RATIONALE FOR A MULTIFACTOR FOREST SITE CLASSIFICATION SYSTEM FOR THE SOUTHERN APPALACHIANS[1]

W. Henry McNab[2]

Abstract.--A method for classifying the forested landscape into homogeneous units is proposed for the Southern Appalachian Mountains. The hierarchical system has seven levels and uses a modification of the land systems inventory structure to group landforms with similar environmental characteristics. The principal factors considered at the seven levels, in increasing order of detail, are: physiographic province (VII), topography (VI), geology (V), slope type (IV), slope aspect and position (III), slope shape and gradient (II), and site (I). Components, such as soils and vegetation, can be integrated with landform in the lower levels. The system is compatible with multifactor terrestrial classifications used in adjacent regions and can be applied by using remote sensing and geographic information systems.

Keywords: Land systems inventory, landform component

INTRODUCTION

The southern portion of the Blue Ridge Physiographic Province extends in a northeast-southwest direction from north Georgia to Roanoke Gap in Virginia and encompasses about 30 million acres. Referred to as the Southern Appalachians by Braun (1950), more than 60 percent of this area is forested with a host of commercially valuable hardwood species. In North Carolina, for example, a favorable growing-season climate and readily available markets combine to make forestry a primary factor of the economy. In addition, about 24% of the almost 4 million acres of commercial forest land is in National Forest ownership and 75% of this forest land consists of hardwood forest-type groups (Craver 1985). However, a basic weakness of forest management in the Southern Appalachian Mountains is the lack of a widely applicable, satisfactory method of site classification.

Ecologically, this area is situated entirely within Braun's (1950) Oak-Chestnut Forest Region of the Eastern Deciduous Forest Formation. Geology is complex and includes igneous and sedimentary rocks that have been metamorphosed during three orographic periods (Cook et al. 1980). Topography is variable and generally steep, with elevations ranging from 1,300 feet in intermountain valleys to over 6,000 feet at numerous peaks in the Blue Ridge Mountains on the east and Unaka Mountains on the west. Topography is somewhat correlated with geology, but there are numerous exceptions to this generalization (Hack 1982). Climate of this region is characterized as mild and humid with conditions generally favorable for tree growth. Mean daily temperature is about 40 °F in January and 75 °F during July. The length of growing season ranges from 5 to 7 months and is related to elevation and latitude. Precipitation is correlated with physiography and topography, and ranges from about 40 inches in low-elevation intermountain valleys to more than 100 inches in the higher mountains, especially in the Southwest. About half of the rainfall occurs during the growing season.

The varied geology, topography, and climate of the Southern Appalachians combine to produce an array of sites. Characteristic of this area is the extremely varied forest and herbaceous growth. Braun (1950) and others have described

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[1]Paper presented at Sixth Central Hardwood Forest Conference, Knoxville, TN, February 24-26, 1987.

[2]Research Forester, USDA Forest Service, Southeastern Forest Experiment Station, Bent Creek Experimental Forest, Route 3, Box 1249, Asheville, NC 28806.

this area as unusual in the richness of species of forest trees and the large size attained by many species. Using an earlier classification of Southern Appalachian forests (SAF 1926), Braun recognized three principal forest groups: (1) the high-altitude northern forest, (2) moist slope and cove forest, and (3) dry slope and ridge. Within each forest group are a number of forest types with varying species composition that require certain environmental regimes of moisture, temperature, and nutrients which allow them to occupy and dominate a particular site.

Past land use and disturbance have had major effects on the forest composition and characteristics of the overstory. Beginning with the time of settlement, extensive clearing of the coves' more gentle slopes and exploitative logging, wildfires, and timber high-grading have changed the composition of most present-day timber stands. Perhaps more significant, from the standpoint of site productivity and species composition, many of today's forest stands originated from unmerchantable or suppressed trees released by the selective harvest of the overstory that occurred even on managed lands until 1970. Site index estimation and observations of species suitability may be biased for many areas.

Soil-site studies have correlated topography and soil variables with site productivity for restricted areas in the Southern Appalachians and adjacent provinces. These studies include a variety of species in north Georgia (Ike and Huppuch 1968) and oaks in western North Carolina (Doolittle 1957). Results, however, are generally not widely applicable throughout the region because of different stand, climatic, geologic, and soil conditions. Also, these and most other studies have been primarily concerned with forest productivity and do not address questions of species suitability, competition, survival, and other management problems. Ecological classifications, or integrated multifactor site classifications, are an attempt to correct deficiencies of limited applicability, restriction to timber resources, and lack of information on other management options. Ecological classifications are now mandated for resource management on National Forest lands (Larson and Schlatterer 1984).

Soils are the basis for classification of National Forest lands in the South. D. Gray Aydelott developed a multifactor system for Region 8 that combines landforms and soils into relatively homogeneous "ecological management units" (USDA 1972). In the mountains, ecological management units consist of five components--landform, source of materials, texture, water regime, and modifiers--and are interpreted for suitability of multiple resource uses that have similar management requirements. The Region 8 guide included most of the components of an ecological classification system but lacked a correlation with vegetation and was sometimes criticized as too subjective.

East of the Mississippi River, ecological classifications of National Forest lands are principally based on variations of land systems inventory (Wertz and Arnold 1975). For example, these techniques have been applied on the Mark Twain (Miller 1981) and Monongahela National Forests (Churchill 1982). Smalley (1979, 1980, 1982, 1983, 1984a, 1986) has applied a variation of the land systems inventory to the Interior Uplands of Alabama, Tennessee, Kentucky, Georgia, and Virginia. The Tennessee Valley Authority has used Bailey's (1980) ecoregions, a modification of land systems inventory, to classify forest sites in much of their watershed (Fink and Elder 1982). These approaches to site classification are various forms of regionalization, whereby geographical areas are successively subdivided into smaller, more detailed homogeneous units (Bailey et al. 1978).

Habitat typing (Pfister and Arno 1980), a taxonomic approach to classification where sites with similar vegetation are grouped into classes, is widely used on public lands in the West. In the East, habitat typing has been applied only on a limited basis in Michigan and Wisconsin (Kotar and Coffman 1984), and in South Carolina (Jones et al. 1981). The Southern Region of National Forests is investigating an ecosystem classification system based on vegetation and soils, which could be useful for resources other than just timber.[3]

Vegetation as part of a multicomponent system has also been studied and successfully applied in the eastern United States. Barnes et al. (1982) describe a system that uses vegetation along with soils and topography for glaciated landscapes of Michigan. Leak (1982) used a similar vegetation-soils approach to classification on glacier-sorted soils in New England.

The purpose of this paper is to describe a first approximation of an integrated, multifactor classification system for the Southern Appalachian forest region of western North Carolina, northwestern South Carolina, northern Georgia, eastern Tennessee, and western Virginia. This region contains three physiographic provinces, including large areas of the Blue Ridge and Ridge and Valley, and a very small part of the Appalachian Plateaus (Fig. 1). Braun's (1950) Oak-Chestnut Forest Region defines this mountainous area, where much of the nonagricultural land is occupied by predominantly hardwood forests. The most detailed classification of forest sites will be for the southern Blue Ridge Province because the majority of our research experience is from this area. Forest managers may use this classification for subdivision of landforms into broad landscape

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[3]Personal communication, Levester Pendergrass, Botanist, USDA Forest Service, Atlanta, GA, May 1985.

features, for evaluation of stands for species suitability, and estimates of forest productivity. This paper is not intended to be an exhaustive review of literature on site classification; these are available elsewhere (Jones 1969, Carmean 1975). Instead, I present selected pertinent references to support my choice of a multifactor classification system for the Southern Appalachians.

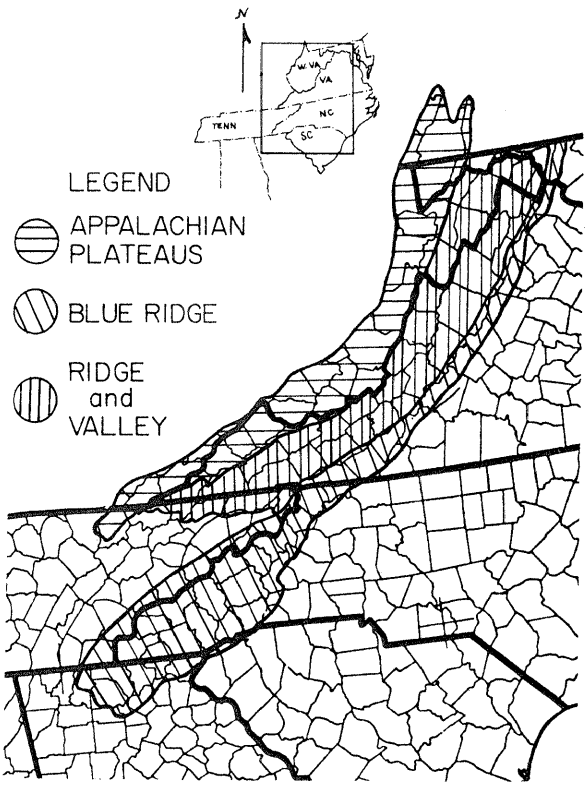

Figure 1.--Physiographic provinces within the Oak-Chestnut Forest Region (Braun 1950) in the southeastern United States.

METHODS

A hierarchical approach to classification and mapping is of the greatest value to land managers. With this technique, mapping units at any level may be combined to form the next higher level, or subdivided to form units on the level below. Thus, aggregation or disaggregation provides a method for information to be displayed or data summarized on many planning levels.

The structure used for this multifactor classification is a modification of the land systems inventory developed by Wertz and Arnold (1975). Land systems inventory is a method of integrating climate, topography, and geology with physical features of landforms that are arranged in a hierarchy of increasing local significance. The landform component, when integrated with other components of soil and vegetation, produces a classification with ecological properties.

The land systems inventory consists of seven levels, ranging from extensively described physiographic provinces to minutely defined measured sites. Following an outline presented by Wertz and Arnold (1975), the classification is shown below.

Level	Name	Basis for Delineation	Size range of area unit (mi^2)
		BASIC COMPONENTS	
VII	Province	Geomorphic history	1000's
VI	Section	Topography, climate	100's to 1000's
V	Subsection	Geology, rock type	10's to 100's
		MANIFEST COMPONENTS	
IV	Landtype Association	Slope type	1 to 10's
III	Landtype	Slope aspect and position	1/10 to 1
II	Landtype Phase	Slope shape and gradient	1/100 to 1/10
		INTEGRATED COMPONENTS	
I	Site	All environmental variables	Acre or less

Similarly, the physical description of each level becomes increasingly specific. With the exception of province, this classification scheme utilizes genetically significant properties of landforms at each level. Other taxonomic classifications have been developed that deal with soils (Soil Survey Staff 1975), aquatic habitats (Cowardin et al. 1979), and habitat types (Daubenmire and Daubenmire 1968) in the United States.

Wertz and Arnold (1975) grouped elements of landforms into two broad types of physical components--basic and manifest. Basic components are the independently acting and largely unapparent environmental properties of the landscape, whereas manifest components are features of landscapes that depend on each other and can be observed. Site, the lowest hierarchical level, is classed as a third interpreted component but will not be evaluated in the present system.

Basic Components

Three levels of basic components dealing with geologic structure, topography and climate, and geologic influences are recognized in the upper hierarchy of the land systems inventory. The basic components may be considered as representing gradients of temperature and nutrients. Information on basic components is available and can be provided to users of this system on maps of proper scale. The land systems inventory begins with the principal subdivisions of the North America Continent.

Level VII--Province

Physiographic province, as delineated by Fenneman (1938), is the basis for differentiation in Level

VII. Province provides an indication of overall geologic structure and, to a lesser degree, climate and forest associations. The structure of this level is:

VII. Province
- A. Blue Ridge
  - 1. Northern
  - 2. Southern
- B. Ridge and Valley
  - 1. Middle
  - 2. Southern
- C. Appalachian Plateaus
  - 1. Cumberland Mountains
  - 2. Allegheny Plateau

Mapping at a scale of 1:5,000,000 can be used to display information at this level.

The Blue Ridge Province is typically subdivided into the northern and southern parts at the Roanoke River Gap in southern Virginia because of differing climate, reduced range of elevations (Fenneman 1938), and differences in vegetation (Braun 1950). The boundary between the two sections of the Ridge and Valley Province in Virginia is at the New River, based on Fenneman's definition. My classification deals principally with the middle section of this province in Virginia, an area in Braun's (1950) Oak-Chestnut Forest Region with forest types similar to those of the Southern Appalachians. Inclusion of the middle section provides an integrated site classification for this area of Virginia and supplies a link with site classification in progress in the Interior Uplands and work planned for the Southern Ridge and Valley.[4] Smalley's (1984a) classification will be used for a small part of the Appalachian Plateau in southwestern Virginia. Our work will initially concentrate in the Southern Blue Ridge Province because most of our knowledge and experience is from this area.

Level VI--Section

Sections are divisions of a province and are differentiated on the basis of climate as modified by topography. Elevation is the main topographic variable considered at this level. It affects soil and air temperature, precipitation, and length of growing season. In the mountains, soils are grouped into thermal classes largely by elevation. For example, the break between mesic and frigid soil temperature regimes, separating the intermediate and high mountains, is between 4,600 to 5,000 feet (Daniels et al. 1984). The lower elevation of intermediate height mountains is about 2,500 feet (USDA 1972) but cannot be precisely defined. Daniels et al. (1984) reports that morphological properties of soils change below 3,000 feet elevation. Intermountain basins also tend to have lower annual precipitation resulting from an orographic influence (Grafton and Dickerson 1969). Empirical models of rainfall applicable to the Blue Ridge Mountains of Georgia are available for use in fishery habitats and site classification.[5]

Precipitation is included as a separate environmental variable because of its direct correlation with the soil moisture regime and growth of woody plants (Zahner 1968). Grafton and Dickerson (1969) found that only about 50% of variation in precipitation could be explained by the effect of elevation. In certain areas precipitation varies predictably, as shown by the high rainfall that occurs in areas along the southwestern Blue Ridge escarpment in North Carolina as a result of an orographic effect on humid air from the Gulf of Mexico (USDA 1941). The Soil Conservation Service accounts for some of the variation in soil site productivity by delineating high rainfall phases of soil series.[6] Growth of hardwood tree species has been correlated with precipitation (Tryon et al. 1957, Beck 1984). Although Beck (1984) found that yellow-poplar radial increment is correlated with growing-season precipitation, he also reported that rainfall can vary widely between a forest site and the nearest National Weather Service climatic station due primarily to local topography. The structure of Level VI is as follows:

VI. Section
- A. Elevation (feet)
  - 1. High mountains (>4,500)
  - 2. Intermediate mountains (2,500 to 4,500)
  - 3. Intermountain basins (<2,500)
- B. Precipitation (inches)
  - 1. Normal (<60)
  - 2. High (>60)

Sections can be adequately displayed on 1:500,000-scale maps.

Climatic variables apparently have a greater effect on the distribution of forest vegetation than geologic variables and therefore enter the hierarchy at a higher level. For example, VanGroenewoud and Ruitenberg (1982) found that climate affects forest vegetation to a greater extent than parent material in New Brunswick, Canada. In the Southern Appalachians, the spruce-fir type is found on several different geologic substrata from metamorphosed igneous to metamorphosed sedimentary rocks but is restricted

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[4] Personal communication, Glendon W. Smalley, Soil Scientist, USDA Forest Service, Sewanee, TN, August 1986.

[5] Personal communication, James Maxwell, Hydrologist, USDA Forest Service, Gainesville, GA, November 1986.

[6] Personal communication, Edward Young, Forester, USDA Soil Conservation Service, Raleigh, NC. February 1984.

to the environment that occurs at elevations above 5,000 feet. Other forest types are also independent of rock type and more restricted by elevation. For example, species of Braun's (1950) Hemlock-White Pine-Northern Hardwoods Forest Region are restricted to the climate at higher elevations, but yellow-poplar and white pine seldom occur above 4,500 feet, regardless of geologic rock type. Whittaker (1956) reported on the importance of elevation in affecting the distribution of species in the Unaka Mountains.

By using the structure prepared for Level VI, much of the Southern Appalachians can be characterized as intermediate mountains, which are comparable to Hammond's (1970) low mountains. In North Carolina, for example, about three-fourths of the Southern Appalachians is classed as intermediate mountains. Subdivision of the intermediate mountains into areas of homogeneous relief and gradient may be desirable; this can be done by using conventional, analytical methods (Hammond 1964) or recently developed techniques involving fractal dimensions (Mandelbrot 1983).

Hack (1982) provides another approach to physiographic subdivisions based on topography and relief. His delineations generally follow the regional classification used by Wertz and Arnold (1975).

Level V--Subsection

Sections are divided into smaller, more uniform subsections on the basis of geology. The Southern Appalachians consist of a complex mosaic of rock types ranging from metamorphosed igneous to metamorphosed sedimentary and with a variety of mineralogical and textural compositions. Relief in mountainous regions is largely controlled by geologic processes, where rocks of various composition weather and erode at different rates to form areas of distinctive landforms (Stuckey and Conrad 1958). Better known examples of geologic-controlled topography include Cades Cove in the Great Smoky Mountain National Park (King et al. 1968), the Mount Rogers Area (Hack 1982), and the Grandfather Mountain Window (Bryant and Reed 1970). It follows that occurrence and productivity of forest types and associated herbaceous vegetation should be affected by landforms and soils derived from these rocks, but little information is available regarding this hypothesis.

Geologic variables will be keyed more closely to genetic characteristics of the rock type instead of the age and chronological sequence of rock formations normally used. Studies have repeatedly shown that soil texture and mineralogical composition, the erosional products of rock types, affect species composition and site productivity to a greater extent than age of the geologic formation. The importance of geological formations in affecting soil properties was demonstrated in the Central Appalachians by Hack and Goodlett (1960).

Tentative geological subdivisions will be based on texture, mineralogical composition, and structural criteria from Whiteside (1953). The structure of Level V includes:

V. Subsection
- A. Rock class
  1. Igneous (includes metamorphics)
  2. Sedimentary (includes metamorphics)
- B. Rock composition
  1. Minerals
  2. Texture
  3. Structure

Geologic features are commonly displayed on maps of 1:250,000 scale. Hadley and Nelson (1971) provide an example of a map of this type.

Because so little detailed soil mapping has been completed for timberlands in the mountains, geologic mapping can provide important information for forest management operations. In forest road construction, knowledge of rock origin provides information on general costs because sedimentary formations, especially those subjected to low-grade regional metamorphism, can often be ripped, whereas metamorphosed igneous rocks must be blasted.[7] Preliminary results indicate that yellow-poplar productivity may be correlated with rock class in the Bald Mountains of western North Carolina.[8] Graves and Monk (1985) studied vegetation on soils situated in similar topographic positions but derived from marble or schist; they found similar overstory basal area stocking but markedly different understory shrubs and herbaceous flora.

Research in the Southern Appalachians has shown the correlation of vegetation with rock composition, which in turn affects soil properties. In a study involving rock composition, Rohrer (1983) reported that soils formed from rocks high in mafic minerals (oxides of Ca, Fe, Mg, and Mn) were more fertile and supported a more varied flora than arkosic sandstones, which were feldspathic and low in mafic minerals. Bowersox and Ward (1972) reported that exchangeable soil Ca and Mg were the most important variables affecting oak site index, apparently through effects on base exchange sites and organic matter mineralization. Hatcher (1981) and Hack and Goodlett (1960) also reported that some forest overstory associations are correlated with geological formation within certain elevation zones.

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[7] Personal communication, D. Manning, Soil Scientist, USDA Forest Service, Asheville, NC. March 1985.

[8] McNab, W. Henry. Integrated site classification in the Southern Appalachians: Geologic variables related to yellow-poplar productivity. Presented at Fourth Biennial Southern Silvicultural Research Conference, Atlanta, GA, November 4-6, 1986.

Mineralogical composition of rock formations can also be an important consideration in planning road construction. The Anakeesta formation (Hadley and Goldsmith 1963) and certain other sulfidic muscovite schists (Acker 1982) are high in sulfur compounds. Surface runoff from road construction through these formations has caused stream pollution and fish mortality.[9]

Subdivisions of elements under rock composition are tentative. Mineralogical composition may include plagioclase feldspars, biotites, amphiboles, sulfuric compounds, calcites, and others. Rock textures will include classes ranging from coarse to fine. Structure, or rock fabric, will range from dense to porous.

Manifest Components

There are three levels of readily apparent, or manifest, environmental components. These components recur in more or less predictable patterns and deal with landtypes[10] as recognizable segments of the landscape, which can be mapped by the user. The levels and the elements within them represent a possible moisture gradient which may be correlated with species composition and stand productivity.

Level IV--Landtype Association

Landtype associations are divisions of sections and are recurring, generally visibly recognized features of the landscape where climate, landform, geology, and soils interact to form conditions suitable for particular, sometimes characteristic, overstory tree communities, especially forest cover types. A landtype association also consists of a group of similar landtypes. For example, a side slope might consist of at least three landtypes: upper, middle, and lower slope positions, all facing in the same direction. Each of these landtypes has its own environmental characteristics which, when combined, form a unique landtype association that differs in mesoscale land surface shape, discernible on maps with scales greater than 1:100,000.

Research has shown that species composition and forest productivity can be related to land surface shape when viewed on a mesoscale. Hack and Goodlett (1960) provide many examples of correlations between geomorphologic processes, terrain shape, and species composition in the Central Appalachians. Auten (1945) demonstrated the importance of mesoscale landscape features in site classification by correlating productivity of yellow-poplar stands with various slope types and exposed or protected environments. Callaway (1983) proposed a method of measuring topographic protection and reported that timber stand cubic-volume production was correlated with this variable. Grafton and Dickerson (1969) quantified exposure to account for its effects on precipitation. Elements of Level IV are:

IV. Landtype Association
- A. Slope type
  1. Coves or headslopes
  2. Sideslopes
  3. Noseslopes and ridges
  4. Flats and river bottoms
- B. Topographic shading and wind protection
  1. Exposed
  2. Protected

Landtype associations can be delineated on 1:60,000-scale maps.

This definition of landtype association has two advantages. First, empirical functions of site quality for yellow-poplar, a very site-sensitive species, indicate that productivity is significantly correlated with slope type (McNab, in press) and overstory community types. Second, some forest types common to coves and ridges in the Southern Appalachian Mountains (Braun 1950) can be identified in the middle levels of the hierarchy, thus simplifying the taxonomy at the lower levels.

In general, landtype associations are roughly equivalent to county soil associations, where alluvium is associated with bottom lands, residuum is typically located on mid-side and upper-side slopes, and colluvium is associated with lower slopes and headslopes. For example, the Evard-Edneyville-Ashe association in Henderson County, North Carolina, "consists of soils on mountain ridgetops and side slopes" (King 1980). Other slope types, such as gaps and peaks, may need to be included at this level.

Level III--Landtype

Landtypes are divisions of the landtype association. Aspect and slope position are the principal environmental variables affecting species composition and productivity observable at this level (Auten 1945, Carmean 1967, Smalley 1967, Johnson 1975, Auchmoody and Smith 1979). Major differences in site index should be evident among landtypes. Practical field application of the classification scheme for recognition of the silvicultural stand type (stands defined by composition, constitution, and age (SAF 1971)) and site type (qualitative classification by climate, soil, and vegetation (SAF 1971)) will likely be made at this level. However, greater

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[9] Personal communication, Sara Browning, Soil Scientist, USDA Forest Service, Franklin, NC, September 1985.

[10] "Visually identifiable areas resulting from homogeneous geomorphic and climatic processes and having defined patterns of soils and vegetation potentials; used as the basic unit for overall land-use planning." (Wertz and Arnold 1975)

confidence in evaluation of site class (quantitative measure of products (SAF 1971)) may be obtained at the next lower level, where several additional environmental variables are considered. Landtypes should support overstory tree associations that are characterized by various associations of understory species, which are somewhat analogous to forest "habitat types" (Daubenmire and Daubenmire 1968). Remote sensing and digital elevation data can be used in the application of the classification system at this and the next lower level. Landtypes are delineated by the following elements:

III. Landtype
- A. Aspect (Smalley 1984a)
  1. Northerly (azimuths from 315° to 135°)
  2. Southerly (azimuths from 136° to 314°)
  3. None (level terrain)
- B. Slope position (Driscoll et al. 1984)
  1. Upper third (shoulder)
  2. Middle third (backslope)
  3. Lower third (footslope)

Landtypes can be displayed on 1:24,000 scale maps. USDI Geological Survey quadrangle topographic maps are suitable for this purpose.

Solar radiation becomes an important environmental factor at this level. Its effects on soil moisture regimes and associated overstory community types is closely correlated with aspect. Insolation may be broadly categorized at this level, but its quantification is accomplished at Level II, where information on slope gradient is available.

Lee and Sypolt (1974) suggest that insolation is the dominant factor affecting overstory photosynthesis through modification of the soil and atmospheric temperature regime on different aspects. For example, within the relative homogeneity of a small east-facing cove, the opposing north-facing and south-facing side slopes are likely to have different moisture regimes and understory communities. Hutchins et al. (1976) studied the effects of aspect on vegetation and found a mixed mesophytic association on northeast slopes and a less diverse, xeric association on southwest slopes. Whittaker (1956) also reported the important effects of aspect on moisture gradients and vegetation. Criteria at this level are highly significant for plant-water relations, forest productivity, and streamflow hydrology (Swift and Knoerr 1973).

Landtypes also represent a division of soil associations from the landtype association level. For example, soils formed in colluvium on lower slopes, or associated with higher temperatures on south-facing slopes, can be identified and mapped at the landtype level. Hutchins et al. (1976) reported that on a small watershed in Kentucky, similar parent material produced two soil mapping units on slopes differing only by aspect. Soil depth, a variable affecting soil moisture storage capacity and tree root occupancy, is largely accounted for at this level through slope position.

Level II--Landtype Phase

Landtype phases are subdivisions of landtypes and consist of a number of similar sites (see Level I). Surface shape and slope gradient cause variation in species composition and productivity but soil-site studies in the eastern United States typically indicate these two variables are less important than those considered at Level III. Where landtype associations are defined on a basis of mesoscale land surface shape, i.e., cove and ridge, species composition and productivity of the stand are also influenced by the terrain shape measured on a microscale, i.e., depression and convex slope (Carmean 1967, Auchmoody and Smith 1979). Landtype phases may have the same soil mapping unit as the landtype in Level III but differ in characteristics such as slope gradient. The landtype phase is somewhat equivalent to the ecological site type when all vegetation is included in the forest site type description. Ecological habitat types should be closely related to one another at this level. However, correlations may not exist between vegetation classification and soil series (Daubenmire and Daubenmire 1968). Level II has the following structure:

II. Landtype Phase
- A. Surface shape
  1. Concave
  2. Linear
  3. Convex
- B. Slope gradient
  1. Nearly level to gently sloping (0 to 8 percent)
  2. Strongly sloping to moderately steep (9 to 30 percent)
  3. Steep to very steep (31 to 100 percent)

Landtype phases are displayed on maps with a scale of 1:20,000 or larger.

Landtype phase represents the smallest areal unit that normally would be useful in land-use planning and management. It recognizes the influence of land surface shape as a variable influencing soil moisture supply and nutrient status on a more detailed scale than for landtype. Slope inclination has been combined with aspect and slope position from the landtype level to derive an index of forest site quality, which is correlated with soil moisture during the growing season (Meiners et al. 1984). Slope inclination has been correlated with tree growth in the Piedmont (Della-Bianca and Olson 1961) and in southeastern Ohio (Carmean 1965).

Solar radiation, roughly classed at the landtype level, can be accurately estimated by using tables (Frank and Lee 1966) or computer algorithms (Swift 1976). Insolation can vary widely within a mountainous watershed (Lee and

Baumgartner 1966, Tajchman 1981) and can be used in an index of moisture availability which is correlated with production (Tajchman 1984). Both surface shape and slope gradient can be important in modifying landtype to further identify a particular plant association or potential land use. Soil phase and drainage class, which are dependent on slope gradient, can be recognized at Level II.

Nonevaluated Components

Level I--Site

A forest site is nonrecurring, is the smallest areal unit recognized, and encompasses the greatest number of variables. This level is similar to the scale used in determining average site index by repeated sampling in a stand. Sites are land-use or project related and therefore vary in size, ranging from perhaps an acre down to the area occupied by a single tree, shrub, or herb. A single site can be classified, but it cannot be accurately evaluated because many physical and chemical factors specific to such a small area cannot be quantified. Although sites can be approximately described in qualitative and quantitative terms, the processes governing species composition, size distributions, productivity--and other processes peculiar to the area--will probably never be completely understood or used in the planning processes.

DISCUSSION

There is a close correspondence between this proposed system of forest site classification for the Southern Appalachian Mountains and other systems now in use. The proposed system is also similar in concept to the Ecological Classification System used on eastern National Forests in Region 9 (Nelson et al. 1984), recent work on the Chattahoochee National Forest in north Georgia,[11] and is consistent with Smalley's (1984b) system for the Interior Uplands, especially at the landtype level. However, my proposed classification deviates from these three systems, and probably from others based on land systems inventory, in one significant concept: regionalization.

Regionalization is an integral part of land systems inventory in which the delineation of hierarchical levels, down to landtype associations, are based on the classifier's knowledge of geomorphic history and climate, topography, geologic structure, and localized geomorphic processes. This procedure should work well for forest site classification where complete knowledge is available on environmental factors affecting species composition and productivity. In my classification, regions are defined only at the physiographic province level, assuming that Bailey's (1980) ecoregions are recognized at the domain and division levels above province. Taxons, however, will be described by the same topographic, geologic, and local geomorphic factors utilized by land systems inventory but not in predefined areal units. Following this broad-scale approach to regionalization, Cowardin et al. (1979) proposed 10 national marine provinces in their wetland classification and pointed out that "...a given taxon has no particular regional alliance..." but that recognition of regional differences is necessary for various reasons.

Another modification of my classification from others based on land systems inventory principles is at the landtype association level. As defined for the Southern Appalachian Mountains, landtype associations tend to be smaller in area compared with other regions and are mapped on a somewhat larger scale than originally suggested by Wertz and Arnold (1975). I have defined landtype associations in terms of slope types. In most systems, landtype associations are typically described on the basis of surface dissection drainage patterns arising from geological and topographic characteristics of plateau regions. In the White Mountain National Forest in New Hampshire, significant landtype associations could not be identified (USDA 1979). Churchill and Tryon (1982) combined landtype association with sections and subsections in their site classification for the Monongahela National Forest in West Virginia. Compared with geographically defined landtype associations (Smalley 1984b), a disadvantage of my proposed definition is that areal estimates may be difficult to obtain.

This proposed system of site classification permits the recognition of a large number of distinct, relatively homogeneous units at various levels of site evaluation. Although this proposed classification provides for the definition of a potentially large number of landtypes and landtype phases, many may not exist. Others will never be defined because significant differences in productivity, species composition, weed competition, erosion potential, and other management problems will not be important or apparent. However, this classification can be expanded as needed to provide the detail required at the disaggregated, project level of planning.

A taxonomic key can be developed to identify forest sites of uniform productivity, species suitability, and for other purposes. The numbers of classes in the key will depend on the intended use of the classification. Evaluation and application of the system will require considerable work.

The proposed classification system can be applied by using remote sensing and geographic information systems. Algorithms are available for quantifying aspect, slope gradient,

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[11] Personal communication, James R. Maxwell, Hydrologist, USDA Forest Service, Gainesville, GA, December 1986.

elevation, and slope position from digitized data based on a square grid (Sharpnock and Akin 1969) or a triangular grid (Tajchman 1975). A similar algorithm to determine mesoland and microland surface shapes at the landtype association and landtype phase levels also seems easily attainable. A computer program written in BASIC is being developed to assist the user in application of this classification system.

This site classification system can be used for a wide range of forest planning purposes. Other uses include monitoring of forest plan implementation, setting geographical limits on extrapolation of research and project experience, and using it as a framework for interdiscipline communication. Thus far, emphasis has been placed on data collection for species suitability and site productivity. Evaluations for other management problems and limitations such as plant competition, hazards, disease and insect problems can be developed. Quantitative description of variables affecting landtype levels has been done. Research is in progress to evaluate important basic components, especially geologic, and to develop correlations between vegetation and landforms to establish the ecological basis of the classification system. Work is also progressing on accounting for the effects of past land use.

One hypothesis concerning this classification can be easily accepted--that many modifications and changes will be necessary to make it work. As previously stated, this is a first approximation to a multifactor site classification for the Southern Appalachians. Its application and testing in areas where little research has been done will reveal where more field work is necessary. Also, links must be established between this proposed system and classifications being developed by advocates of site evaluation by use of habitat typing and soil survey data.

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