exposures.

Understory-Site Relationships

Five site variables: thickness of the A-horizon, slope direction, percent slope, slope position and the pH of the soil were found to be significantly correlated with density of timber species found in the understory (Table IV). The first three variables were coded in such a manner that higher values were given for more severe site conditions; thinner A-horizons, southern exposures and steep slopes were given high values mainly due to the relatively low soil moisture available. The pH obtained from the top six inches of the soil was recorded as the actual reading, and slope position was coded as a percent of the distance from the ridge to the bottom.

High densities of scarlet oak, black oak and blackgum were associated with thinner and more acid soil in the A-horizon. Bitternut hickory, on the other hand, was more abundant on sites with a thicker and less acid A-horizon. On the cooler north and east slopes reproduction of white pine, northern red oak, yellow-poplar, sweet pignut hickory and beech was favored while the warmer south and west slopes had higher densities of black oak and blackgum. Steep slopes were usually characterized by chestnut oak reproduction; but white pine, sweetgum and beech were abundant on gentle slopes. Slope position was the only significant site factor effective in determining density of white oak reproduction; more white oak was found on the upper slope positions. In contrast, the moisture-demanding sweetgum and beech were usually found near the bottom of the slopes.

A multiple regression analysis using 12 soil and site characteristics as independent variables and density of reproduction as the dependent variable was employed to construct predictive equations for understory density. Slope direction was the most important variable in determining total density, accounting for 17 percent of the variation. By adding texture of B-horizon and percent shrub cover a total of 30 percent of the variation in understory density was accounted for by the multiple regression equation.

Only a small proportion of the variation in densities of individual species could be explained by multiple regression equations. The best equation was obtained for beech ($R^2 = .21$): $Y = 2.01 - .104X_2 - .337X_3 + .142X_4$, where X_2 = slope direction; X_3 = percent slope and X_4 = position on slope. In other words, maximum density of beech reproduction was found on gentle lower slopes on the north side of the mountain. The white oak equation explained only 11 percent of the variation: $Y = .967 \pm .226X_1 - .239X_4$; larger amounts of reproduction was present on sites with shallow A-horizons and on upper slopes.

Conclusions

Although statistically significant relationships of site properties with species distribution and density were observed, most of the variation is unaccounted for. Some of the failure to account for more of the variation may be due to unsuccessful selection of variables or statistical design. However, much genetic variation of the species concerned or insufficient time since disturbance for establishment of site-related patterns may also be important factors.

Some species, such as red maple and chestnut oak, were rather uniformly distributed over the various sites encountered. On the other hand, ash, black oak and beech reproduction was absent on some sites. (Although some rather clear-cut differences among species were found with regard to frequency (occurrence) of reproduction on specific exposures and topography, the effort to construct meaningful predictive equations for density (number of stems) of the various species met with only limited success.

The advance desirable reproduction observed (470 stems per acre) is probably adequate for the establishment of a new stand following a clearcut operation; this is especially true since reproduction of yellow-poplar originating from seed stored in the duff (Clark and Boyce 1964) may become established after a clear-cut.

Small seedlings of oak cannot compete with the dense reproduction of intolerant species which usually follows clearcutting (Merz and Boyce 1958). Sander (1966) found that areas with large amounts of established oak advance reproduction had large numbers of oaks in the new stand regardless of how the old stand was cut. The oaks that developed in the new stand were the ones that were there before any cutting was done, plus stump sprouts. On Wilson Mountain northern red oak, white oak, and black oak are considered desirable oak species, and on the average 170 stems per acre of these three species were present as established reproduction.

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