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LANDSCAPE ECOSYSTEM CLASSIFICATION IN THE CHEROKEE NATIONAL FOREST

A Thesis
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ABSTRACT

Landscape ecosystem classification is gaining acceptance by the USDA Forest Service as essential to ecosystem management of public lands. Such a management approach has previously been rejected in the southern Appalachians in favor of traditional methods such as site-index. A long history of natural and man-made disturbance combined with highly complex interactions between climate, geology, topography and soils has made ecological classification in this region inherently difficult. Consequently, very few classification efforts have integrated vegetation, landform and soils in identifying ecologically equivalent sites.

An ecological classification for the 43,800 hectares comprising the Foothills section (300 m to 610 m elevation) of the southern unit of the Cherokee National Forest is described. Vegetative cover, landform and soils data were obtained from sixty 0.04 ha plots located in stands representing late successional stages. Vegetation data were grouped by dominant cover type utilizing (1) agglomerative, hierarchical clustering and (2) detrended correspondence analysis. Detrended canonical correspondence analysis (DCCA) was used in conjunction with stepwise discriminant analysis (SWDA) to identify patterns in species composition explained by environmental variables.

Four site units were identified: Eastern Hemlock - Sugar Maple - American Beech - White Ash, Eastern Hemlock - Rosebay Rhododendron, Chestnut Oak, and Chestnut Oak - Scarlet Oak - Red Maple. A recently developed "Landform Index" that quantifies slope type and degree of protection by adjacent land masses was identified through DCCA and SWDA as the most important predictor of species variation between site units. The strength of the correlations between elevation and several soil thickness variables with DCCA axis 1 indicated vegetation varies along a moisture gradient. No ecological meaning was attributed to the second axis.

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I. INTRODUCTION

Site classification has been a central concept of American forestry for much of the 20th century. Numerous systems have been developed with the primary purpose of predicting site productivity and understanding site and vegetation relationships. The most widely accepted of these, site-index, utilizes the height of a dominant tree at a specified base age to estimate site quality. Easily measured and directly related to volume growth, site-index has long been popular with forest managers (Van Lear, 1990).

However, the traditional emphasis on timber production as the primary goal of forestry is not compatible with modern resource management. Today's forest manager must view the land not only as a source of timber, but as a complex ecosystem supporting a wide variety of plant and animal species. Recognizing public demand, the USDA Forest Service has adopted a new philosophy of ecosystem management which emphasizes sustainable development as well as conservation. Such a management approach requires a structured ecological database upon which long-term decisions can be based.

Landscape ecosystem classification (LEC) is an attempt to provide an ecological framework to support this new objective. An LEC is based on the integration of three ecosystem components: landform, soils, and vegetation.

Interactions among these ecosystem components are what ultimately determine productivity differences. Single component classification and subsequent development of overlays cannot be considered as viable ecological methods (Barnes et. al., 1982).

Development of an ecological classification is generally completed in four phases (McNab, 1991a):

Phase 1

Identification of ecologically equivalent site units (based on the three ecosystem components) in stands relatively free of disturbance for at least 75 years. Species possessing narrow ecological amplitudes are identified and used in the delineation of site unit boundaries.

Phase 2

Identification of ecologically equivalent site units in disturbed stands and subsequent relation of seral vegetation to units delineated in Phase 1.

Phase 3

Site unit mapping utilizing ground surveys and Geographic Information Systems (GIS).

Phase 4

Development of management strategies utilizing site unit attributes such as growth and yield, species composition and successional trends.

Phase 1 of a Landscape Ecosystem Classification has been completed for the Foothills of the southern unit of the Cherokee National Forest (CNF) and is described in this thesis. The CNF, located in east Tennessee, lies within the belt of mountain ranges west of the Piedmont known as the southern Blue Ridge province. Distinguished by highly complex interactions between climate, geology, topography and soils, the Blue Ridge is an area of great biological diversity (Fenneman, 1938). Partially because of this diversity, very few classification efforts using ecological methods have been attempted.

The objectives of this study are: 1) identify one or more species distributions along environmental gradients, 2) delineate ecologically equivalent site units and 3) provide a practical system of classification for use by USFS personnel in the management of forest ecosystems.

II. LITERATURE REVIEW

The following review is arranged in two sections. First, a brief discussion concerning the history of natural and anthropogenic disturbance in the southern Appalachians is presented. A general understanding of the region's history is useful when interpreting study results. Second, various site classifications and descriptions of the forests of the southern Appalachians are summarized. A background in previous classification techniques helps clarify the current progression toward ecological methods.

A. Disturbance History of the Southern Appalachians

The forests of the southern Appalachians are included in Braun's (1950) Oak-Chestnut region. She described forest composition that graded from Mixed Mesophytic communities on protected slopes, to Oak-Chestnut on moist slopes, to Oak-Hickory on drier slopes, and finally Oak-Pine on exposed, dry ridgetops. American chestnut (*Castanea dentata)* was included as a major overstory component despite having been virtually eradicated by chestnut blight (*Cryphonectria parasitica*) by 1950. However, at that time standing dead trees had not yet been replaced by other species. Previous to the blight, chestnut ranged from New England to Georgia reaching its maximum abundance in the Great Smoky Mountains

(Woods and Shanks, 1957). With an elevation range from 396 m to 1372 m (1300 feet to 4500 feet), it was a species of wide ecological amplitude often forming pure stands (Braun, 1950). The blight steadily killed trees after its introduction around 1925. Approximately 85% of the chestnuts in the Smoky Mountains were either dead or dying by 1938 (Pyle, 1988).

In addition to the long-term effects of the loss of a major species, anthropogenic disturbances, particularly fire, have played a major role in forest composition. Although lightning induced fires are uncommon in the southern Appalachians, fire has long been a part of its history. First inhabited by Paleo-Indians 12,000 years ago, the early culture was characterized by a hunter-gatherer existence. Evidence suggests Indians used fire in clearing brush and flushing out game (DeVivo, 1990). The subsequent Archaic Period was of a higher sophistication as is evident by artifacts found in archaeological excavations. It is believed that broad areas of forest were burned and cleared for use in primitive agriculture. The Archaic period was followed by the Woodland, Mississippian, and Historic periods. These periods were all characterized by a gradually increasing dependence on shifting agriculture. Once again, fire was the most likely tool used to clear the forest (Buckner, 1989). Fire was also used to improve visibility for hunting, to encourage growth of species such as blueberries, and control insect populations (Martin, ND; DeVivo, 1990; Pyle, 1988).

Persistent burning resulted in the establishment of "park-like" stands with little or no undergrowth (Martin, ND). These open canopies eventually allowed establishment of shade intolerant species and uneven-aged conditions (Buckner, 1989). European settlers continued the use of fire in shifting agriculture having learned the practice from Native Americans. Livestock were introduced and allowed to forage in the woods which were frequently burned to encourage growth of grasses (Martin, ND; Pyle, 1988). Throughout the 1930's and 40's, timber high-grading and agricultural land abandonment became common practices (Healy, 1985). Also during this time, a national campaign encouraging fire suppression was beginning to take shape. The rapid degradation of once valuable land had long been viewed mainly as the result of repeated burning (Sargent, 1884). Fire suppression eventually became official policy on public lands and has remained firm throughout most of the 20th century (Martin, ND).

B. Site Classification and Description

Assessment of the potential productivity of these complex ecosystems has been attempted through a variety of classification systems. One such system, the soil-site method was developed for estimating site-index in disturbed stands where trees are considered poor indicators of site quality. With this method, site-index estimates are correlated with soil, topography, or climatic variables through the development of regression equations. In general, soil properties found to be most highly correlated with productivity are depth, texture, and drainage class (Carmean, 1975).

Trimble and Weitzman (1956) studied soil-site relations of upland oak species in the northern Appalachians. Aspect, slope position (distance from ridge line), slope gradient, and solum depth were found to significantly influence site-index. Data developed from the regression analysis concluded that site-index: 1) is consistently higher on northeasterly facing slopes, 2) increases with distance from the ridge-line, 3) decreases with increasing steepness of slope, and 4) increases with increasing soil depth.

Doolittle (1957) studied soil-site relations of scarlet oak (*Quercus coccinea)* and black oak (*Quercus velutina)* in the southern Appalachians. Within an elevation range of 457 m to 1981 m (1500 feet to 6500 feet), "A" horizon thickness was the best predictor of site-index. Deeper A horizons were correlated with higher index values and accounted for 91% of the variation in site-index. Not as significant, but nonetheless important, were slope position and percent sand in the A horizon. Valley bottom sites containing little sand in the A horizon were identified as the most highly productive.

Ike and Huppuch (1968) investigated site factors in the north Georgia mountains. In an area ranging in elevation from 366 m to 1219 m (1200 feet to 4000 feet), ten tree species were studied including northern red oak *(Quercus rubra)*, scarlet oak, white oak *(Quercus alba)*, Virginia pine *(Pinus virginiana)* and tulip-poplar (*Liriodendron tulipifera*). Numerous variables relating to soil and topographic position were measured. The most reliable productivity predictors were variables directly influencing microclimate and water supply such as slope position, elevation, aspect, and slope gradient. Soil chemical and physical properties were only weakly correlated with site productivity.

Losche (1967) studied soil properties in the mountains of North Carolina and Virginia. Differences in species composition and site-index on opposing north and south facing slopes were investigated. Patterns in species variation were found to be most highly correlated with aspect, slope position, and clay content of the subsoil. Differences in soil morphology of opposing slopes were found to be more significant in North Carolina than in Virginia possibly due to greater annual precipitation.

Although soil-site studies such as these above, provided a valuable compilation of variables related to site quality, practicality was limited in terms of real management needs. The resulting regression equations were often difficult to use and not readily adaptable to mapping. Physiographic classifications were developed as an alternative method. In these systems, complex landscapes are reduced to units of equal productivity based on distinct landforms (Van Lear, 1990). Highly correlated with soil characteristics, landforms represent the most stable ecosystem component. In addition, they are readily mapped and easily recognized making them highly practical for multi-disciplinary use (Rowe, 1991).

Smalley (1986, 1991) developed a comprehensive physiographic-based classification system for the Cumberland Plateau and Highland Rim provinces of the Interior Uplands. The system is based on five successive stratifications of the landscape adapted from Wertz and Arnold's (1972) Land Systems Inventory. The lowest level of the classification (landtypes) is the level at which management interpretations are made. Because vegetation was not considered in landtype delineation, plant community and landtype relations are being determined through separate research. Clatterbuck (1988) identified valid relationships between landtype and plant communities on six landtypes that were developed in the Cheatham Wildlife Management area in Tennessee. Arnold (1990) found forest types to be relatively distinct within landtypes developed for the Prentice Cooper State Forest on the Cumberland Plateau. However, similar communities were found to occur on more than one landtype.

Daubenmire's (1952) study of the forest vegetation of northern Idaho and Washington initiated a long period of research and development concerning vegetation-based classification methods. Vegetation types as site quality indicators have since been used extensively in areas characterized by relatively undisturbed landscapes (Pfister and Arno, 1980). Natural vegetation reflects the complex interactions between ecosystem components and is, therefore, a logical basis for a classification system. On relatively undisturbed landscapes, vegetation is generally in equilibrium with the physical factors of the site. Consequently, sites characterized by similar plant communities represent areas of ecological equivalency. Although undisturbed stands are rare, steady-state conditions generally exist under closed canopies. Seral shrubs and herbs quickly disappear under closed canopies and give way to more tolerant species. Such states approximate climax conditions and demonstrate the feasibility of using the vegetation-based classification methods in areas characterized by second-growth forests (Daubenmire, 1976).

Whittaker's (1956) classic study of the vegetation of the Great Smoky Mountains National Park (GSMNP) represents an early attempt to integrate ecosystem components. Vegetation was related to elevational and qualitative moisture gradients based on topographic variables. Annual precipitation and length of growing season were identified as the most important variables affecting species composition. This work resulted in a classification system for eastern forests based on varying degrees of exposure along these moisture and elevational gradients. Mesic, non-quercine forests were seen to grade into intermediate oak communities followed by xeric pine forests on highly exposed sites. A classification system for the boreal forest was also described.

Golden (1981) expanded Whittaker's study through the clarification of vegetation-site relationships in the middle elevation range of the GSMNP between 750 m to 1600 m (2460 feet to 5249 feet). Site variables measured in this study included elevation, slope gradient, slope position, and aspect. Consistent with Whittaker's earlier results, vegetation patterns varied along moisture and elevation gradients. The pH of the A horizon and percent clay in the B horizon were the most discriminating variables between the nine community types identified.

Mowbray and Oosting (1968) studied species distribution along an elevational gradient in Thompson Gorge in the southern Blue Ridge mountains. Trees, shrubs, and herbs were sampled along slopes with northerly and southerly aspects. Numerous site and soil variables were measured. Four plant communities were identified and appeared to vary according to slope position and exposure. Southerly slopes maintained the warmest and driest environments, and consequently were characterized by more drought tolerant species. Percent clay in the B horizon, which is an indirect measure of available water, was the most highly discriminating variable between plant communities.

Callaway et. al. (1987), in a study of the vegetation of the western GSMNP, attempted to develop an index to quantify topographical shape and exposure. Earlier studies completed by Whittaker (1956) and Golden (1981) cited the importance of land shape changes in vegetation distribution, but were unsuccessful in their quantification. In addition to the index, they measured soil horizon thickness, soil texture, aspect, and slope gradient. Twelve forest cover types were identified within an elevation range of 300 m to 1800 m (980 feet to 5900 feet). Vegetation varied along elevation and topographical exposure gradients. The pH of the A horizon and the water-holding capacity of the A and B horizons were the most discriminating variables between forest types. The topographical shape and exposure index was concluded to be of limited use. Although landforms situated above the plot were successfully quantified, the index could not account for landforms below the plot.

McNab (1993) continued the development of landform quantification through a study on the Bent Creek Experimental Forest in North Carolina. Measurement of mean vertical slope gradient from plot center to the visible skyline was concluded to successfully quantify landscape features blocking the view of the horizon. The degree of protection provided by adjacent landmasses was found to be strongly correlated with slope type (cove, slope, ridge) and slope position. In addition, significant correlations were identified between "Landform Index" and site-index of tulip-poplar. A second index quantifying the geometric shape of the plot was also developed (McNab, 1989). This "Terrain Shape Index" is derived from the mean of eight slope gradient (at 45^0 intervals in percent scale) measurements from plot center to the perimeter of an outer plot. Positive values represent concave shapes, while negative values represent convex shapes such as narrow ridgetops.

McNab (1990) developed a model in the Bent Creek Experimental Forest to predict forest cover type from on-site measured topographic variables. At elevations below 1075 m (3500 feet), four forest cover types were identified. A five variable model including, elevation, aspect, slope, and the two topographical indices discussed above correctly classified 75% of the sample sites. Soil variables, such as texture and solum thickness derived from soil survey maps were only moderately useful as predictors of cover type. Results from this preliminary analysis suggested an ecological based classification may be appropriate for the forest ecosystems of the Blue Ridge Province.

Gattis (1992) completed a Landscape Ecosystem Classification of the Highland Ranger District, Nantahala National Forest based on a model developed by Barnes et. al. (1982) in northwest Michigan. Six vegetation site units were identified within an elevation range of 700 m to 1280 m (2300 feet to 4200 feet). Although numerous soil chemical properties were measured, the majority were largely unsuccessful as site unit predictors. Topographic variables including elevation, McNab's (1993) "Landform Index", solum thickness, and epipedon thickness were the most significant discriminating variables.

The Landscape Ecosystem method has also been successfully applied in the southeast outside the southern Appalachians. Jones et al. (1984) completed a classification of the Savannah River Site located within the upper Coastal Plain of South Carolina. Eight hardwood and twelve pine community types were identified. Vegetation was found to vary along an environmental gradient corresponding to topographic position. Although the majority of community types identified were not existing under steady-state conditions, the LEC approach was still successful as a site classification tool.

III. METHODS AND DATA ANALYSIS

A. Study Area

The study area is located in the southern unit of the Cherokee National Forest of east Tennessee (Figure 1). Sampling was limited to the Tellico Ranger District which lies within Monroe County. The Little Tennessee River constitutes the northern boundary between the study area and the GSMNP, while the eastern boundary is the Tennessee-North Carolina state line. Topography from west to east ranges from low ridges and valleys, to a belt of intermediate relief, to mountain highlands with peaks reaching 1,524 m (5000 feet) (SCS, 1981). These ranges are included in the southern Blue Ridge physiographic province and are commonly known as the Unaka Mountains (Fenneman, 1938).

A regionalization approach, based on a seven-level hierarchial system developed by Wertz and Arnold (1972), was used in dividing the study area into units of relatively uniform characteristics. A variation of this system has also been used by Smalley (1986) in the Interior Uplands and McNab (1991b) in the southern Appalachians. Readily available resource materials, such as geology and soils maps, were used to delineate naturally occurring units in the landscape. From the top-down, the first three levels of Wertz and Arnold's hierarchy were followed in delineation of

Figure 1. Study location in the southern unit of the Cherokee National Forest, Tennessee.

the study area. The levels are:

VII. PROVINCE

Representing areas of similar geomorphic history and climate.

VI. SECTION

Representing areas of uniform climate generally correlated with elevation and relief.

V. SUBSECTION

Representing areas of similar geologic formations relating to soil properties.

Resource materials previously compiled by Fenneman (1938), SCS (1981), Scott (ND), Hack (1982), Hatcher (1981) and Hardeman (1966) were used in adapting the hierarchy to the natural divisions represented within the Tellico District. Two sections, Foothills and Mountain Highlands, were identified (Figure 2). Following consultation with USFS personnel, the Foothills section, comprising an area of approximately 22,800 hectares (56,340 acres) was chosen for the study. Although sampling was limited to Monroe County, the LEC model is possibly applicable to the entire Foothills section of the southern CNF with a total area of approximately 43,800 ha (108,400 acres) or about 35% of the

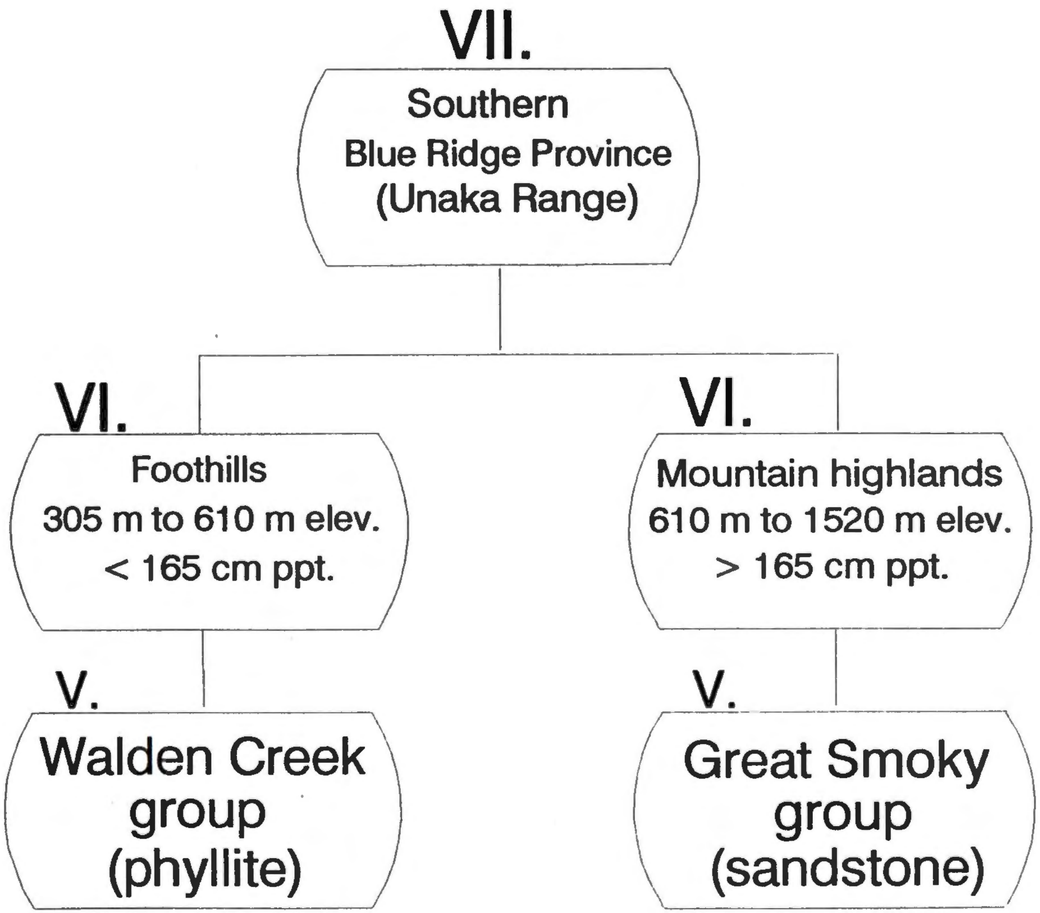


Figure 2. Province, section and subsection delineations of the Tellico Ranger District, Cherokee National Forest within Monroe County, Tennessee.

121,000 ha (299,000 acres) comprising the southern unit of the CNF.

The Foothills are situated between the Ridge and Valley Province to the west and the Mountain Highlands section to the east (Hack, 1982). Elevation ranges from 305 m to 610 m (1000 feet to 2000 feet). The climate is characterized by mild winters and warm summers with a mean annual temperature of 13° C (55° F). Precipitation averages 142 cm (56 inches) annually, and is approximately 64 cm (25 inches) less than average rainfall in the Mountain Highlands (SCS, 1981).

Topography is characterized by a dendritic drainage pattern with streams generally incised along more erodible rock formations. Ridgetops are narrow and irregular while slopes range from steep to very steep. Coves and narrow tracts of flat land are commonly found at the base of V-shaped drains throughout the area (Springer and Elder, 1980). Slightly metamorphosed phyllites, sandstones, and shales of the Walden Creek group are the dominant rocks underlying these low foothills (Hatcher, 1981).

Soils, mainly silt-loams and channery silt-loams of the Ranger-Citico-Fletcher association, range in depth from 0.6 m (2 feet) to 1.8 m (6 feet). They are formed from colluvium on lower slopes and in coves, and from parent rock on upper slopes and ridgetops. The Ranger series, a well-drained, moderately deep soil, dominates the landscape on narrow ridgetops and upper and middle side slopes. The Citico series, also well-drained but deeper than Ranger soils, is found along coves and protected slopes. The Fletcher series is located predominantly along broad ridgetops, but was encountered only rarely in the study area. Although substantial variation may occur within mapping units, available moisture and soil fertility are highest among Citico soils (Scott, ND).

B. Field Methods

Stand Selection

Ninety-one stands established before 1910 were initially selected using stand age data supplied by USFS personnel. Ground reconnaissance was used to further evaluate stand suitability according to the following criteria:

1) Vegetation must be comprised of a homogenous mixture of overstory and understory species indicative of late successional conditions (Jones, 1988).

2) Stands must exhibit a low disturbance level based upon a disturbance history checklist (Pyle, 1988) that includes presence of exposed roots, cut

stumps, old trails/roads, and fire wounds.

A total of sixty plots were established in stands meeting these criteria.

Sampling Procedures

To draw a representative sample of all possible environmental conditions present within the study area, a critical variable matrix was constructed based on aspect and slope type. Five broad classes of slope type were identified from USGS topographic maps including: narrow ridges, upper side slopes, middle side slopes, lower side slopes and coves. Aspect was classified broadly as either northerly (315 degrees to 135 degrees) or southerly (136 degrees to 314 degrees) and then combined with each slope type to form nine combinations. Ridgetops were considered as having no aspect. A goal of seven plots within each combination was set. Plots were located so as not to cross any recognizable ecotones or soil mapping units as identified by USGS topographic maps and USFS in-service soil maps.

Plot Layout

In the approximate center of each stand the following series of nested plots were established (Figure 3):

1. Circular plot: 0.04 hectare (400 m^2)
2. Circular nested plot: 0.01 hectare (100 m^2)
3. Square nested plot: 0.004 hectare (40 m^2)
4. Eight square nested plots, 1 m * 1 m: 0.001 hectare (8 m^2)

Vegetation Sampling

Vegetation was stratified by size class and morphology following the work of Jones (1988) in old-growth forests in the Piedmont of South Carolina (Table 1). Species and crown radii of individual trees, saplings and shrubs were recorded within their respective strata. The length of crown interception (by species) along five, 6.32 m transects was recorded within the regeneration stratum. A modification of the Daubenmire (1959) coverage class was used in estimating herbaceous species within eight, 1 square meter frames placed along the perimeters of the circular plots (Figure 3).

Landform Variables

The following quantitative topographic variables were recorded on each plot:

1. *Aspect.* Aspect was recorded in azimuths with values between 315^0 to 135^0 classified as northerly, and 136^0 to

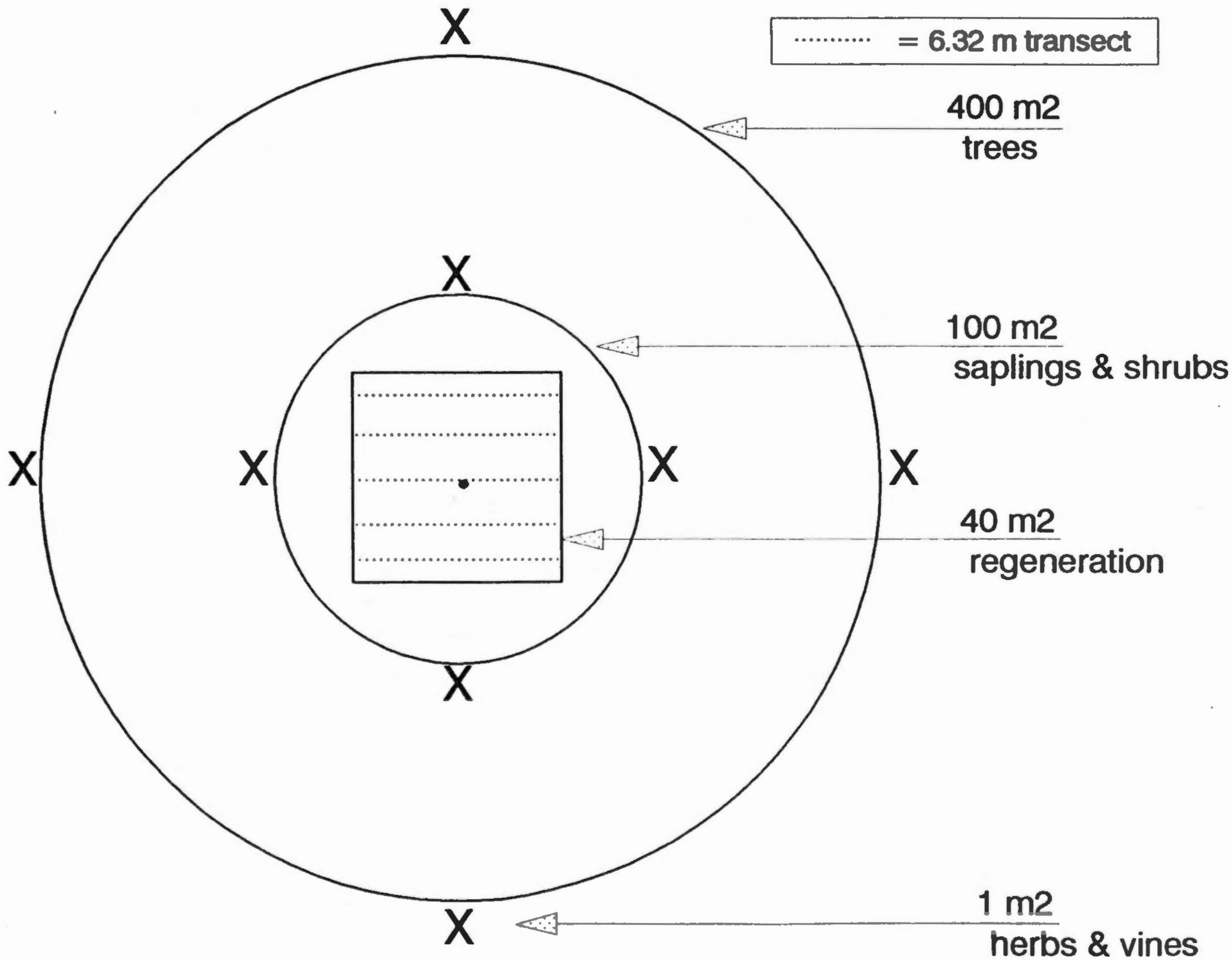


Figure 3. Arrangement and sizes of plots used to sample various types of vegetation.

Table 1. Plot areas and measurements taken for vegetation of various sizes.

Vegetation size class	Plot area	Measurement
Trees ¤12.5 cm DBH	0.04 ha	Species and crown radii
Saplings and shrubs <12.5 cm DBH ¤1.3 m height	0.01 ha	Species and crown radii
Regeneration with height <1.3 m >30.5 cm	0.004 ha	Species and length of crown interception along five equally spaced transects
Herbs and vines	0.001 ha	Species and Daubenmire coverage class

314^0 as southerly (Glendon W. Smalley, personal communication).

2. *Slope gradient.* Slope gradient of the major plot was measured in percent with a clinometer.

3. *Elevation.* Elevation was determined from USGS 1:24,000 scale topographic maps.

4. *Landform Index.* Slope shape and degree of protection by adjacent land masses was quantified with a "Landform Index" (McNab, 1993). The index value is derived from the average of eight slope gradient measurements (percent scale) made from plot center to the surrounding horizon at 45^0 azimuth intervals. Sign of the slope is considered in calculating the average. Higher index values are indicative of low, protected slopes, while low values represent xeric, exposed sites.

5. *Terrain Shape Index.* The geometric shape of the plot was quantified using a "Terrain Shape Index" developed by McNab (1989). The index value is derived from the mean of eight slope gradient measurements (percent scale) made from plot center to the perimeter of the outer plot at 45^0 intervals. Sign of the slope is considered in calculating the average. Positive index values represent concave

shapes, while negative values represent convex shapes such as narrow ridgetops.

Three qualitative topographic variables were recorded for descriptive purpose only and were not used in the analysis. They were as follows:

1. *Slope position.* An estimate of the relative distance of the plot between the bottom and top of the ridge was based on a subjective determination. A scale from 0 to 100 was used, with 100 representing the ridgetop.

2. *Slope type.* Slope type was classified according to five general categories: ridge, upper side slope, middle side slope, lower side slope, and cove.

3. *Surface shape.* Surface shape was classified according to five general categories: convex, undulating convex, linear, undulating concave, and concave.

Soil Variables

On sites exhibiting strong differences in parent material, soil chemical properties have been identified as important discriminators between vegetation types (Doolittle, 1957; Ike and Huppuch, 1968; Losche, 1967; Mowbray and Oosting, 1968; Franklin et al., 1993). Because the study area was delineated according to similarities in parent material, soil chemical variables were not sampled. Instead, variables were limited to those that could be measured in the field. A soil pit was dug in each plot and the following horizon thicknesses were recorded:

1. *Humus thickness*
2. *A Horizon thickness*
3. *Solum thickness*

The proportion and size of coarse fragment content was noted.

C. Data Analysis

Vegetation data were summarized by species and size class in terms of percent of plot area coverage, a measure of dominance determined from crown radii measurements. Relative dominance was calculated for all strata. Relative density was calculated for the tree, sapling & shrub, and regeneration strata only. Importance Value 200 (relative dominance + relative density) was determined for all strata except herbaceous. Importance Value 100 (relative dominance) was determined for the herbaceous stratum. A data matrix (set A) based on these Importance Values was composed of 189 species and 60 plots. Woody vegetation occurring in each stratum were considered individual species.

Because composite indices have been criticized as including non-additive properties (Orloci, 1975; Daubenmire, 1968), a second matrix (set B) was developed. Set B utilizes absolute dominance as the measure of importance and is composed of 189 species and 60 plots. Data sets A and B were analyzed separately according to the following procedures.

Plots were grouped by dominant vegetation type using an agglomerative, hierarchical clustering technique with the computer program COMPAH (Boesch 1977). This hierarchical grouping and arrangement of plots helps reveal species relationships and facilitates environmental interpretation of the data (Gauch, 1982). In preparation for the classification analysis, absolute dominance values of set B were standardized using "species standardization by totals." In this procedure, abundance of a given species is expressed as a percentage of the total across all plots. The results are presumably a more accurate expression of site distributions of species with varying abundances (Clifford and Stephenson, 1975). The Bray-Curtis similarity coefficient was used as the resemblance function in plot clustering of each data set. Entities with identical attributes have a resemblance function of one, while highly dissimilar units show values closer to zero (Boesch, 1977). In addition, species with less than 5 occurrences were excluded from both data sets. It is believed that the presence of rare species can be attributed more to chance than actual habitat similarities and therefore their presence may obscure important vegetation trends (Clifford and Stephenson, 1975).

To reduce subjectivity of the cluster delineation, classification analysis was employed in conjunction with detrended correspondence analysis (DCA) using the computer program DECORANA (Hill, 1979). DCA is a method of ordination whereby species and plots are arranged along hypothetical environmental gradients (ordination axes). Similar entities are placed close together and dissimilar ones far apart. The goal of ordination is to extract dominant patterns of variation from species data. These patterns were then related to environmental variables in a separate step using stepwise discriminant analysis (SWDA). Eight quantitative variables were entered into the analysis including humus thickness, A horizon thickness, solum thickness, elevation, slope gradient, Terrain Shape Index, Landform Index, and aspect. Prior to entry, aspect was transformed into a linear scale ranging from 0 for northeast aspects, to 2 representing southwest aspects (Beers et al., 1966).

This two-step procedure, commonly referred to as indirect gradient analysis (Gauch, 1982), was used in conjunction with a more innovative method, detrended canonical correspondence analysis (DCCA) (Ter Braak, 1987) to reveal and interpret environmental gradients. The use of independent methods is recommended as a means of reducing subjectivity in results (Gauch et al., 1981). DCCA is a direct gradient analysis approach that simultaneously reveals patterns in species composition and relates them to environmental variables. The eigenvalue, representing variance accounted for by each ordination axis, ranks axes in terms of significance in species composition. The importance of each environmental variable in determining species composition is interpreted from the strength of the correlations between variables and axes. Correlation coefficients represent rates of change in species composition per unit change in environmental variables (Ter Braak, 1986).

Results of the direct and indirect analyses were compared and evaluated in terms of correlation coefficients, significance levels, and prior knowledge of the ecosystem. When possible, ordination axes were ecologically interpreted. Variables strongly correlated with ordination axes were entered into a separate discriminant analysis to investigate the overall classification accuracy. Using a cross-validation procedure, the number of correctly classified plots were determined and subsequently divided by the total number of plots to calculate the prediction accuracy (Klecka, 1980).

Results from analysis of data sets A and B were evaluated in terms of classification accuracy and concurrence with known field conditions. The data set successfully conveying the greatest amount of site information was used in the final LEC model.

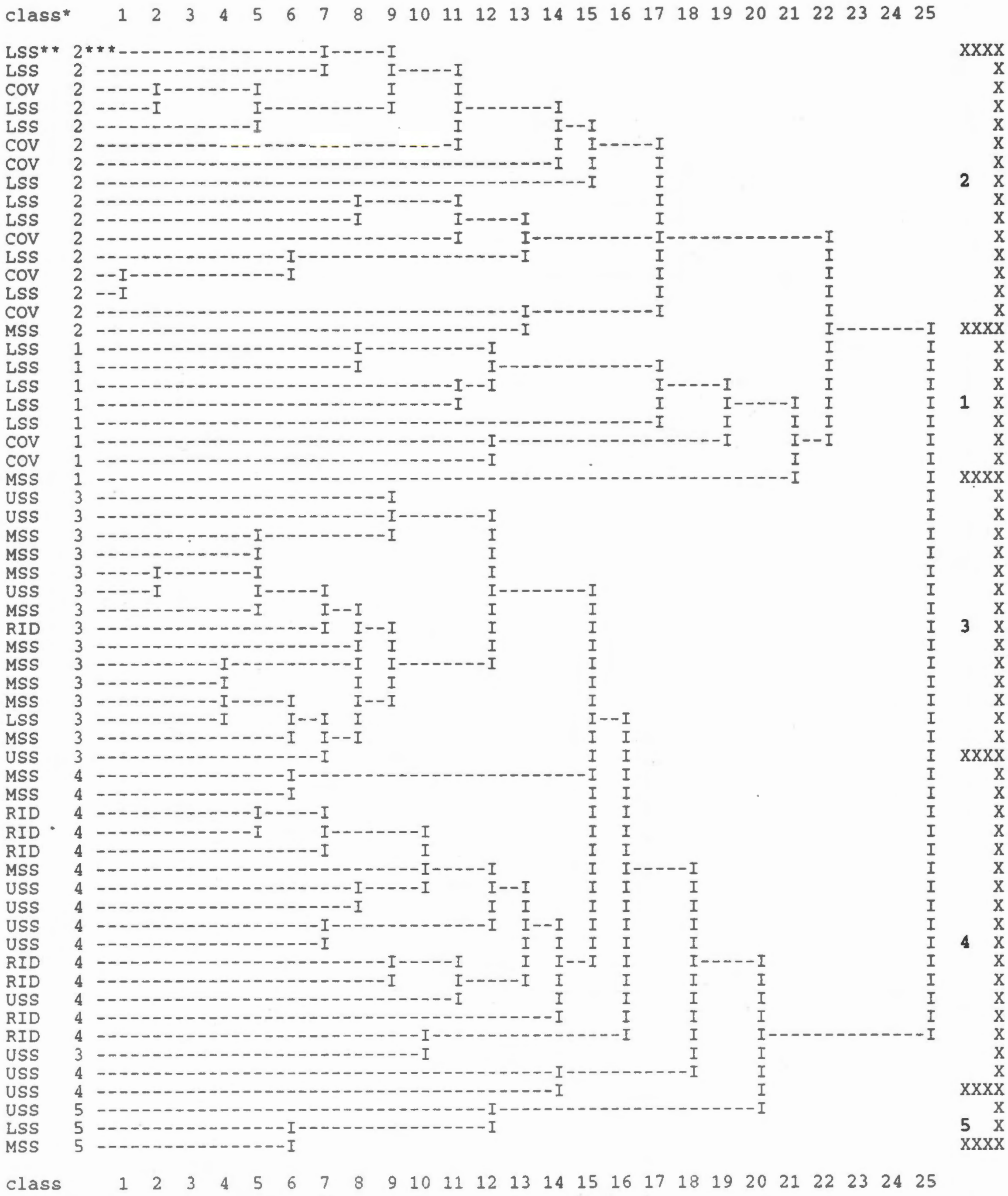
IV. RESULTS

A. Classification and Ordination

Based on plot groupings developed from the COMPAH classification, five site units were delineated in data set A (Figure 4), and four in data set B (Figure 5). Tables 2 and 3 list the Bray-Curtis percent similarity coefficients represented by the twenty-five classes shown at the top and bottom of Figures 4 and 5, respectively. The degree of similarity between plots is represented by the point at which they are joined in the diagram and the class number associated with this position. For data set A, the most highly similar plots had approximately 72% of their attributes in common, while for data set B, this value was slightly higher at 76%.

Agreement between COMPAH classification results and DCA ordination results is evident in the diagrams presented in Figures 6 and 7. These diagrams illustrate the combined results of the classification and ordination. The numbers represent COMPAH derived site units arranged in DCA ordination space. Plots were grouped similarly under both techniques.

Because unit five of set A was represented by only three plots, these plots were eliminated from the data set. Attempts to integrate the plots into the four remaining



* Bray-Curtis percent similarity classes: values shown in Table 2.

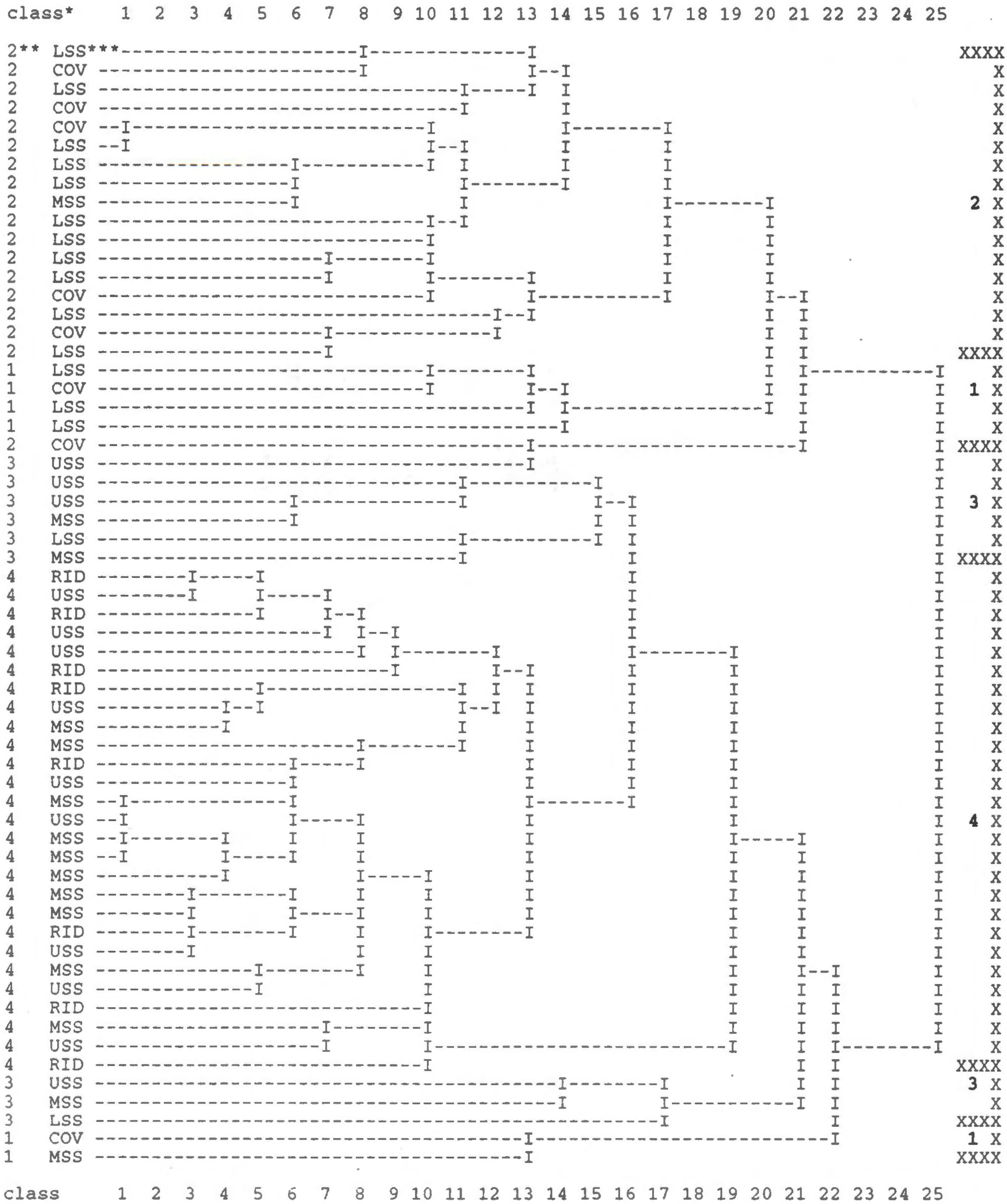
** Slope type: COV = Cove, LSS = Lower side slope, MSS = Middle side slope, USS = Upper side slope and RID = Ridgetop.

*** Site Unit number.

Figure 4. Classification of sixty plots into site units based on data set A using COMPAH. Plot groupings were subjectively determined.

Table 2. Bray-Curtis percent similarity class values for data set A, continued from Figure 4.

CLASS	PERCENT SIMILARITY COEFFICIENTS
1	0.718
2	0.693
3	0.668
4	0.643
5	0.619
6	0.594
7	0.569
8	0.544
9	0.519
10	0.494
11	0.469
12	0.444
13	0.419
14	0.394
15	0.369
16	0.344
17	0.320
18	0.295
19	0.270
20	0.245
21	0.220
22	0.195
23	0.170
24	0.145
25	0.120



* Bray Curtis percent similarity classes: values shown in Table 3.

** Slope Type: COV = Cove, LSS = Lower side slope, MSS = Middle side slope, USS = Upper side slope and RID = Ridgetop.

*** Site Unit number.

Figure 5. Classification of sixty plots into site units based on data set B using COMPAH. Plot groupings were subjectively determined.

Table 3. Bray-Curtis percent similarity class values for data set B, continued from Figure 5.

CLASS	PERCENT SIMILARITY COEFFICIENTS
1	0.759
2	0.732
3	0.705
4	0.679
5	0.652
6	0.626
7	0.599
8	0.572
9	0.546
10	0.520
11	0.493
12	0.467
13	0.440
14	0.414
15	0.387
16	0.360
17	0.334
18	0.307
19	0.280
20	0.254
21	0.228
22	0.201
23	0.175
24	0.148
25	0.122

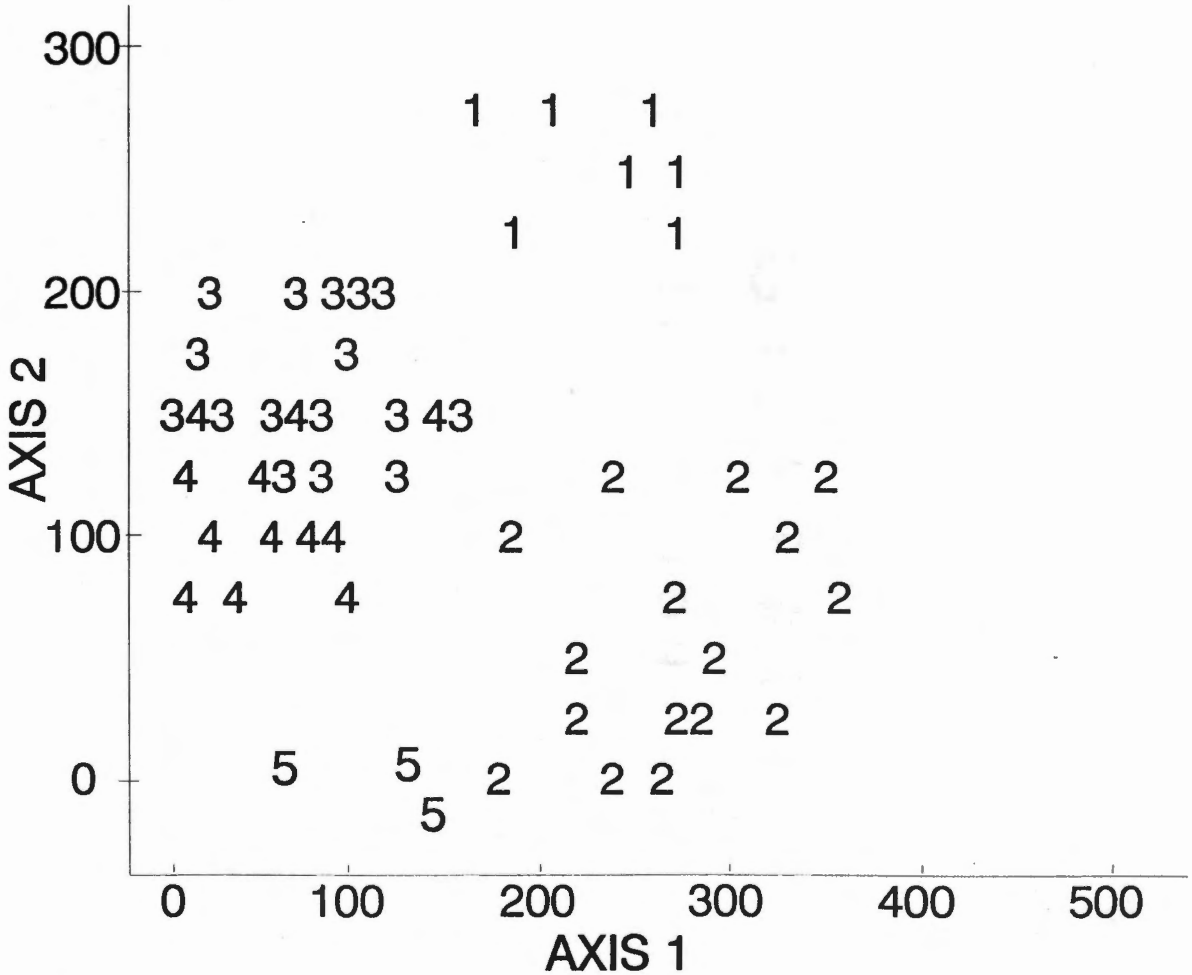


Figure 6. DCA ordination of sixty plots for data set A. Numbers represent COMPAH derived plot groupings.

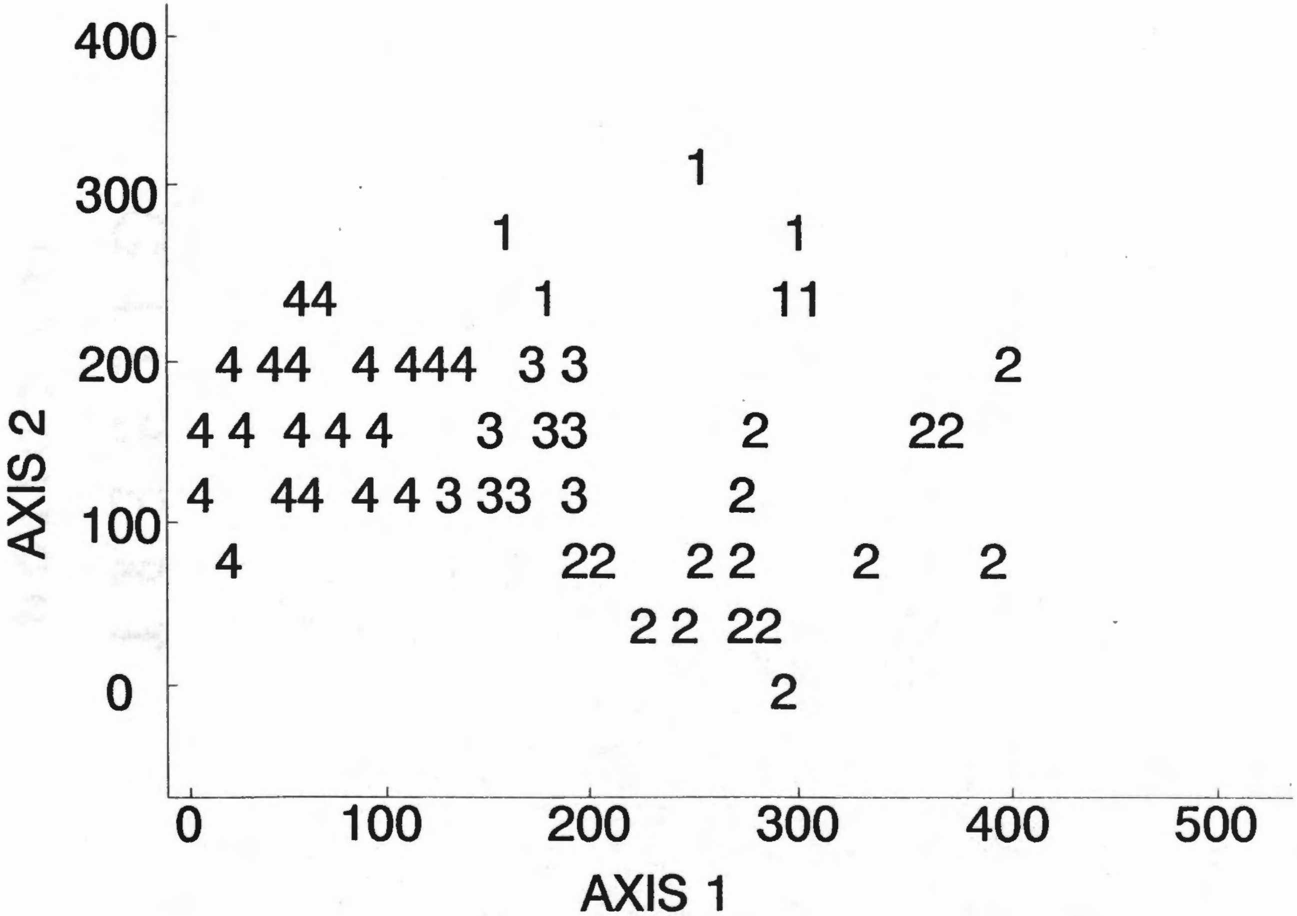


Figure 7. DCA ordination of sixty plots for data set B. Numbers represent COMPAH derived plot groupings.

units were largely unsuccessful. A second ordination was performed on the remaining 57 plots and the results are presented in Figure 8.

DCA ordination axes representing hypothetical environmental gradients are expressed in units of "beta diversity". These units depict the degree of change in species composition along each gradient (Whittaker, 1975). Beta diversity in the DECORANA diagram is actually standard deviation multiplied by 100. A species along a hypothetical gradient appears, rises to its mode, and disappears within approximately four standard deviations. Theoretically, plots spaced greater than four standard deviations apart contain no common species (Hill, 1979).

DCA axes 1 and 2 of set A represent beta diversities of approximately 450 and 250, respectively (Figure 8). Set B results are similar to set A with values of 450 and 300 for axes 1 and 2, respectively (Figure 7). The relatively long length of the first axis is indicative of substantial species diversity. Separation of site units is distinct, although overlap clearly occurs between units 3 and 4 of both data sets. The second axes reveal shorter gradients with considerably less variation in species composition. The eigenvalues for axes 1 and 2 of set A (0.70 and 0.3338) and set B (0.69 and 0.339) are nearly identical. The large difference in magnitude between eigenvalues of axes 1 and 2 suggests the significance of only a single environmental

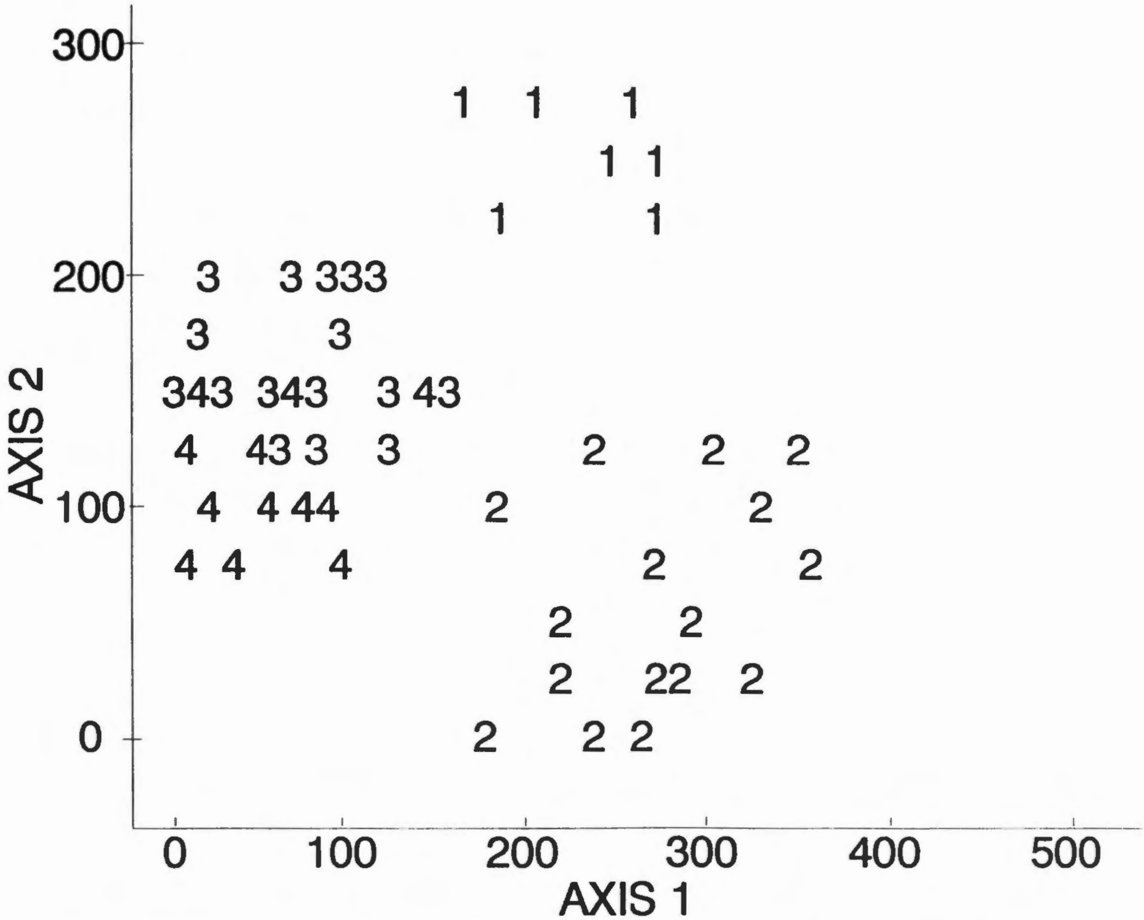


Figure 8. Second DCA ordination of data set A with fifty-seven plots. Numbers represent COMPAH derived plot groupings.

gradient in both data sets.

DCCA axis 1 and 2 eigenvalues also indicate a single axis accounts for the majority of species variation. The first and second axes have eigenvalues of 0.522 and 0.141 for set A, and 0.53 and 0.135 for set B. Once again, the large difference in magnitude between axes 1 and 2 eigenvalues strongly suggests a single environmental gradient in both data sets. Table 4 lists the correlation coefficients of environmental variables with axes. Landform Index and elevation, highly correlated with axis 1, appear to be the most important predictors of species composition in both data sets. Humus thickness, solum thickness, A horizon thickness and Terrain Shape Index showed moderately strong correlations with the first axis. Aspect and slope, however, show a surprisingly high correlation with axis 2. Nonetheless, no ecological meaning could be attributed to the second axis of either data set.

B. Stepwise Discriminant Analysis

Tables 5 and 6 present the results of the stepwise discriminant analysis. Landform Index achieved the greatest separation between site units and accounted for 57% and 52% of species variation in sets A and B, respectively. Slope had the next highest significance level in both analyses. However, R^2 values for slope were substantially lower than

Table 4. Intraset correlation coefficients of environmental variables with DCCA axes 1 and 2 for data sets A and B.

	Set A Axes		Set B Axes	
Variable	1	2	1	2
Humus thickness	0.45	0.35	0.41	0.22
A horizon thickness	0.42	0.07	0.39	- 0.29
Solum thickness	0.44	0.13	0.35	0.20
Elevation	- 0.68	0.10	- 0.69	0.15
Aspect	- 0.01	0.70	0.03	- 0.58
Slope	0.17	0.40	0.15	- 0.41
Landform Index	0.87	0.11	0.91	- 0.22
Terrain Shape Index	0.32	0.40	0.47	- 0.18

Table 5. Stepwise discriminant analysis results for data set A with site units as dependant variables[1]. Significance level for entry and retention at $p < 0.15$.

Variable	R^2	Prob. >F
Landform Index	.5728	.0001
Slope	.2161	.0051
Humus thickness	.1919	.0119
Solum thickness	.1014	.1449
Elevation	.0977	.1656
A horizon thickness	.0587	.3922
Terrain shape index	.0527	.4435
Aspect	.0217	.7806

[1] Variables arranged in order of entry into analysis.

Table 6. Stepwise discriminant analysis results for set B with site units as dependant variables[1]. Significance level for entry and retention at $p < 0.15$.

Variable	R^2	Prob. >F
Landform Index	.5198	.0001
Slope	.1955	.0072
Aspect	.1510	.0304
Elevation	.1448	.0390
Humus thickness	.1114	.1023
A horizon thickness	.0953	.1608
Terrain Shape Index	.0642	.3314
Solum thickness	.0208	.7811

[1] Variables arranged in order of entry into analysis.

for Landform Index. Results obtained from sets A and B differ slightly from step 3 onward. Humus thickness ($p = 0.01$) and solum thickness ($p = 0.14$) were the next most significant discriminating variables in set A, while aspect ($p = 0.03$), elevation ($p = 0.04$) and humus thickness ($p = 0.10$) were more significant in set B.

C. Comparison of Indirect and Direct Gradient Analysis

Generally, variables identified as strong predictors of species composition were the same for both direct and indirect gradient analysis. Landform Index was consistently identified as the most important variable and was correlated with Terrain Shape Index ($r = 0.61$), elevation ($r = -0.55$) and slope ($r = 0.42$). Elevation was identified through DCCA as a strong predictor of species composition but performed poorly in the SWDA of data set A. Although elevation was not significantly different between all four site units, it may be an important predictor for at least two of the groups. Environmental differences between strongly mesic and xeric vegetation types are readily identifiable. However, variations between similar moisture classes are gradual and less easily quantified. Consequently, elevation was included in the discriminant analysis to test its effect on site unit separation.

D. Discriminant Analysis

The classification success of each data set was tested using a discriminant analysis cross-validation procedure. For set A, an initial analysis was performed with variables identified as significant at $p < 0.05$ from the indirect gradient analysis. A three variable model that included Landform Index, slope, and humus thickness correctly predicted group membership 61% of the time (Table 7). The predictive ability of the model rose to 67% when elevation ($p = 0.17$) and solum thickness ($p = 0.10$) were added in a second analysis (Table 8). The addition of elevation and solum thickness, important variables in the direct gradient analysis, strengthened the performance of site units 3 and 4 by 19% and 6%, respectively. A third analysis which included all of the environmental variables reduced the predictive ability of the model to 58% (Table 9). Consequently, the five variable model (Landform Index, slope, humus thickness, elevation, and solum thickness) appears to be the most appropriate for data set A.

For data set B, a four variable model that included Landform Index, slope, elevation and aspect correctly predicted site unit membership 63% of the time (Table 10). A second analysis adding humus thickness (as identified through DCCA) did not improve the model accuracy rate (Table 11). A final analysis including all eight variables reduced

Table 7. Classification performance results, cross-validation procedure using a three variable model (Landform Index, slope, and humus thickness) from data set A. The upper number equals the number of plots and the lower number equals the posterior probability of membership in predicted site unit.

actual site unit	predicted site unit			
	1	2	3	4
1	**3** **37.5**	1 12.5	4 50.0	0 0
2	1 6.25	**12** **75.0**	3 18.75	0 0
3	1 6.25	1 6.25	**9** **56.25**	5 31.25
4	0 0	0 0	6 35.29	**11** **64.71**

Classification accuracy rate: 61%

Table 8. Classification performance results, cross-validation procedure using a five variable model (Landform Index, slope, humus thickness, solum thickness and elevation) from data set A. The upper number equals the number of plots and the lower number equals the posterior probability of membership in predicted site unit.

actual site unit	predicted site unit			
	1	2	3	4
1	**3** **37.5**	3 37.5	2 25.0	0 0
2	2 12.5	**11** **68.75**	3 18.75	0 0
3	0 0	1 6.25	**12** **75.0**	3 18.75
4	0 0	0 0	5 29.41	**12** **70.59**

Classification accuracy rate: 67%

Table 9. Classification performance results, cross-validation procedure using all variables in the analysis from data set A. The upper number equals the number of plots and the lower number equals the posterior probability of membership in predicted site unit.

actual site unit	predicted site unit			
	1	2	3	4
1	**2** **25.0**	4 50	2 25.0	0 0
2	2 12.5	**10** **62.5**	3 18.75	1 6.25
3	0 0	1 6.25	**11** **68.75**	4 25.0
4	0 0	0 0	7 41.18	**10** **58.82**

Classification accuracy rate: 58%

Table 10. Classification performance results, cross-validation procedure using a four variable model (Landform Index, slope, elevation and aspect) from data set B. The upper number equals the number of plots and the lower number equals the posterior probability of membership in predicted site unit.

actual site unit	predicted site unit			
	1	2	3	4
1	**1** **16.67**	4 66.67	1 16.67	0 0
2	3 16.67	**12** **66.67**	0 0	3 16.67
3	0 0	1 11.11	**3** **33.33**	5 55.56
4	0 0	1 3.70	4 14.81	**22** **81.48**

Classification accuracy rate: 63%

Table 11. Classification performance results, cross-validation procedure using a five variable model (Landform Index, slope, elevation, aspect and humus thickness) from data set B. The upper number equals the number of plots and the lower number equals the posterior probability of membership in predicted site unit.

actual site unit	predicted site unit			
	1	2	3	4
1	**2** **33.33**	2 33.33	1 16.67	1 16.67
2	3 16.67	**12** **66.67**	0 0	3 16.67
3	0 0	1 11.11	**2** **22.22**	6 66.67
4	0 0	0 0	5 18.52	**22** **81.48**

Classification accuracy rate: 63%

the predictive ability of the model to 58% (Table 12). Success rates for data set B are apparently optimal using a four variable model (Landform Index, slope, elevation, and aspect).

E. Comparison of Data Sets and Model Selection

Although classification accuracy rates are relatively equal for both data sets, site unit separation is clearly less distinct in the model created from set B. Posterior probability of plot membership in site units 1 and 3 is noted to be unacceptably low at 16.7% and 33.3%, respectively. The majority of misclassified plots were placed in site units 2 and 4 (Table 10). Although field observations strongly suggest the existence of four separate site units, results of the set B analysis do not support this conclusion.

Data set A was slightly more successful in detecting gradual species variation and was therefore selected for the final LEC model. Discussion in the remainder of this thesis refers to results derived from data set A with Landform Index, slope, elevation, humus thickness, and solum thickness as discriminating variables.

Table 12. Classification performance results, cross-validation procedure using all variables in the analysis from data set B. The upper number equals the number of plots and the lower number equals the posterior probability of membership in predicted site unit.

actual site unit	predicted site unit			
	1	2	3	4
1	**0** **0**	3 50.00	1 16.67	2 33.33
2	1 5.56	**13** **72.22**	1 5.56	3 16.67
3	0 0	1 11.11	**2** **22.22**	6 66.67
4	1 3.7	0 0	6 22.22	**20** **74.07**

Classification accuracy rate: 58%

F. Axis Interpretation and Site Unit Descriptions

The magnitude and direction of the correlation coefficients of Landform Index (+ 0.87) and elevation (- 0.68) with DCCA Axis 1 strongly suggests a moisture gradient. The weighted average, or center of a species distribution along each environmental variable, determines each species' position in the ordination diagram (Ter Braak, 1986). Figures 9 and 10 depict the DCCA ordination of plots and individual species. A xeric to mesic moisture gradient of species and plots increasing from left to right is evident. Environmental variables are shown as vectors in Figure 11 with position and direction dependant on the intraset correlations with axes. Vector length represents the relative importance of the variable in species composition. Species occurring primarily at the drier sites, such as scarlet oak and chestnut oak (*Quercus prinus*), have a higher weighted average with respect to elevation and lower average with respect to Landform Index and soil depth variables. The reverse is true for species occurring within mesic sites, such as American beech (*Fagus grandifolia*) and sweet birch (*Betula lenta)* as presented in Figures 10 and 11.

Four site units representing gradual changes along a moisture gradient are described in the following section and are illustrated in Figure 12. Mean and standard deviation

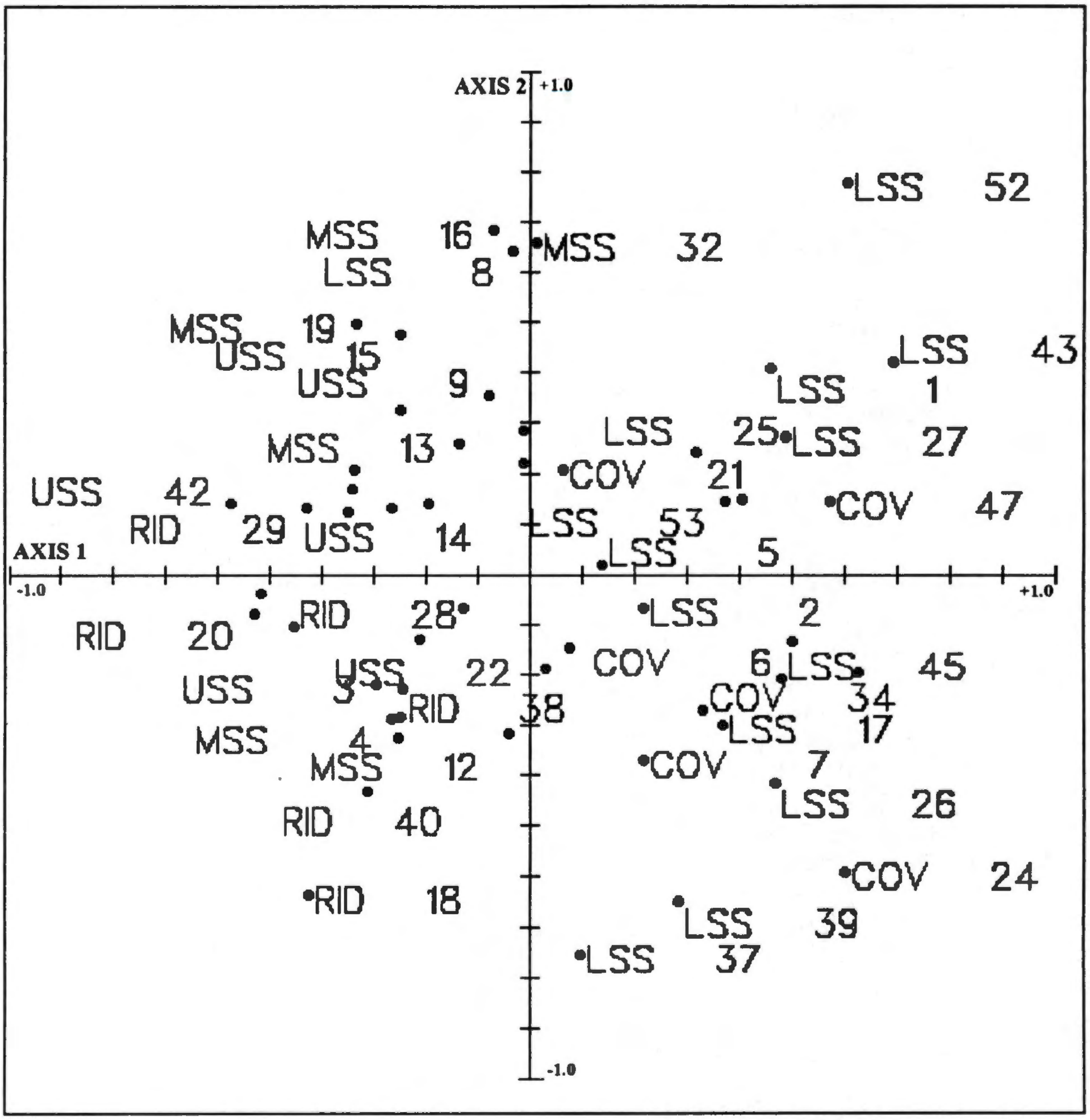


Figure 9. DCCA ordination diagram with plots. Slope type followed by plot numbers are shown. Slope types are: COV = Cove, LSS = Lower side slope, MSS = Middle side slope, USS = Upper side slope and RID = Ridge.

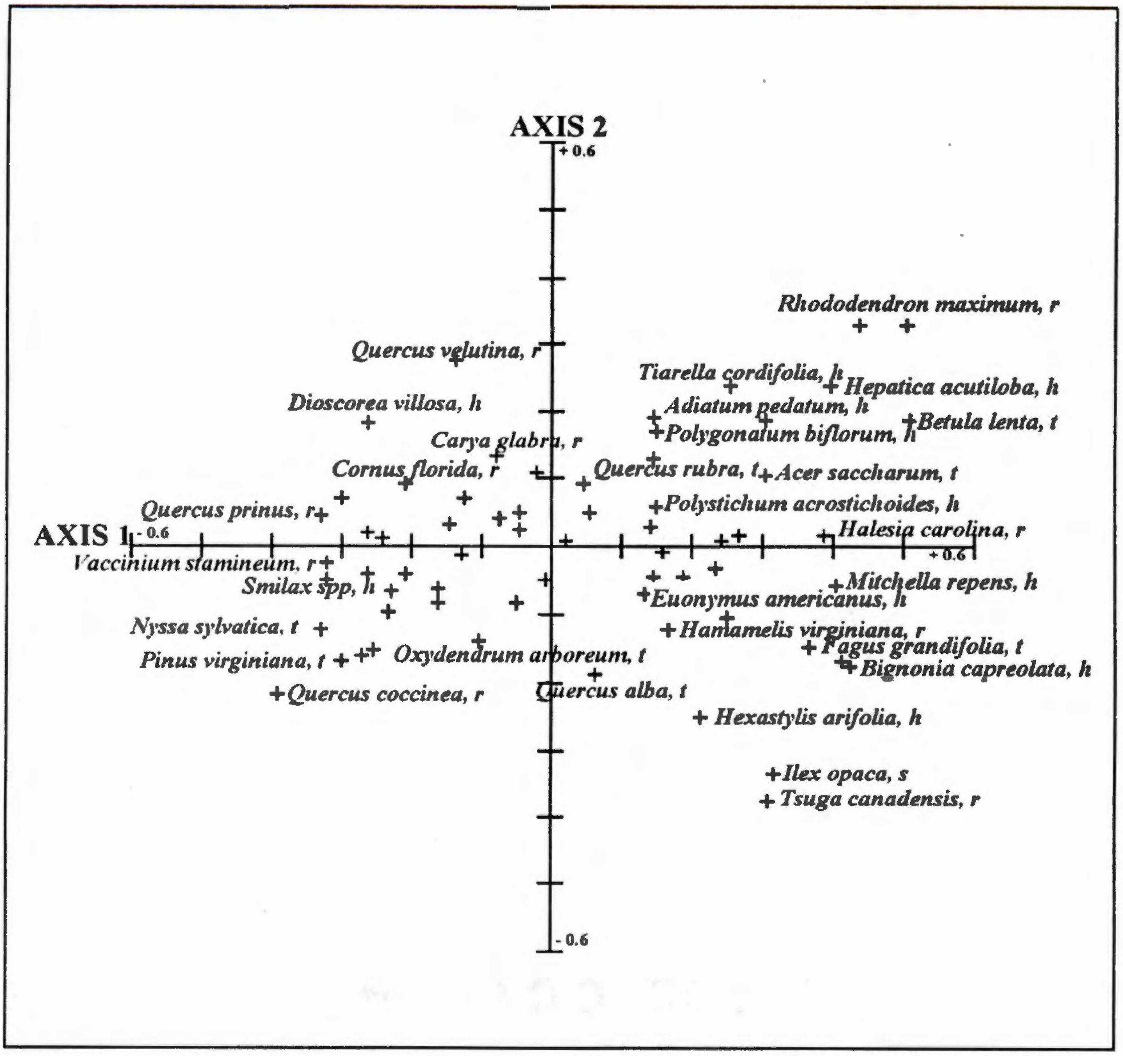


Figure 10. DCCA ordination diagram of selected species. T, s, r and h following species names represent Tree, Sapling & shrub, Regeneration and Herbaceous strata, respectively.

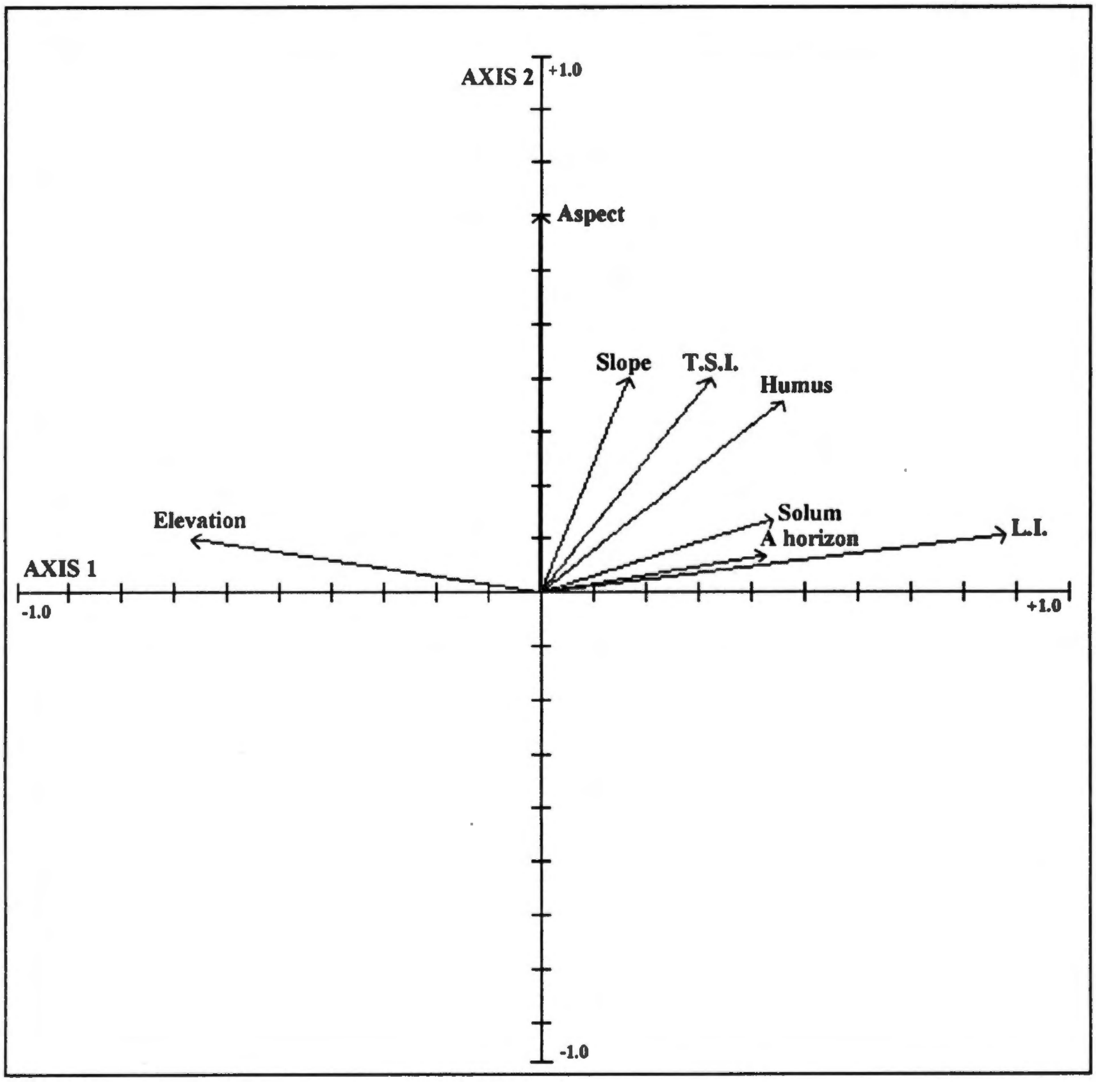


Figure 11. DCCA ordination diagram with environmental variables. T.S.I. = Terrain Shape Index, Humus = Humus thickness, Solum = Solum thickness, A horizon = A horizon thickness, and L.I. = Landform Index.

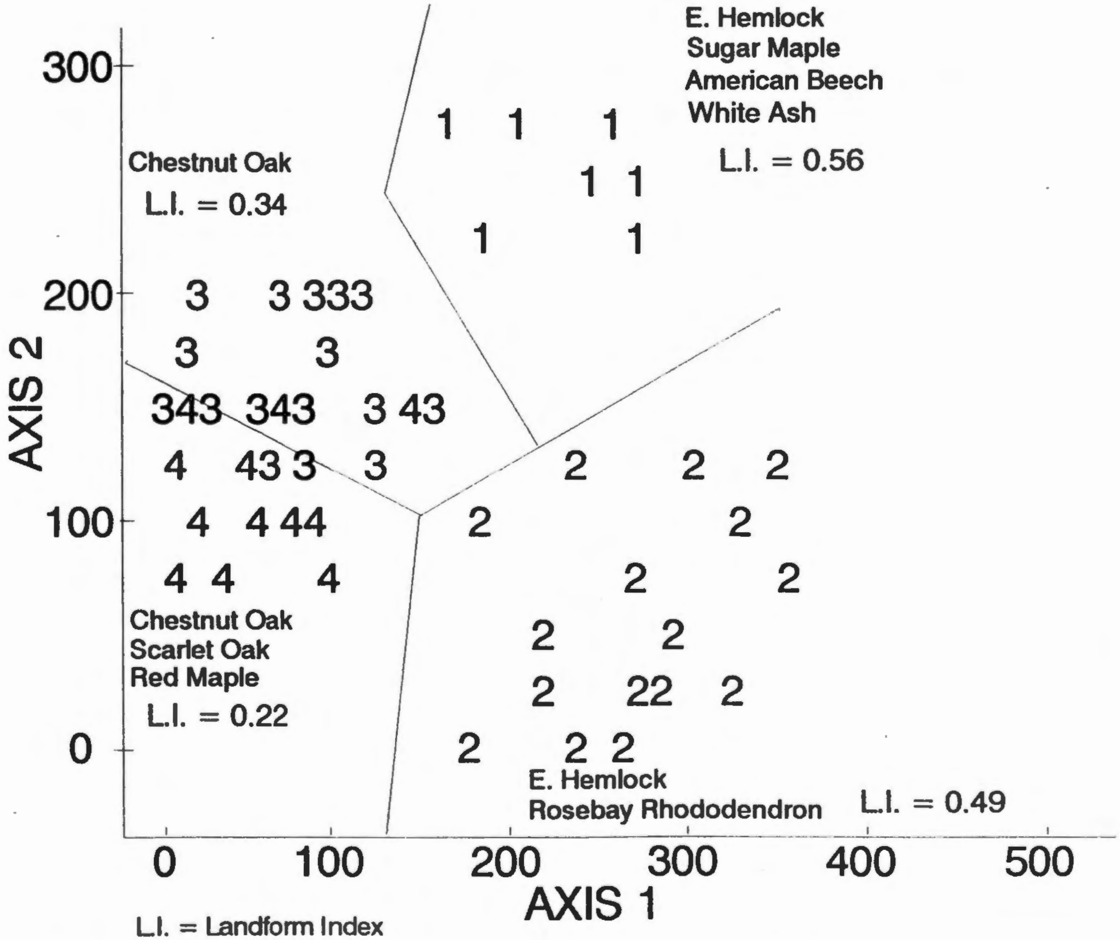


Figure 12. DCA ordination of fifty-seven plots for data set A with final site units and Landform Index values.

of each environmental variable as grouped by site unit are presented in Table 13. A complete list of species and average Importance Values as grouped by site unit and stratum are presented in the Appendix.

Site Unit 1

Eastern Hemlock - Sugar Maple - American Beech - White Ash type

The stands comprising site unit 1 are located on protected lower side slopes and coves and are the most mesophytic of the classification. These sites have steep to very steep slopes and are often adjacent to small streams. The high Landform Index values with an average of 0.56, are indicative of protected, low elevation landforms and are associated with high DCA axis 1 scores (Figure 12). Elevation averages 359 m (1178 feet) and ranges from 311 m to 415 m (1020 feet to 1360 feet). Soils are moderately deep, averaging 58 cm (23 inches). B and C horizons frequently contain siltstone fragments between 13 to 30 cm (5 to 12 inches) long. The humus layer is in excess of 2 cm (1 inch) thick.

Eastern hemlock *(Tsuga canadensis)* shares canopy co-dominance with numerous species including sugar maple *(Acer saccharum)*, beech, white ash *(Fraxinus americana)*, mockernut hickory *(Carya tomentosa)*, and tulip-poplar. Less prevalent

Table 13. Means and standard deviations (in parentheses) for environmental variables by site unit.

VARIABLES	MEAN AND STANDARD DEVIATION			
	Site Unit 1	Site Unit 2	Site Unit 3	Site Unit 4
Landform Index	.56 (.12)	.49 (.08)	.34 (.105)	.22 (.134)
Slope (percent)	66.5 (14.9)	41.63 (27.7)	57.38 (18.87)	36.65 (22.67)
Humus thickness (cm)	2.19 (1.6)	3.28 (1.71)	1.94 (.57)	1.96 (.87)
Solum thickness (cm)	58.5 (25.64)	59.43 (19.29)	54.19 (14.57)	39.0 (17.32)
Elevation (m)	359 (35.05)	383 (65)	442 (55)	458 (55)
A horizon thickness (cm)	12.25 (5.7)	10.45 (6.1)	8.63 (3.64)	5.9 (3.5)
Aspect (transformed)	1.09 (.6)	1.07 (.71)	1.09 (.81)	1.0 (.6)
Terrain Shape Index	.05 (.05)	.02 (.05)	.02 (.05)	-.03 (.06)

but represented in relatively equal amounts are basswood *(Tilia heterophylla)*, white oak and sweet birch. Contrary to findings in the GSMNP, silverbell *(Halesia carolina)* is not a co-dominant overstory species in this vegetation type. However, it is common in the understory and regeneration strata. Additional understory dominants include beech, flowering dogwood *(Cornus florida)*, sugar maple, hemlock, and basswood. The majority of these species are also found in the canopy and are, therefore, indicative of a steady state condition (Jones, 1988). Although witch hazel *(Hamamelis virginiana)* is present in small amounts there are no primary shrub species. The herbaceous layer is impressive and sometimes forms a "carpet" approaching complete ground cover. Christmas fern *(Polystichum Roth acrostichoides)* is the most abundant species in the herbaceous stratum. Virginia creeper (*Parthenocissus quinquefolia)*, hepatica *(Hepatica acutiloba)*, foamflower *(Tiarella cordifolia)*, cross vine *(Bignonia capreolata)* and many species of violet *(Viola spp.)* are also amply represented. Maidenhair fern (*Adiantum pedatum)* and marginal wood fern (*Dryopteris marginalis)* are common. Hepatica is limited almost exclusively to this site unit (Table 14).

Table 14. Mean Importance Values of selected species arranged by DCCA ordination scores. Maximum score for all strata excluding herbaceous is 200. Maximum score for the herbaceous stratum is 100.

	Mean Importance Values By Site Unit			
Species	1	2	3	4
Sweet birch - T[1]	6.5	4.2		
Rosebay rhododendron - S[2]		32.3		
Rosebay rhododendron - R[3]		45.4		
Cross vine - H[4]	****[5]	5.1	****	
American beech - T	22.4	11.5		
Partridge berry - H	****	17.0		
Hepatica acutiloba - H	7.8	****		
Silverbell - R	51.0	24.0		
Eastern hemlock - S	11.9	90.3		
Eastern hemlock - T	42.7	77.2	****	
Eastern hemlock - R	10.5	48.5		
Sugar maple - T	33.0	****	****	
White ash - T	22.2	****	****	
American beech - S	46.1	****	****	****
Sugar maple - R	34.6	****	****	
Little brown jug - H	****	7.4	****	****
Sugar maple - S	30.4		****	****
White pine - T		19.2	****	4.6
White oak - T	8.2	15.6	7.2	4.6
Northern red oak - T	5.8	7.0	12.7	****
Pussy-toes - H			****	4.4
Red maple - T	****	21.1	19.0	18.0
Flowering dogwood -S	38.4	9.8	115.3	40.6
Red maple - S	****	19.9	23.2	44.6
Chestnut oak - S		****	17.4	9.9
Red Maple - R	****	****	22.6	35.8
Chestnut oak - T	****	5.2	115.0	82.0
Smilax spp. - H	****	9.9	12.9	36.6
Blackgum - R		****	23.2	33.7
Blackgum - S		****	12.4	55.5
Black oak - T		****	****	11.0
Pipsissewa - H		****	8.2	15.8
Scarlet oak - T		****	8.7	22.9
Blackgum - T			****	11.7

[1] T Tree strata
[2] S Sapling and shrub strata
[3] R Regeneration strata
[4] H Herbaceous and vines strata
[5] **** Mean I.V. score < 4.0

Site Unit 2

Eastern Hemlock - Rosebay Rhododendron type

Landform Index values averaging 0.49 are representative of the slightly less protected slopes and flats of site unit 2. Typical landforms include very steep lower side slopes and less frequently narrow, flat tracts adjacent to small streams. Soils are moderately deep, averaging 59 cm (23 inches) and contain up to 70% coarse fragment content in the B horizon. Mean elevation of 383 m (1258 feet) is only slightly greater than site unit 1. However, the range extends further upslope and overlaps slightly with xerophytic vegetation types (Table 13). Humus is typically greater than 2 cm (1 inch) thick.

As site conditions become slightly less mesic, hemlock emerges as the dominant tree species with crown cover almost four times greater than any other canopy species (Table 14). red maple (*Acer rubrum)*, white pine *(Pinus strobus)*, and white oak are represented in approximately equal amounts as lesser components of the overstory. Also present, but contributing significantly less crown cover, are several mesic species seen in site unit 1 such as beech, mockernut hickory and tulip-poplar. Conspicuously absent from the tree stratum is sugar maple, having been replaced by red maple and white pine, neither of which are canopy components in site unit 1. The understory and regeneration strata are dominated by hemlock associating with rosebay rhododendron *(Rhododendron maximum)*, the primary shrub species found exclusively in this site unit. Red maple, flowering dogwood and silverbell make up the majority of the remaining understory cover with other species effectively suppressed by the heavy shade of hemlock and rhododendron. In contrast to the lush ground cover of site unit 1, herbaceous cover was practically nonexistent depending on the degree of rhododendron dominance. Nonetheless, partridge berry *(Mitchella repens)* is common and appears to be the most diagnostic of the plant species of this site. Other species include *Smilax* spp., Christmas fern, little brown jug *(Hexastylis arifolia)*, and hay scented fern *(Dennstaedtia punctilobula)*.

Site Unit 3

Chestnut Oak type

Located on well-drained, middle to upper side slopes and V-shaped drains, site unit 3 has a higher degree of topographical exposure than site units 1 or 2. Considerably lower mean Landform Index values (0.34) correspond to the increased exposure and higher mean elevation (442 m [1451 feet]). Mean soil thickness of 54 cm (21 inches), is slightly thinner than previous units. Humus was typically less that 2 cm (1 inch) thick.

A trend toward xeric site conditions is evident in the species composition of this unit. Chestnut oak is the single dominant overstory species making up greater than 50% of the canopy (Table 14). Associated species are red maple, northern red oak and tulip-poplar. Also present but in less significant amounts are scarlet oak, white oak and pignut hickory (*Carya glabra*). Noticeably absent from the canopy is eastern hemlock having moved from complete dominance to complete absence with the increase in xeric conditions. Other mesophytic species such as basswood and sweet birch are also absent. Flowering dogwood, present only as a minor component in previous site units, is the primary understory species associating with a small mixture of red maple, chestnut oak, and blackgum (*Nyssa sylvatica*). Maple-leaf viburnum (*Viburnum acerifolium*) is the most abundant shrub species. Herbaceous coverage is generally low and often characterized by low tangles of *Smilax* spp. Other common species include desmodium (*Desmodium* spp.), wild yam (*Dioscorea villosa*), pipsissewa (*Chimaphila maculata*), and Christmas fern, none of which appear to be specific to this site unit.

Site Unit 4

Chestnut Oak - Scarlet Oak - Red Maple type

Site unit 4 is the most xeric of the units in this classification as is evident by low mean Landform Index scores (0.22) and position on the ordination axis (Figure 12). Stands are located on upper side slopes and narrow, irregular ridgetops. An elevation range between 403 m to 513 m (1320 feet to 1680 feet) represents the highest portions of the Foothills section. Soils are shallow averaging 39 cm (15 inches). The C horizon is often characterized by rippable siltstone, reddish in color. Mean humus thickness is less than 2 cm (1 inch).

The vegetation of this site unit is dominated by species better adapted to dry sites with species preferring more moist sites still present, but less frequent (Table 14). Soils are partly exposed and the microclimate is warmer. The sites receive more direct sun then the cooler, shadier more mesic sites of units 1 and 2. Chestnut oak is again the main overstory species, but less prevalent than in site unit 3. Scarlet oak, second in dominance, is associated with red maple and small amounts of Virginia pine, blackgum, and black oak. The understory is dominated by an abundance of blackgum and red maple seedlings, while flowering dogwood has been reduced in importance. Deerberry *(Vaccinium stamineum)* is the primary shrub species often associating with a thick undergrowth of *Smilax* spp. Herbaceous coverage is low consisting primarily of pipsissewa, Christmas fern, desmodium and pussy-toes *(Antennaria solitaria)*.

V. DISCUSSION

A. Comparison of Results With Previous Vegetation Studies in the Southern Appalachians

Several of the dominance types described in Braun's (1950) Oak-Chestnut Forest Region parallel the findings of this study. The Mixed Mesophytic community, consisting of a wide variety of mesic species existing as co-dominants, closely resembles a combination of site units 1 and 2. A variation of this community dominated by eastern hemlock in the overstory, rosebay rhododendron in the shrub layer and partridge berry in the herbaceous stratum is equivalent to site unit 2. The majority of the mesic species described by Braun were common in the present study with the exception of yellow buckeye *(Aesculus octandra)* which was almost completely absent from the CNF site units. Site units 3 and 4 exhibit the same species combination (chestnut oak, northern red oak, white oak, black oak, and scarlet oak) as Braun's dry slope and ridge community with the exception of red maple, omitted from Braun's study as an overstory dominant.

Of the fifteen site types described by Whittaker (1956), four were consistent with types identified in this study. The Cove Hardwood forest with a habitat restricted to valleys and lower slopes, resembles site unit 1.

Dominant trees include eastern hemlock, silverbell, yellow buckeye, basswood, sugar maple, tulip-poplar, and American beech. The majority of these species are represented in site unit 1, with the exception of silverbell which did not occur in the overstory of CNF forests. Subcanopy species common to both studies are Fraser magnolia *(Magnolia fraseri)*, American holly *(Ilex opaca)*, and hophornbeam *(Ostrya virginiana)*.

Site unit 2 strongly resembles Whittaker's low elevation eastern hemlock type. In both studies, stands are located on sites slightly less mesic than protected coves and are dominated by hemlock in the overstory and rosebay rhododendron in the shrub layer. Also similar are American holly and sweet birch in the subcanopy and partridge berry in the herbaceous stratum. However, GSMNP overstory dominants, tulip-poplar and American beech, are less prevalent in the CNF type. Instead, red maple, white pine, and white oak are the more important species.

Species composition of site unit 3 is similar to Whittaker's Chestnut Oak-Chestnut type. Described as the most extensive type of lower and middle elevations of the GSMNP, it was found primarily on sheltered southerly and open northerly slopes. Chestnut oak is the primary overstory species and previously grew in association with American chestnut. Other associated species common to both studies and comprising less than 25% of the canopy are northern red oak, white oak, black oak, blackgum, and red maple. However, red maple achieves a position of greater canopy dominance in the CNF study. Subcanopies of the two studies are similar consisting of red maple, sourwood *(Oxydendrum arboreum)*, and flowering dogwood. Herbaceous species identified in both studies include figwort *(Aureolaria laevigata)*, rattlesnake root *(Prenanthes trifoliata)*, *Desmodium nudiflorum*, rattlesnake plantain *(Goodyera pubescens)*, and characteristic tangles of *Smilax* spp.

Whittaker's Virginia pine type, located on ridgetops and south facing slopes of low hills, appears to be a seral type of site unit 4. Mixtures of Virginia pine, scarlet oak, chestnut oak, black oak and blackgum characterize the overstory. Red maple is present as a small-tree, while deerberry and *Smilax* spp. are the dominate ground cover. Overall, vegetation composition strongly parallels site unit 4, although Virginia pine is breaking up and is not the dominant overstory species. In addition, red maple has a position of greater status in the tree and sapling strata of the CNF study. Whittaker did not consider the Virginia pine forest to be a seral type, although fire was described as critical to its maintenance. Consequently, fire suppression policies could have resulted in more shade tolerant species succeeding the pine, leading to a species composition more closely resembling site unit 4.

Mowbray (1966) described vegetational gradients in the Blue Ridge escarpment at elevations between 425 m to 975 m (1400 feet to 3200 feet). Conclusions common to both studies are: 1) sweet birch is a characteristic species of lower elevation moist habitats, 2) basswood occurs on moist sites near streams, 3) red maple is tolerant of xeric conditions, but may be found in any moisture regime, and 4) chestnut oak reaches peak importance at mid-elevations on relatively xeric sites.

Two of the four community types identified in Mowbray and Oosting's (1968) study in the Blue Ridge mountains correspond with site units in the present study. An Upland Oak community dominated by chestnut oak and northern red oak resembles site unit 3. Both are located on mid-slope, subxeric sites and exhibit understories dominated by flowering dogwood. However, chestnut oak was less dominant in the 1968 study and the herbaceous strata were highly dissimilar. The Upland Oak type grades into the more xeric Mixed-Oak Ridgetop community similar in habitat and species composition to site unit 4. An overstory composed primarily of scarlet oak, chestnut oak, and red maple and a shrub layer dominated by ericaceous shrubs was identified in both studies.

Three of Golden's (1981) GSMNP vegetation "complexes" were consistent with this study: 1) the Cove Hardwoods of narrow valleys and protected flats, 2) the Eastern Hemlock-

Red Maple complex of steep, protected slopes and sometimes coves, and 3) the Chestnut Oak complex found on dry sites and ridges. This complex was subdivided into several types, two of which correspond closely with site units 3 and 4. The single species dominant Chestnut Oak type closely resembles site unit 3 and the Chestnut Oak-Red Maple type parallels site unit 4.

B. Significance of Environmental Variables

Numerous combinations of environmental variables have been related to species composition in the southern Appalachians. However, the majority of studies focused on areas characterized by strong climatic, geologic, and topographic differences. Consequently, relative uniformity within the study area, particularly the narrow elevation range, may have been a factor in the weak correlations between several environmental variables and species variation. Solum thickness uniformly decreased with increasing elevation, but actual differences between site units were practically negligible. Humus thickness, although strongly statistically significant, showed differences of less than 2 cm (1 inch) between site units. Sampling difficulties due to large rock fragments throughout the solum may have contributed to the poor performance of soil variables in the statistical analysis.

Although soil thickness variables have frequently been cited as important in site quality differences (Mowbray and Oosting, 1968; Trimble and Weitzman, 1956; Gattis, 1990) topographic variables may serve as more accurate predictors in the southern Appalachians (Whittaker, 1957; Golden, 1981; Ike and Huppuch, 1968; McNab, 1990). Characteristics associated with moisture regime such as elevation, slope type and slope position are more easily measured and yield more consistent results. Landform Index effectively quantified a combination of the above mentioned variables. Identified as the most highly discriminating variable between site units in the present study, Landform Index values consistently decreased with increasing xerophytic conditions. In addition, high correlations with Terrain Shape Index, elevation and slope gradient demonstrate the effectiveness of the Index in accounting for numerous variables.

Elevation was judged to be the second most discriminating variable according to strong DCCA results and an increase in classification accuracy with its inclusion. The ordination revealed a strong correlation between elevation and species variation along axis 1 in spite of the limited 300 m (1000 feet) elevation range. Weak performance in the SWDA can possibly be attributed to the limitations of the procedure to directly relate species composition to environmental variables. Consequently, variation accounted for by certain variables may go undetected (Ter Braak, 1986). Similarly, slope percent performed strongly in the SWDA but appeared to have no ecological meaning based on site unit attributes. Alternatively, DCCA results indicate a moderately strong correlation between slope and ordination axis 2. A logical explanation might be that although slope *is* affecting species composition in some way, information conveyed by this data set is insufficient for further interpretation.

For purposes of a management oriented system, Landform Index and elevation appears to be sufficient for predicting vegetative cover type in the Foothills section of the southern unit of the Cherokee National Forest (Figure 13).

C. Dominant Species Distribution

Because of its status as a canopy and understory dominant in well over 50% of the sampled stands, the distribution of red maple will be briefly discussed. While the wide ecological amplitude of this species is well documented (Burns and Honkala, 1990), it has rarely been cited as a major overstory component. Although testing for an increase in red maple overstory dominance is beyond the scope of this study, explanations for its "perceived" increase will be discussed.

Within the study area, ideal conditions for maximum

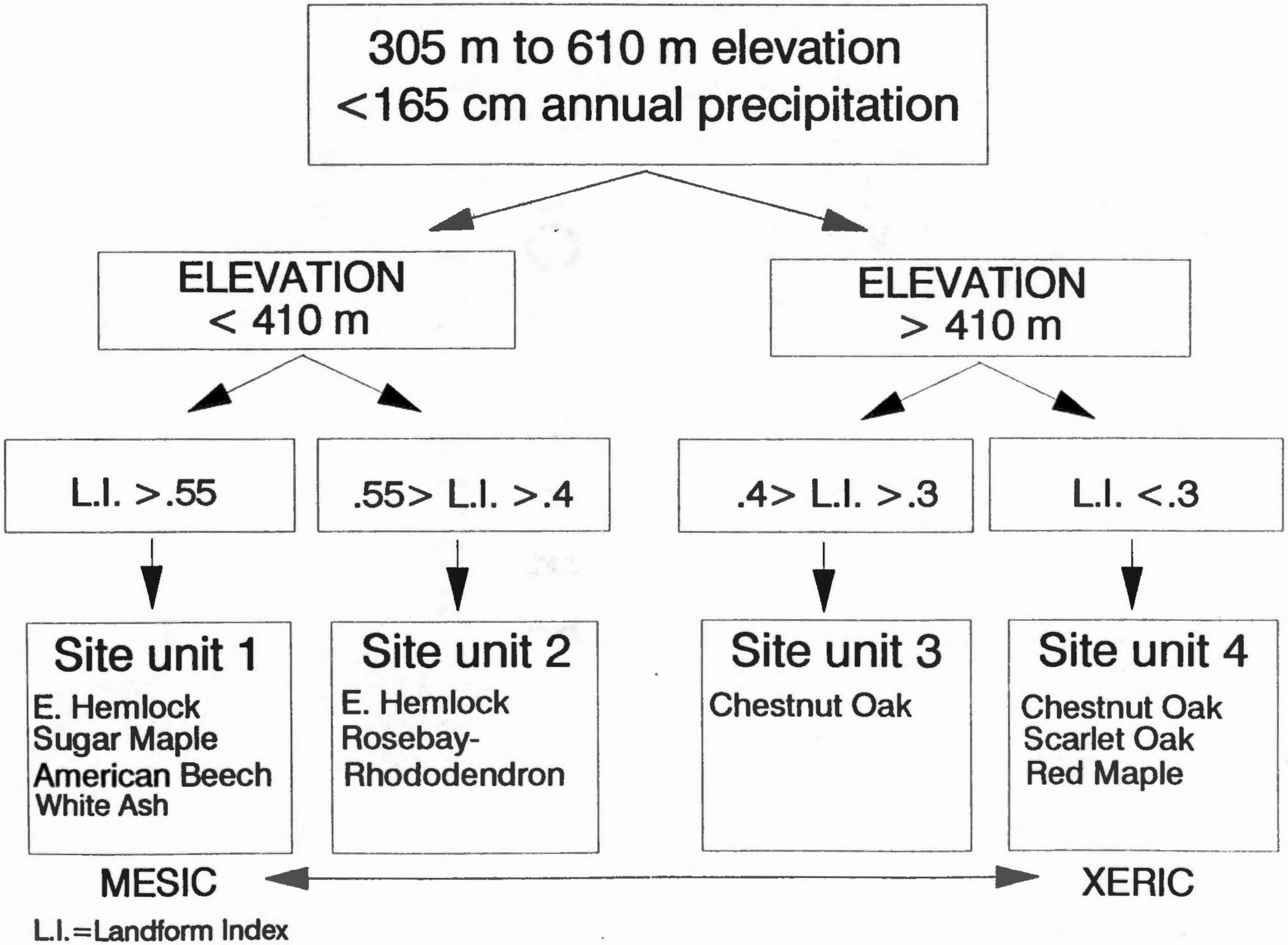


Figure 13. Landscape Ecosystem Classification model for the Foothills section of the southern unit of the Cherokee National Forest, Tennessee.

dominance appear to occur on intermediate and xeric sites, although it is found on mesic sites as well. It is an important component of all site units excluding the most mesic (unit 1) where it is replaced by sugar maple. On upper slopes and ridgetops, it is often found in combination with blackgum. Crowns are generally expansive and sprouting is prolific especially on xeric sites.

Whittaker (1956) included red maple as an important understory tree in several of his Great Smoky Mountains vegetation types, including: Red oak-Pignut hickory, White oak-Chestnut, Chestnut oak-Chestnut, Virginia pine, Pitch pine-Heath, and Table Mountain pine-Heath. The Chestnut oak-Chestnut type contained "dense stands of small stems of red maple, flowering dogwood and others." Mowbray (1966) cited red maple as a codominant overstory species in Mixed Bottomland forests, Moist Cove forests, and mid-slope Chestnut oak forests in the Bearwallow Gorge of the Blue Ridge escarpment. Mowbray and Oosting (1968) found red maple to be the most widely distributed understory tree of the Thompson Gorge in the southern Blue Ridge mountains. Represented as only a few scattered individuals in the overstory, it was found on all site types excluding the extreme mesic.

One of the most abundant trees in eastern North America, red maple is classified as a shade tolerant, early successional species. However, with a life span of up to

150 years, it is longer lived and more shade tolerant than most successional types. Seed production is prolific and germination requires little light. Although seedlings eventually die under conditions of minimal light exposure, newly germinated seedlings quickly sprout in response to an increase in light. Highly intolerant of fire, even large canopy trees are susceptible to moderately hot blazes. Conversely, vigorous sprouting can also be stimulated by fire. Following disturbance, red maple may achieve canopy dominance in stands where it once was only a minor component. Canopy dominance may be maintained for decades or indefinitely dependant upon site conditions and disturbance regime (Burns and Honkala, 1990).

Whittaker (1956) suggested that the death of American chestnut opened previously closed canopies and allowed opportunistic species, such as red maple, to flourish. Woods and Shanks (1957) found large increases in red maple crown cover in GSMNP stands formerly dominated by chestnut. Golden (1981) cites the presence of a "Disturbance Red maple complex" in GSMNP. Described as a mixture of successional stands and disturbed mesic sites, dominance was explained as a result of either windthrow, logging, or the disappearance of chestnut. A recent history of fire suppression on land once burned regularly by Native Americans and settlers has also been suggested as a partial explanation for increases in red maple dominance. Overstories comprised of red maple and other fire intolerants such as blackgum could be fire suppression indicators (Martin, ND).

Consequently, the high percent of crown cover exhibited by red maple in the present study could be the result of several factors: 1) fire suppression policies on land previously burned by Native Americans and settlers, 2) the disappearance of American chestnut, 3) logging and natural disturbances resulting in open canopy conditions, and 4) the aggressive nature of red maple in terms of gene pool and ecological amplitude (William H. Martin, personal communication).

D. Disturbance Effects on Study Results

A variety of uncontrollable factors pertaining to the study site deserve mention. The Foothills section of the CNF is easily accessible and more suitable for timber management. Consequently, it has been logged more extensively than the less accessible Mountain Highlands. Ironically, the same conditions that make an ecological classification highly desirable make it more difficult to develop. As a result of disturbance, tracts of land meeting sampling criteria were difficult to locate. In particular, coves, ridgetops, and south-facing upper slopes without signs of recent disturbance were scarce. In addition, the majority of "undisturbed" sites were located on very steep slopes with gradients averaging 48% and sometimes exceeding 90%. While gentle slopes are uncommon in this area, they do exist, and may not be adequately represented in the sample.

A recent series of natural disturbances have also affected the study area. Large sections of the southern unit of the CNF were devastated by a tornado followed by a rare winter storm in March 1993. Approximately 20% of the stands meeting stand age criteria had to be eliminated due to complete devastation. Streamside and lower slope communities appear to have been most strongly affected by the blizzard. Hundreds of large trees, particularly eastern hemlock, were completely uprooted and prevented accessibility into many areas without the aid of heavy equipment.

The loss of suitable stands in a sampling area already strongly limited by heavy disturbance could have biased the results of this study. The relatively low percent similarity between plots within site units, as shown in Figures 4 and 5, suggests substantial species variability. Therefore, it is recommended that these results be interpreted cautiously.

VI. SUMMARY AND CONCLUSIONS

A data set using relative dominance + relative density as input values was developed for designing Phase 1 of a landscape ecosystem model. Based on a combination of landform, soils and vegetation, the following site units were identified for the Foothills section of the Tellico Ranger District: 1) Eastern Hemlock - Sugar Maple - American Beech - White Ash 2) Eastern Hemlock - Rosebay Rhododendron 3) Chestnut Oak and 4) Chestnut Oak - Scarlet Oak - Red Maple. A five variable model including Landform Index, slope, humus thickness, solum thickness, and elevation, correctly predicted site unit membership 67% of the time. DCCA axis 1, interpreted as a moisture gradient, was the only axis that could be associated with any ecological meaning.

For purposes of a management oriented system, Landform Index and elevation appear to be sufficient for predicting vegetative cover of the study area (Figure 13). At elevations below 410 m (1340 feet) site units 1 and 2 can be distinguished by Landform Index values. Site unit 1, occupying highly mesic positions, was characterized by index values greater than 0.55. Unit 2, slightly less mesic, had average index values between 0.55 and 0.40. Elevations greater than 410 m (1340 feet) were more strongly dominated by site units 3 and 4. The intermediate vegetation of site unit 3 was common on positions with Landform Index values between 0.40 and 0.30. The most xeric sites of the classification were included in site unit 4 and had index values less than 0.30.

A LEC model has many potential applications. Ecologically equivalent site units may be substituted for site-index as predictor variables in growth and yield models. Growth curves can then be calculated for each site unit and applied to equivalent tracts of land (Lloyd, 1991). In addition, species selection is facilitated in complex areas dominated by numerous and/or exotic species (Fox, 1991). The most appropriate sites for management of pine, hardwood, or pine-hardwood mixtures can be identified (Jones, 1989). Equally important, interpretations for non-commodity values such as wildlife and endangered plant species habitat are possible. As the public becomes increasingly informed concerning conservation issues, more effective resource management is being demanded. The LEC model strives to support resource managers in meeting this demand.

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APPENDIX

APPENDIX. Average site unit Importance Values (I.V.) of all species identified in study area. Species are arranged by stratum.

SITE UNIT 1

E. Hemlock - Sugar Maple - American Beech - White Ash

TREE STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	1.74
Acer saccharum	Sugar maple	32.95
Betula lenta	Sweet birch	6.47
Carya glabra	Pignut hickory	9.21
Carya tomentosa	Mockernut hickory	16.64
Fagus grandifolia	American beech	22.37
Fraxinus americana	White ash	22.18
Liriodendron tulipifera	Tulip-poplar	14.41
Magnolia acuminata	Cucumber tree	1.94
Magnolia fraseri	Fraser magnolia	1.41
Ostrya virginiana	Hop hornbeam	2.51
Quercus alba	White oak	8.15
Quercus prinus	Chestnut oak	1.75
Quercus rubra	Northern red oak	5.84
Tsuga canadensis	Eastern hemlock	42.69
Tilia heterophylla	Basswood	9.76

SAPLING & SHRUB STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	1.47
Acer saccharum	Sugar maple	30.42
Carya tomentosa	Mockernut hickory	1.75
Cornus florida	Flowering dogwood	38.37
Fagus grandifolia	American beech	46.11
Fraxinus americana	White ash	3.95
Halesia carolina	Silverbell	18.66
Hamamelis virginiana	Witch hazel	3.54
Ilex opaca	American holly	4.51
Magnolia acuminata	Cucumber tree	1.07
Ostrya virginiana	Hop hornbeam	4.09
Tilia heterophylla	Basswood	8.53
Tsuga canadensis	Eastern hemlock	11.88
Viburnum acerifolium	Maple-leaf viburnum	0.67

REGENERATION STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	2.25
Acer saccharum	Sugar maple	34.62
Asimina triloba	Pawpaw	4.27
Carpinus caroliniana	American hornbeam	8.83
Carya glabra	Pignut hickory	3.13
Cornus florida	Flowering dogwood	2.65
Fagus grandifolia	American beech	2.68
Halesia carolina	Silverbell	50.91
Hamamelis virginiana	Witch hazel	7.79
Hydrangea arborescens	Wild hydrangea	1.57
Magnolia fraseri	Fraser magnolia	4.93
Ostrya virginiana	Hop hornbeam	15.83
Pinus strobus	White pine	1.44
Pyrularia pubera	Buffalo nut	4.24
Quercus alba	White oak	0.57
Quercus rubra	Northern red oak	1.51
Tilia heterophylla	Basswood	10.06
Tsuga canadensis	Eastern hemlock	10.45
Viburnum acerifolium	Maple-leaf viburnum	7.26

HERBACEOUS & VINES STRATUM

Scientific name	Common name	I.V. 100
Actaea pachypoda	Doll's eyes	2.05
Adiantum pedatum	Maidenhair fern	2.85
Astilbe biternata	False goatsbeard	1.09
Aster spp.	Aster spp.	2.57
Bignonia capreolata	Cross vine	3.22
Dentaria diphylla	Toothwort	0.30
Desmodium nudiflorum	Desmodium nudiflorum	1.23
Desmodium spp.	Desmodium spp.	2.83
Dioscorea villosa	Wild yam	2.09
Dryopteris marginalis	Marginal wood fern	0.71
Euonymus americanus	Strawberry bush	1.74
Eupatorium purpureum	Joe-pye weed	0.94
Galium circaezans	Bedstraw	0.22
Hepatica acutiloba	Hepatica acutiloba	7.78
Hexastylis arifolia	Little brown jug	0.50
Hypericum spp.	Hypericum spp.	0.56
Iris cristata	Dwarf crested iris	0.48
Mitchella repens	Partridge berry	1.62
Osmorhiza claytonii	Sweet cicely	0.42
Panicum spp.	Panicum spp.	0.89
Parthenocissus quinquefolia	Virginia creeper	10.12
Polystichum Roth acrostichoides	Christmas fern	21.72
Polygonatum biflorum	Solomon's seal	1.47
Prenanthes trifoliata	Rattlesnake root	0.67
Sanguinaria canadensis	Bloodroot	0.57
Sanicula canadensis	Snakeroot	0.07
Smilax spp.	Smilax spp.	1.20

Smilacina racemosa	False solomon's seal	2.19
Spigelia marilandica	Indian pink	0.11
Thaspium barbinode	Meadow parsnip	1.57
Thalictrum thalictroides	Rue anemone	1.63
Tiarella cordifolia	Foamflower	4.04
Toxicodendron radicans	Poison ivy	2.14
Uvularia perfoliata	Bellwort	0.14
Viola spp.	Violet	18.06
Vitis spp.	Grapevine	0.22

SITE UNIT 2

E. Hemlock - Rosebay Rhododendron

TREE STRATUM

Scientific name	Common name	I.V 200
Acer rubrum	Red maple	21.10
Acer saccharum	Sugar maple	0.91
Aesculus octandra	Yellow buckeye	1.41
Betula lenta	Sweet birch	4.17
Carpinus caroliniana	American hornbeam	4.53
Carya glabra	Pignut hickory	1.03
Carya tomentosa	Mockernut hickory	10.26
Cornus florida	Flowering dogwood	0.50
Fagus grandifolia	American beech	11.47
Liriodendron tulipifera	Tulip-poplar	9.24
Magnolia tripetala	Umbrella magnolia	0.34
Oxydendrum arboreum	Sourwood	6.59
Pinus echinata	Shortleaf pine	0.47
Pinus strobus	White pine	19.22
Pinus virginiana	Virginia pine	0.37
Platanus occidentalis	Sycamore	0.75
Quercus alba	White oak	15.55
Quercus coccinea	Scarlet oak	0.59
Quercus prinus	Chestnut oak	5.15
Quercus rubra	Northern red oak	7.01
Quercus velutina	Black oak	1.37
Tsuga canadensis	Eastern hemlock	77.19
Tilia heterophylla	Basswood	0.78

SAPLING & SHRUB STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	19.89
Betula lenta	sweet birch	5.20
Carpinus caroliniana	American hornbeam	1.96
Cornus florida	Flowering dogwood	9.80
Fagus grandifolia	American beech	2.44
Fraxinus americana	White ash	1.08
Halesia carolina	Silverbell	8.07
Hamamelis virginiana	Witch hazel	0.37
Ilex opaca	American holly	4.70
Juniperus virginiana	Eastern red-cedar	0.58
Liquidambar styraciflua	Sweet gum	2.09
Magnolia fraseri	Fraser magnolia	3.51
Magnolia tripetala	Umbrella magnolia	0.68
Nyssa sylvatica	Blackgum	3.32
Oxydendrum arboreum	Sourwood	3.51
Pinus strobus	White pine	4.70
Pyrularia pubera	Buffalo nut	2.77

Quercus prinus	Chestnut oak	0.88
Rhododendron maximum	Rosebay rhododendron	32.32
Sassafras albidum	Sassafras	0.62
Tilia heterophylla	Basswood	0.83
Tsuga canadensis	Eastern hemlock	90.28
Viburnum acerifolium	Maple-leaf viburnum	0.45

REGENERATION STRATUM

Scientific name	Common name	I.V. 200
Acer pensylvanicum	Striped maple	4.51
Acer rubrum	Red maple	3.95
Acer saccharum	Sugar maple	3.59
Aesculus octandra	Yellow buckeye	3.11
Asimina triloba	Pawpaw	8.69
Cornus florida	Flowering dogwood	2.08
Fagus grandifolia	American beech	0.72
Fraxinus americana	White ash	1.49
Halesia carolina	Silverbell	23.98
Hamamelis virginiana	Witch hazel	2.34
Ilex opaca	American holly	0.88
Kalmia latifolia	Mountain laurel	2.43
Leucothoe fontanesiana	Dog hobble	7.47
Magnolia fraseri	Fraser Magnolia	1.37
Nyssa sylvatica	Blackgum	2.10
Oxydendrum arboreum	Sourwood	10.33
Pinus strobus	White pine	2.80
Quercus rubra	Northern red oak	1.79
Quercus velutina	Black oak	2.80
Rhododendron maximum	Rosebay rhododendron	45.39
Sassafras albidum	Sassafras	1.11
Tilia heterophylla	Basswood	1.66
Tsuga canadensis	Eastern hemlock	48.41
Viburnum acerifolium	Maple-leaf viburnum	4.47

HERBACEOUS & VINES STRATUM

Scientific name	Common name	I.V. 100
Adiantum pedatum	Maidenhair fern	0.46
Aster spp.	Aster spp.	0.30
Bignonia capreolata	Cross vine	5.07
Chimaphila maculata	New Jersey tea	0.90
Dennstaedtia punctilobula	Hay scented fern	5.87
Desmodium spp.	Desmodium spp.	0.17
Dioscorea villosa	Wild yam	2.36
Dryopteris marginalis	Marginal wood fern	1.76
Euonymus americanus	Strawberry bush	5.06
Eupatorium purpureum	Joe-pye weed	0.26
Fragaria virginiana	Wild strawberry	0.34
Galax aphylla	Beetleweed	1.23
Galium circaezans	Bedstraw	0.24
Gaultheria procumbens	Wintergreen	0.74

Goodyera pubescens	Rattlesnake plantain	0.88
Hepatica acutiloba	Hepatica acutiloba	0.55
Hexastylis arifolia	Little brown jug	7.43
Hieracium venosum	Rattlesnake weed	0.20
Juniperus virginiana	Eastern red-cedar	0.53
Lobelia inflata	Indian tobacco	0.17
Mitchella repens	Partridge berry	17.02
Osmorhiza claytonii	Sweet cicely	0.53
Panicum spp.	Panicum spp.	0.72
Parthenocissus quinquefolia	Virginia creeper	3.14
Polystichum Roth acrostichoides	Christmas fern	9.74
Polygonatum biflorum	Solomon's seal	3.10
Prenanthes trifoliata	Rattlesnake root	0.37
Rubus spp.	Rubus spp.	0.31
Sanguinaria canadensis	Bloodroot	0.07
Senecio aureus	Golden ragwort	0.17
Smilax spp.	Smilax spp.	9.91
Smilacina racemosa	False solomon's seal	0.90
Thalictrum thalictroides	Rue anenome	1.63
Thelypteris hexagonoptera	Broad beech fern	0.07
Thelypteris noveboracensis	New york fern	1.94
Tiarella cordifolia	Foamflower	0.31
Toxicodendron radicans	Poison ivy	2.92
Trillium spp.	Trillium spp.	2.37
Uvularia perfoliata	Bellwort	0.11
Viola spp.	Violet	7.20
Vitis spp.	Grapevine	2.88

SITE UNIT 3

Chestnut Oak

TREE STRATUM

Scientific name	Common name	I.V 200
Acer rubrum	Red maple	18.93
Acer saccharum	Sugar maple	0.69
Carya glabra	Pignut hickory	6.35
Carya tomentosa	Mockernut hickory	4.89
Cornus florida	Flowering dogwood	0.55
Fraxinus americana	White ash	2.47
Liriodendron tulipifera	Tulip-poplar	12.25
Nyssa sylvatica	Blackgum	2.90
Pinus echinata	Shortleaf pine	0.86
Pinus strobus	White pine	2.76
Pinus virginiana	Virginia pine	3.16
Quercus alba	White oak	7.19
Quercus coccinea	Scarlet oak	8.68
Quercus prinus	Chestnut oak	115.02
Quercus rubra	Northern red oak	12.69
Quercus velutina	Black oak	0.27
Robinia pseudoacacia	Black locust	0.76

SAPLING & SHRUB STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	23.17
Acer saccharum	Sugar maple	0.83
Asimina triloba	Pawpaw	0.62
Carya glabra	Pignut hickory	5.58
Carya tomentosa	Mockernut hickory	2.48
Cercis canadensis	Redbud	2.17
Cornus florida	Flowering dogwood	115.29
Fagus grandifolia	American beech	1.63
Fraxinus americana	White ash	2.52
Halesia carolina	Silverbell	3.15
Liriodendron tulipifera	Tulip-poplar	1.63
Magnolia fraseri	Fraser magnolia	0.30
Nyssa sylvatica	Blackgum	12.39
Oxydendrum arboreum	Sourwood	2.42
Pinus strobus	White pine	3.71
Quercus prinus	Chestnut oak	17.35
Robinia pseudoacacia	Black locust	0.28
Viburnum acerifolium	Maple-leaf viburnum	7.13

REGENERATION STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	2.60
Acer saccharum	Sugar maple	2.76
Amelanchier arborea	Serviceberry	1.39
Carpinus caroliniana	American hornbeam	1.20
Carya glabra	Pignut hickory	6.98
Carya tomentosa	Mockernut hickory	4.41
Castanea dentata	American chestnut	3.95
Ceanothus americanus	New Jersey tea	0.88
Cercis canadensis	Redbud	3.20
Cornus florida	Flowering dogwood	55.23
Fagus grandifolia	American beech	3.94
Fraxinus americana	White ash	4.38
Liriodendron tulipifera	Tulip-poplar	2.13
Nyssa sylvatica	Blackgum	23.16
Ostrya virginiana	Hop hornbeam	1.37
Oxydendrum arboreum	Sourwood	2.03
Pinus echinata	Shortleaf pine	0.43
Pinus virginiana	Virginia pine	1.45
Prunus serotina	Wild black cherry	3.59
Quercus coccinea	Scarlet oak	0.46
Quercus prinus	Chestnut oak	0.75
Quercus rubra	Northern red oak	1.14
Quercus velutina	Black oak	0.33
Robinia pseudoacacia	Black locust	2.45
Rosa spp.	Rosa spp.	0.41
Sassafras albidum	Sassafras	7.24
Vaccinium spp.	Vaccinium spp.	2.20
Vaccinium stamineum	Deerberry	6.17
Viburnum acerifolium	Maple-leaf viburnum	32.37

HERBACEOUS & VINES STRATUM

Scientific name	Common name	I.V. 100
Actaea pachypoda	Doll's eyes	0.26
Adiantum pedatum	Maidenhair fern	2.39
Antennaria solitaria	Pussy-toes	0.28
Aster spp.	Aster spp.	2.69
Aster undulatus	Aster undulatus	2.12
Aureolaria laevigata	Figwort	3.74
Bignonia capreolata	Cross vine	0.17
Ceanothus americanus	New Jersey tea	0.24
Chimaphila maculata	Pipsissewa	8.17
Coreopsis major	Coreopsis major	0.63
Desmodium nudiflorum	Desmodium nudiflorum	6.28
Desmodium spp.	Desmodium spp.	9.75
Dioscorea villosa	Wild yam	9.29
Epigaea repens	Trailing arbutus	0.25
Euonymus americanus	Strawberry bush	0.78
Eupatorium purpureum	Joe-pye weed	0.96

Galium circaezans	Bedstraw	0.73
Goodyera pubescens	Rattlesnake plantain	0.16
Hexastylis arifolia	Little brown jug	0.38
Houstonia purpurea	Bluets	0.52
Iris cristata	Dwarf crested iris	0.05
Panicum spp.	Panicum spp.	0.63
Parthenocissus quinquefolia	Virginia creeper	3.05
Passiflora lutea	Passion flower	0.12
Polystichum Roth acrostichoides	Christmas fern	6.81
Polygonatum biflorum	Solomon's seal	0.68
Porteranthus trifoliatus	Indian physic	0.21
Prenanthes trifoliata	Rattlesnake root	0.54
Rosa spp.	Rosa spp.	1.30
Sanguinaria canadensis	bloodroot	0.30
Sanicula canadensis	Snakeroot	0.56
Smilax spp.	Smilax spp.	12.89
Smilacina racemosa	False solomon's seal	1.29
Solidago caesia	Bluestemed goldenrod	2.50
Solidago spp.	Solidago spp.	0.23
Spigelia marilandica	Indian pink	1.21
Thalictrum thalictroides	Rue anenome	0.97
Tiarella cordifolia	Foamflower	0.95
Toxicodendron radicans	Poison ivy	4.50
Uvularia perfoliata	Bellwort	0.08
Viola spp.	Violet	3.89
Viola triloba	Viola triloba	2.25
Vitis spp.	Grapevine	5.13

SITE UNIT 4

Chestnut Oak - Scarlet Oak - Red Maple

TREE STRATUM

Scientific name	Common name	I.V 200
Acer rubrum	Red maple	17.90
Carya glabra	Pignut hickory	6.41
Carya tomentosa	Mockernut hickory	7.64
Cornus florida	Flowering dogwood	1.51
Fraxinus americana	White ash	1.07
Liriodendron tulipifera	Tulip-poplar	2.48
Nyssa sylvatica	Blackgum	11.65
Oxydendrum arboreum	Sourwood	4.11
Pinus echinata	Shortleaf pine	4.20
Pinus strobus	White pine	4.60
Pinus virginiana	Virginia pine	13.85
Quercus alba	White oak	4.56
Quercus coccinea	Scarlet oak	22.87
Quercus falcata	Southern red oak	0.67
Quercus prinus	Chestnut oak	81.98
Quercus rubra	Northern red oak	1.49
Quercus velutina	Black oak	10.99
Robinia pseudoacacia	Black locust	0.41
Tsuga canadensis	Eastern hemlock	1.63

SAPLING & SHRUB STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	44.61
Acer saccharum	Sugar maple	1.86
Calycanthus floridus	Sweetshrub	0.22
Carya glabra	Pignut hickory	5.06
Carya tomentosa	Mockernut hickory	4.92
Cercis canadensis	Redbud	0.48
Cornus florida	Flowering dogwood	40.61
Fagus grandifolia	American beech	0.18
Fraxinus americana	White ash	0.44
Hamamelis virginiana	Witch hazel	2.07
Liriodendron tulipifera	Tulip-poplar	4.40
Nyssa sylvatica	Blackgum	55.52
Oxydendrum arboreum	Sourwood	7.90
Pinus echinata	Shortleaf pine	0.77
Pinus strobus	White pine	12.90
Prunus serotina	Wild black cherry	0.38
Pyrularia pubera	Buffalo nut	1.15
Quercus alba	White oak	0.44
Quercus coccinea	Scarlet oak	0.72
Quercus prinus	Chestnut oak	9.85
Quercus velutina	Black oak	1.73

Rhododendron calendulaceum	Flame azalea	2.15
Sassafras albidum	Sassafras	0.29
Vaccinium spp.	Vaccinium spp.	0.56
Vaccinium stamineum	Deerberry	0.45
Viburnum acerifolium	Maple-leaf viburnum	0.32

REGENERATION STRATUM

Scientific name	Common name	I.V. 200
Acer rubrum	Red maple	35.75
Amelanchier arborea	Serviceberry	2.06
Asimina triloba	Pawpaw	1.80
Calycanthus floridus	Sweetshrub	4.17
Carya glabra	Pignut hickory	4.13
Carya tomentosa	Mockernut hickory	9.72
Cornus florida	Flowering dogwood	19.39
Fagus grandifolia	American beech	0.50
Hamamelis virginiana	Witch hazel	4.09
Ilex decidua	Possum haw	0.49
Liriodendron tulipifera	Tulip-poplar	2.15
Nyssa sylvatica	Blackgum	33.65
Oxydendrum arboreum	Sourwood	2.48
Pinus echinata	Shortleaf pine	1.83
Pinus strobus	White pine	10.31
Pyrularia pubera	Buffalo nut	2.29
Quercus alba	White oak	1.06
Quercus coccinea	Scarlet oak	6.34
Quercus prinus	Chestnut oak	19.33
Quercus velutina	Black oak	3.13
Rhododendron calendulaceum	Flame azalea	0.55
Robinia pseudoacacia	Black locust	4.59
Rubus spp.	Rubus spp.	1.80
Sassafras albidum	Sassafras	5.33
Vaccinium spp.	Vaccinium spp.	7.05
Vaccinium stamineum	Deerberry	11.22
Viburnum acerifolium	Maple-leaf viburnum	4.80

HERBACEOUS & VINES STRATUM

Scientific name	Common name	I.V. 100
Antennaria solitaria	Pussy-toes	4.39
Apocynum spp.	Apocynum spp.	0.10
Aster spp.	Aster spp.	1.37
Aster undulatus	Aster undulatus	0.58
Aureolaria laevigata	Figwort	1.25
Chimaphila maculata	Pipsissewa	15.81
Desmodium nudiflorum	Desmodium nudiflorum	0.53
Desmodium spp.	Desmodium spp.	4.52
Dioscorea villosa	Wild yam	1.36
Euonymus americanus	Strawberry bush	0.98
Eupatorium purpureum	Joe-pye weed	0.62
Fragaria virginiana	Wild strawberry	4.57

Galax aphylla	Beetleweed	0.44
Gaultheria procumbens	Wintergreen	1.00
Goodyera pubescens	Rattlesnake plantain	0.33
Hexastylis arifolia	Little brown jug	1.60
Hieracium venosum	Rattlesnake weed	0.40
Houstonia purpurea	Bluets	0.97
Monarda spp.	Monarda spp.	0.13
Panicum spp.	Panicum spp.	4.25
Passiflora lutea	Passion flower	0.10
Polystichum Roth acrostichoides	Christmas fern	7.03
Polygonatum biflorum	Solomon's seal	0.83
Polypodium polypodioides	Resurrection fern	0.33
Prenanthes trifoliata	Rattlesnake root	0.93
Rosa spp.	Rosa spp.	0.53
Silene stellata	Starry campion	1.66
Smilax spp.	Smilax spp.	36.63
Smilacina racemosa	False solomon's seal	4.33
Solidago spp.	Solidago spp.	0.18
Uvularia perfoliata	Bellwort	0.32
Viola spp.	Violet	1.90

VITA

Kathleen A. Yoke was born in Bradford, Pennsylvania on March 6, 1965. She attended primary and secondary schools in Anniston, Alabama before entering Auburn University in 1983. She received the Bachelor of Science Degree in Economics in August 1987. Following a tour with the U.S. Peace Corps in northern Thailand, she entered the University of Tennessee in August 1991. She is scheduled to receive the Master of Science Degree in Forestry in May, 1994.