FOREST COMMUNITIES AND THEIR RELATIONSHIPS WITH LANDTYPES ON THE WESTERN HIGHLAND RIM OF TENNESSEE[1/]

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Abstract: During the summers of 1982 and 1983, 135 sample plots were established within six landtypes on the strongly dissected plateau of the Western Highland Rim in Tennessee. These landtypes were narrow ridges, broad ridges-north aspect, broad ridges-south aspect, north slopes, south slopes, and bottoms. Six forest communities were identified using cluster analysis--Chestnut oak, Post oak-Mixed oak, White oak, White oak-Scarlet oak-Pignut hickory, White oak-Tuliptree-Northern red oak, and Sweetgum-White oak-Mockernut hickory. Distribution of these forest communities is related to topography. Discriminant analyses revealed that the communities were not significantly different among the three ridge landtypes. North slopes, south slopes and bottoms supported distinct vegetation. Overstories of the ridge landtypes and south slopes were dominated by oaks, including chestnut oak (*Quercus prinus*), post oak (*Q. stellata*), white oak (*Q. alba*), and scarlet oak (*Q. coccinea*). White oak, chestnut oak and tuliptree (*Liriodendron tulipifera*) were abundant on north slopes, while bottoms supported white oak, sweetgum(*Liquidambar styraciflua*) and mockernut hickory (*Carya tomentosa*).

Keywords: Western Highland Rim, forest communities, landtypes

INTRODUCTION

The landscape of the strongly dissected plateau of the Western Highland Rim (WHR) ranges from mesic streambottoms to xeric ridges and slopes of all aspects. This variation in topography causes differences in soil structure, fertility, and moisture, which in turn influence forest structure and composition. In this study forest vegetation was measured and analyzed to determine its relationships to landtypes.

Only a few vegetational studies have been conducted on the WHR. Most were local studies on the northwestern portion of the Rim (Duncan and Ellis 1969, Jensen 1972, 1979, Schibig 1972, Stack 1982), but some encompassed the entire WHR (DeSelm and Schmalzer 1982, Smith et al. 1983).

The WHR is an important timber and forest wildlife section of Tennessee. It is predominantly forested. Sixty-four percent of the West Central forest resource region in Tennessee, which includes most of the WHR, is commercial forest land, considerably above Tennessee's average of about 50% (Birdsey 1983). The dissected plateau portion of the WHR contains a greater proportion of forest land than other parts of the Rim, and should remain largely forested because its topography makes it unsuitable for agriculture (Smalley 1980).

The objectives of our study were: (1) to classify and describe forest plant communities on the strongly dissected plateau of the WHR; and (2) to delineate the relationships between forest vegetation and some of the major landtypes described in Smalley's (1980) site classification system.

STUDY AREA

The WHR, as described by Smalley (1980), is mostly in Tennessee, extending south into northern Alabama and north into northwestern Kentucky (figure 1). The Nashville Basin and Eastern Highland Rim form the eastern boundary.

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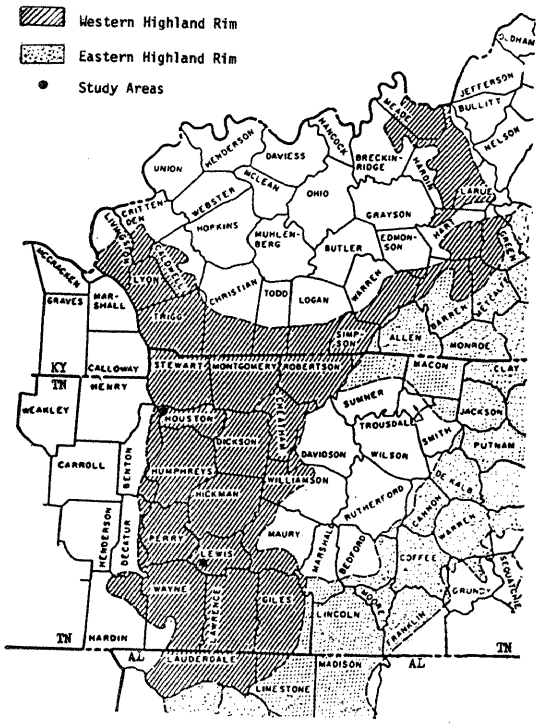


Figure 1. Map of the Western Highland Rim (Smalley 1980:ii) and the study area locations.

The boundary between the WHR and Eastern Highland Rim in Tennessee north of the Nashville Basin is in Sumner County and south of the basin at the Giles-Lincoln County line. Most of the WHR is east of the Tennessee River, except for a narrow band west of the river that extends from Henry to Hardin counties, Tennessee.

The strongly dissected plateau landtype association is primarily in the southern half of the WHR. It also extends northward into Kentucky on both sides of the Tennessee River and occurs in narrow bands around the Nashville Basin (DeSelm 1959, Smalley 1980, DeSelm and Schmalzer 1982).

Our study area encompassed only the strongly dissected plateau landtype association of the WHR. The sedimentary rock formations are primarily Warsaw and Fort Payne chert limestones; St. Louis limestone is largely absent (Thornbury 1965). The strongly dissected plateau corresponds to the Bodine-Mountview-Dickson soil association (Springer and Elder 1980). Mountview and Dickson soils are weathered from Warsaw and Fort Payne formations and Bodine soils are from the Fort Payne formation (Overton et al. 1959).

Topography of the strongly dissected plateau consists of broad to narrow ridges with steep side slopes that extend down to narrow, V-shaped valleys. As these valleys approach the major river bottoms they broaden and become U-shaped (Smalley 1980). Drainage is predominantly by surface streams that have dissected the uplands. The Tennessee, Cumberland, Duck and Buffalo rivers and their tributaries drain this portion of the WHR.

METHODS AND MATERIALS

Lewis State Forest in Lewis County, Tennessee and private land in western Houston County, Tennessee were selected for study. These areas contained pole-size and sawtimber stands representative of the region and the six land types selected for study.

Plot Location

Within each landtype plot locations were selected in a stratified random manner. Reference corners for the plots were selected with the aid of a table of random numbers on sites meeting landtype definitions of Smalley (1980) and forest condition criteria. We restricted our placement of plots on the six landtypes to the azimuths described below:

1. Narrow ridges and convex upper slopes
3. Broad ridges-north aspect (N. azimuth 0° to 90°)
4. Broad ridges-south aspect (N. azimuth 180° to 270°)
5. Cherty north slopes (N. azimuth 0° to 90°)
6. Cherty south slopes (N. azimuth 180° to 270°)
9. Footslopes, terraces, and stream bottoms with good drainage (bottoms)(no restrictions).

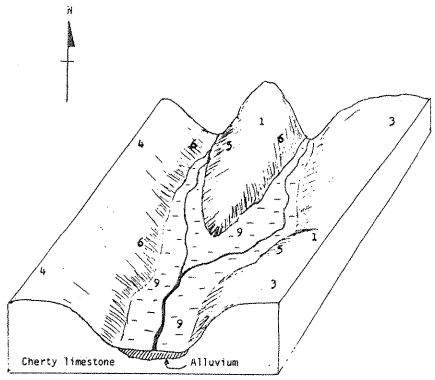
The position of these landtypes in the landscape is shown in Figure 2.

Forest stands were pole size (8-10 inches dbh--20.3-25.5 cm) and/or sawtimber ($\geq$ 11 inches dbh--27.9 cm) hardwoods free from recent disturbance.

Data Collection and Analysis

A nested plot design was used to sample three forest strata. Overstory vegetation was measured in rectangular 0.1 acre (0.04 ha) plots with the long axis of the plot parallel to the slope. Midstory vegetation was measured on one-half of the overstory plot. Overstory trees included those $\geq$ 5.6 inches (14 cm) dbh; trees, shrubs and vines 1.6-5.5 inches (4-14 cm) dbh were considered midstory vegetation.

Relative density and relative basal area were determined for each tree species in the overstory and midstory. The sum of these two statistics equals the species'importance value



1. Narrow ridges and convex upper slopes.
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9. Footslopes, terraces, and stream bottoms with good drainage.

Figure 2. Landtypes as described by Smalley (1980).

(IV) in each plot. Forest communities were identified using SAS 82's cluster analysis procedures. Discriminant analysis was used to determine if each landtype supported a distinct overstory composition.

RESULT AND DISCUSSION

Overstory vegetation was classified into forest communities using cluster analysis. The SAS 82 CLUSTER procedure (SAS Institute, Inc. 1982) was utilized. CLUSTER is an agglomerative hierarchical clustering procedure that starts with each observation (plot) in a cluster (group) by itself. This procedure then joins the 2 observations that are most similar and combines their information to form a single cluster. This is continued until all observations are combined to form 1 cluster. The point at which this procedure produces the most logical clusters (forest community), based on the researcher's field experience, must be arbitrarily decided. The data used in CLUSTER were in the form of a multivariate matrix in which the rows were individual plots (observations) and the columns were overstory tree species (variables). Importance value for each overstory tree species within each plot was the numeric value in the data matrix. Basal area was also used for comparison purposes.

Fifteen of 29 overstory species were used in the analysis (table 1). Species present in less than 5% of the plots were considered rare for the area and eliminated from the analysis. Species present in 10% or more of the plots were included in the analysis. The species between 5 and 10% were examined carefully and those that appeared to contribute significantly to a forest community type were included. American beech (Fagus grandifolia) and sugar maple (Acer saccharum) were included because they were perceived as possible dominants of one community.

Table 1. Frequency of overstory species in the plots (N = 135).

Species	Number of Plots	Frequency
White oak[a]	112	83.0
Chestnut oak[a]	82	60.7
Post oak[a]	68	50.4
Scarlet oak[a]	62	45.9
Pignut hickory[a]	55	40.7
Black oak[a]	52	38.5
Mockernut hickory[a]	43	31.8
Sourwood[a]	30	22.2
Northern red oak[a]	27	20.0
Blackgum[a]	22	16.3
Yellow poplar[a]	22	16.3
Sweetgum[a]	15	11.1
Shagbark hickory[a]	14	10.4
Southern red oak	13	9.6
White ash	13	9.6
Black-jack oak	10	7.4
Sugar maple[a]	8	5.9
American beech[a]	7	5.2
Black cherry	6	4.4
Red maple	5	3.7
Winged elm	5	3.7
Sycamore	4	3.0
Eastern hop hornbeam	3	2.2
Sassafras	3	2.2
Flowering dogwood	2	1.5
Bitternut hickory	1	0.7
Black walnut	1	0.7
Chinkapin oak	1	0.7
Slippery elm	1	0.7

[a]Used in the analysis.

Classification of the Forest Communities

Cluster analysis using species importance value revealed six forest communities: Chestnut oak, Postoak-Mixed oak, White oak, White oak-Scarlet oak-Pignut hickory, White oak-Tuliptree-Northern red oak, and Sweetgum-White oak-Mockernut hickory. The communities produced from the analysis using species basal area were essentially the same as those listed above.

Description of the Forest Communities

Chestnut oak . A total of 15 overstory species were present within this community type. Chestnut oak was the dominant species, often occuring in nearly pure stands. Common overstory associates were white oak, scarlet oak and post oak. Sourwood (Oxydendrum arboreum) and chestnut oak were dominant midstory species; blackgum and pignut hickory (Carya glabra) were also common.

The Chestnut oak community occurred primarily on the driest landtypes--narrow ridges and south slopes. Chestnut oak was also dominant on a few north slopes. Chestnut oak is typically encountered on dry, rocky upland sites, but it can also be found in moist areas (Harlow et al. 1979). Jensen (1972) encountered chestnut oak only on xeric ridges of the northwestern Highland Rim.

The importance of chestnut oak in all forest strata suggests stability in this community. It is intermediate in tolerance (Core 1971) allowing it to survive and maintain itself in the midstory

and understory. Since it is able to persist on dry, gravelly sites better than most hardwood species (Core 1971), it is likely to remain dominant on these sites.

Post oak-Mixed oak. Of 13 overstory species present seven were oaks. Post oak was dominant, contributing almost 40% of the IV. The mixed oaks in order of abundance were black oak (*Q. velutina*), white, chestnut, scarlet and blackjack (*Q. mar ilandica*). Dominant midstory species were pignut hickory, white oak and post oak.

The Post oak-Mixed oak community occurred primarily on broad ridges with both north and south aspects. Post oak is typically found on dry rocky ridges (Harlow et al. 1979). Jensen (1972) indicated that post oak preferred dry sites such as xeric ridges and south-facing slopes on the northwestern Highland Rim.

The community appears to be fairly stable. Post oak may decrease in importance because pignut hickory and white oak were more important in the midstory. Post oak, an intolerant slow-growing species is less likely to survive when overtopped. However, it is extremely drought resistant allowing it to dominate drier sites where more mesic species cannot compete (Harlow et al. 1979).

White oak. This community contained 15 overstory species of which white oak was clearly dominant. Post oak, chestnut oak and black oak were principal overstory associates. Common midstory species were pignut hickory, blackgum, sourwood and white oak.

Stands dominated by white oak were present on all landtypes but occurred chiefly on north and south broad ridges. Broad ridges are subxeric sites with well-drained to moderately well-drained soils. White oak occurs on a wide range of soils and topographic sites, but grows best in deep well-drained soils (Harlow et al. 1979, Elias 1980). Broad ridges are not as dry as the narrow ridges that were occupied by chestnut oak. Core (1971) noted that white oak may occur on any upland site except the extremely dry, shallow-soil ridges. On the northwestern Highland Rim white oak occurred on most topographic positions, but was most abundant on drier sites (Jensen 1972).

The dominance of white oak seems stable due to its high density in the midstory and understory. White oak is intermediate in tolerance in youth, becoming more intolerant with age. It is a slow-growing, long-lived tree (Harlow et al. 1979). Its tolerance and longevity contribute to its ultimate dominance (Core 1971). Pignut hickory may become more important as an overstory species because of its dominance in the midstory.

White oak-Scarlet oak-Pignut hickory. Of 17 species comprising overstory, white oak and scarlet oak were approximately equal in dominance with pignut hickory only slightly less important. Post oak and chestnut oak were common overstory associates. The midstory was comprised largely of white oak, blackgum, sourwood, chestnut oak and pignut hickory. Scarlet oak was not important in the midstory, contributing less than 5% of the IV.

White oak-Scarlet oak-Pignut hickory communities occurred equally on all landtypes except bottoms. Within this community, scarlet oak was more abundant on the driest landtypes, while white oak dominated more moist sites. White oak occurred on all topographic sites and scarlet oak was abundant only on the most xeric areas on the northwestern Highland Rim (Jenson 1972). Harlow et al. (1979) indicated that scarlet oak was most abundant on dry ridges and upper slopes. On the northeastern Highland Rim pignut hickory occurred chiefly on dry slopes and ridges (Schibig 1972).

This community appears to be succeeding toward a White oak-Miked oak-Hickory type, especially on subxeric to mesic sites. White oak was the major dominant understory species, indicating it should remain a stable component of the community. Pignut hickory also should maintain its position. Scarlet oak was rare in the midstory and understory. Its extreme intolerence (Core 1971) and relatively short life span (Elias 1980) contribute to its subclimax nature in most stands. However, its rapid growth on dry soils (Harlow et al. 1979) and its drought resistance (Core 1971) make it a climax species on the driest sites. As the forest matures, this community should be limited to the more xeric sites.

White oak-Tuliptree-Northern red oak. Of 25 overstory species present in this community type, white oak, tuliptree and northern red oak were most abundant. Other associates were chestnut oak, black oak, and hickories. American beech and sugar maple were abundant in the overstory on a few sites in Houston County. Common midstory species were white oak, sourwood, flowering dogwood (*Cornus florida*), blackgum, and tuliptree. Northern red oak was almost absent from the midstory.

This community occured primarily on north slopes and in some bottoms. White oak is found on a wide variety of sites, growing best on north slopes and in coves (Core 1971). Intolerant tuliptree grows best on north and east slopes and in sheltered coves (Beck and DellaBianca 1981). On poor sites, many other species grow better than tuliptree (Harlow et al. 1979). Northern red oak most commonly occurs on northerly aspects and in coves (Core 1971). A related forest community, Tuliptree-White oak-Northern red oak, occurs on north and east slopes (Eyre 1980).

The White oak-Tuliptree-Northern red oak forest type appears to be subclimax to a White oak-Mixed hardwoods type. Eyre (1980) reported that Tuliptree-White oak-Northern oak is a subclimax forest that will be replaced by an upland oak climax. Since white oak was the dominant midstory species, it should maintain or increase its importance in the overstory. Its lack of importance as a midstory species indicates the temporary status of tuliptree. Because of its intolerance, without disturbance it will gradually be replaced by more tolerant species (Eyre 1980). Northern red oak is not reproducing itself and should decline in importance.

Sweetgum-White oak-Mockernut hickory. Of 22 species in the overstory, sweetgum, white oak and mockernut hickory were most abundant. Other common associates were southern red oak (*Q. falcata*), pignut hickory, and shagbark hickory. Eastern hophornbeam (*Ostrya virginiana*), pignut hickory, and white oak were the most important midstory species. Sweetgum and mockernut hickory were less common.

The Sweetgum-White oak-Mockernut hickory community occurred exclusively in bottoms. Sweetgum was rarely encountered on any other landtype. Though sweetgum occurs on a wide variety of sites, it obtains its best growth on rich, moist, alluvial soils (Harlow et al. 1979). Hebb (1962) noted that topography was a significant factor in the growth of sweetgum in west Tennessee; terraces and bottoms were the best sites. White oak was common on all but the driest sites on the WHR. Mockernut hickory occur red on all six landtypes, but was most abundant in the bottoms.

This community seems to be a subclimax to another White oak-Mixed hardwood community. Sweetgum was not abundant in the midstory and almost absent from the understory. Even though it is intermediate in tolerance (Harlow et al. 1979), it does not appear to be reproducing itself. Mockernut hickory, a species of intermediate tolerance, had a low IV in the midstory; it was common in the understory. White oak was very abundant in both the midstory and understory and should at least maintain its importance in these stands.

Relationships Between Vegetation and Landtypes

The definition of the landtypes is based mostly on topography and soils. Do the landtypes support distinctive forest communities? To answer this question, two multivariate statistical techniques were utilized: principal component analysis and discriminant analysis.

Principal component analysis is a multivariate technique that detects linear dependencies among several variables and combines these variables to produce scores that represent this linear relationship (SAS Institute, Inc. 1982). This analysis was used to determine relationships between the overstory tree species and to produce principal component scores that represent combinations of species that commonly occured together. These principal component scores are the data base that is used in the discriminant analysis. The FACTOR procedure (SAS Institute, Inc. 1982) was used to perform the principal component analysis.

As in cluster analysis, the data input was a multivariate matrix, with rows as individual plots (observations) and columns as overstory tree species (variables). These species were the same 15 overstory tree species used in the cluster analysis (table 1). A presence/absence value was the numeric value in the matrices. A value of 1 was assigned if the species was present in the plot, and 0 if it was absent.

Discriminant analysis was used to classify observations into known classes based on numeric variables (SAS Institute, Inc. 1982b). Observations were plots, classes were landtypes, and variables were the principal component scores computed by the FACTOR procedure. The SAS 82 DISCRIM procedure establishes classification criteria for the landtypes based on information provided by the principal component scores. Each plot was classified into one of the six landtypes that most closely resembled the vegetation data of the plot. Consequently, a plot was not necessarily classified into the landtype in which it actually occurred. The rate of misclassification or correct classification (table 2) was used to determine which landtypes have distinct overstory composition. Only 55% of the plots were classified into correct landtypes, indicating that the overstory composition is similar among some landtypes. Most of the misclassification occurred within the three ridge landtypes (narrow ridge, broad ridge with a north aspect, and broad ridge with a south aspect). About 64% of the plots on ridges were classified into an incorrect landtype; 63% of these incorrect classifications were assigned to one of the other ridge landtypes. We conclude that the overstory composition of the three ridge landtypes was similar. A 75% correct classification rate indicated that bottoms contained a distinctive species composition. South slopes were similarly distinct with a classification rate of 73%. About 20% of the plots in each of the three ridge landtypes were misclassified as south slopes. Some of the ridge plots had an overstory composition similar to that of the south slopes. North slopes had a classification rate of 68%.

CONCLUSIONS

The frequent disturbance history of the WHR, ranging from complete deforestation to periodic high-grading, has disrupted natural successional

patterns, producing a landscape comprised of a variety of individualized plant communities. Nevertheless, certain patterns of forest community-landtype relationships did emerge.

Table 2. Discriminant analysis classification rates[a] for the overstory plots within each landtype.

From Landtype[b]	Into Landtype[b] 1	3	4	5	6	9	Total
1	36.36 (8)	9.09 (2)	27.27 (6)	4.55 (1)	22.73 (5)	0.00 (0)	100.00 (22)
3	19.05 (4)	19.05 (4)	38.10 (8)	0.00 (0)	23.81 (5)	0.00 (0)	100.00 (21)
4	9.52 (2)	19.05 (4)	52.38 (11)	0.00 (0)	19.05 (4)	0.00 (0)	100.00 (21)
5	8.00 (2)	0.00 (0)	0.00 (0)	68.00 (17)	16.00 (4)	8.00 (2)	100.00 (25)
6	13.64 (3)	9.09 (2)	0.00 (0)	4.55 (1)	72.73 (16)	0.00 (0)	100.00 (22)
9	4.17 (1)	8.33 (2)	0.00 (0)	8.33 (2)	4.17 (1)	75.00 (18)	100.00 (24)

[a]Percentages (frequencies).

[b]1 = Narrow ridges; 3 = Broad ridges-north aspect; 4 = Broad ridges-south aspect; 5 = North slopes; 6 = South slopes; 9 = Bottoms.

The high productivity sites of north slopes and bottoms have moved toward a unique combination of species which compete most effectively on good sites. South slopes, intermediate in productivity, were also characterized by distinct forest communities, generally dominated by oaks. The poorest sites (narrow ridges, upper slopes of broad ridges), although supporting a large variety of xeric species, were not distinctly different from one another. We do not interpret that circumstance to mean that all xeric sites should be managed similarly. Though the forest species composition may be similar, other differences, i.e. height, volume and quality may justify separation. Other management restrictions such as steepness of slope, rockiness, and productivity, also may necessitate delineating land types for planning forest management.

Forest managers may view the preponderance of low value species in the mid and understories as indicating a need for timber stand improvement to control species composition and lessen competition with desirable species. Wildlife managers may recognize the opportunity for relating forest and wildlife management practices to specific land types. For example, the preponderance of oaks on the drier and intermediate sites suggests that these should be favored for production of hard mast, whereas forest communities on mesic sites may be managed to produce browse and high stem densities for protective cover. Understanding these relationships between landtypes and forest communities should facilitate large-scale wildlife management planning on the strongly dissected plateau of the Western Highland Rim.

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