HISTORY OF FOREST SITE CLASSIFICATION IN THE SOUTH[1]

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Abstract.--Potential productivity has been a cornerstone of most land characterization systems used in the South. Soil-site studies identified many variables related to site quality in the exploited southern landscape. Early attempts to use county soil survey maps to delineate site quality were generally unsuccessful, although maps refined to reflect soil and site features important to tree growth have been successfully used for the past 20 years. More recently, landform has been recognized as the primary factor controlling repetitive patterns on the landscape, a realization which has markedly increased understanding of forest-site relationships. Current research focuses on development of landscape ecosystem classification systems which integrate relationships among landform, soil, and vegetation, and which can be linked with modern remote sensing capabilities.

Keywords: landform, landscape ecosystem, GIS, physiography

INTRODUCTION

The evaluation of site quality and development of site classification systems have been among the dominant themes of American forestry for nearly all of the 20th century. Because land is the foundation on which the art and science of forest management must be built, foresters have long appreciated the need to understand the relationships between forests and their physiographic environment. "Students of forestry in the United States are constantly demanding a guide to the topography, drainage, soils, and climatic features of the country." So stated Isaiah Bowman of Yale University in the preface of his book Forest Physiography, published in 1914. We now have many guides, or land classification systems, that enhance our understanding of forest-site relationships.

Most site classification systems used in Southern forestry have been primarily concerned with grouping land units on the basis of productivity. Foresters needed to know what the land could produce. This issue, or subtle variations of it, has been the stimulus of much of the site classification research over the past seven decades. Although certainly an important issue, one can see that there is some historical justification to the criticism that foresters are often too production oriented. We would have saved ourselves much grief if we had been more concerned in the beginning about ecological, as well as economic, values of sites. Unfortunately, the discipline of ecology was still in its formative stages when foresters were first becoming concerned about site classification.

The South is a region of extremely variable physiography (Hunt 1974). Soil, topography, climate, and biotic factors interact to produce a multitude of forest sites in the different physiographic provinces (Ralston 1978; Zahner 1984; Smalley 1986; McNab 1987). In addition, the land has a history of human occupation for thousands of years, during which time it has been exploited to various degrees by all manner of people from the original Indians (Hudson 1976) to the timber barons of the late 19th century (Healy 1985). This long and complex land-use history superimposed on a complex physiography presented a great challenge to foresters seeking to characterize the land.

FOREST SITE CLASSIFICATION IN THE SOUTH

An Appropriate Expression of Site Quality

Early in this century foresters were primarily concerned with forest protection and the productive potential of the land. Productivity is

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a complex concept and difficult to define. It basically deals with the ability of land to produce biomass, not just at the present time but in the future as well. Productivity is a function of both biotic factors and abiotic factors and their interaction (Switzer 1978). Biotic factors which influence productivity include species, stocking, competition, the incidence of disease and insects, and the past history of the stand. Abiotic, or non-living, factors of the environment include soil and site features which control the availability and supply of soil moisture and nutrients for plant use. Site quality was considered immutable by early foresters, but it is now recognized that land has an inherent productivity which can be increased or decreased by management activities.

Productivity was a logical basis for site classification. Early foresters recognized the need for, as well as the difficulty of developing, a standard method of expressing site productivity. Some argued that site quality should be expressed in terms of volume growth (Bates 1918). However, problems in using volume at this time were abundantly apparent (lack of yield tables, difficulty of measurement, differences in units and merchantability limits, periodic vs. final yield, evenage vs. uneven age stands, etc.). Consequently, this concept did not receive wide endorsement.

Another school favored the use of forest site-types, using plant indicators (Zon 1913). This method failed to gain favor in the eastern United States because it was thought that too many factors other than site influence composition and development of understory plant species, especially in the highly disturbed forests of the South.

A third group, which prevailed, favored the use of height at a given age as an index of site quality (Frothingham 1921). Site index was favored because it was directly related to volume growth in normally stocked stands, easily measured, and considered free of the effects of stand density over a rather wide range of stand density. In 1923, the Society of American Foresters recommended that site index, in conjunction with soon to be developed yield tables, be used throughout the country to express the productive potential of forest land.

The theory of using tree height as an index of site quality has been widely criticized (Mader 1963; Grigal 1984; Monserud 1984). Space limitations prevent discussion of these criticisms, many of which are valid. Alternatives have been proposed, but none have gained the wide acceptance of site index. Gale and Grigal (1987) and Henderson et al. (1990) recently proposed a productivity index in which the sufficiency of soils to support root growth is related to forest growth and yield. While this concept is attractive potential, it tacitly assumes that the relationship between above-ground biomass and root biomass of forest trees is the same for all sites. This assumption may or may not be true, but in any event requires further research. Despite the fact that site index has many problems associated with its use, its simplicity, general applica-bility, and long tradition insures that it will continue to be a commmon method of expressing site quality.

Soil-Site Studies

The Society of American Forester's decision to recommend the use of site index as the appropriate expression of site quality initiated a half century of soil-site research. In the South, foresters pondered the question of how could sites be classified into productivity classes in the absence of suitable forest cover? Much of the South's forest had been heavily cut over and cleared for crop production by 1935. Crop land acreage in the South (excluding Texas and Oklahoma) peaked in the mid 1930s at about 65 million acres and between 1900 and 1925 the South led the nation in timber volume cut (Healey 1985). It was against this background of worn-out farmland and cutover forests that the first soil-site studies were conducted in the South.

In 1935, T. S. Coile of Duke University published a paper which concluded that the site index of Piedmont land in North Carolina for shortleaf pine was related to the nature of the subsoil and the thickness of the A horizon. Similar relationships were later found for loblolly pine (Coile 1948). At about the same time, Turner (1938) found that site index of loblolly and shortleaf pines in the Coastal Plain of Arkansas was related to surface soil depth, subsoil texture, and internal drainage. Turner observed that topographic features such as slope position and steepness correlated with site index. Coile also recognized the relationship between topographic position and site index, but did not include it in his regression equations because slope position was correlated to soil depth and did not improve the precision of his equations.

The regression approach used in these studies was apparently addictive, because the pioneering efforts of Coile and Turner were followed by decades of similar studies throughout the southeastern United States and the nation. Numerous investigators (see Carmean 1975) identified many soil and site variables related to site index of different species in various locations and physiographic regions. Variables associated with site quality were those that directly or indirectly influenced availability and supply of water and nutrients for tree growth.

The same soil factors that affect the availability and supply of water and nutrients may also correlate with the quality of the growing space for tree roots. However, topographic features of the landscape may insure a supply of water and nutrients via internal drainage which could compensate for a lack of quality growing space for roots on some sites. Topographic features such as aspect, slope position, and slope shape consistently relate to site index (Carmean 1975).

In mountainous or hilly terrain, topographic features are often equally or more important to site quality than soil factors (Doolittle 1957; Ike and Huppuch 1968; McNab 1987; and Rightmyer 1988). Aspect in steep terrain influences evapotranspiration, which affects development of water stress and subsequent tree growth (Lee and Sypolt 1974). Subsurface flow of water (Hewlett 1982) benefits trees growing on sites located on lower slope positions.

It has been difficult to determine relationships between measured soil/site variables and site quality for hardwoods in the Coastal Plain (Broadfoot 1969), probably because of the complexity of drainage patterns in bottoms. However, Baker and Broadfoot (1977) devised a technique of site evaluation for eight southern hardwoods which combined objective and subjective evaluations of the relative importance of soil physical condition, moisture availability during the growing season, nutrient availability, and aeration. This method is somewhat similar to the concept of a productivity index mentioned earlier (Gayle and Grigal 1987, Henderson et al. 1990), except here the sufficiency of each soil and site factor was related to site index rather than to a soil rooting potential. Baker and Broadfoot developed their method from long years of field experience and found that, when tested, the technique accurately predicted site index of eight southern hardwoods.

Soil-site studies identified many features of the environment that related to tree growth and site quality. However, the relationships are not general for all sites. The essence that one can derive from all these studies is that various combinations of site factors influence the magnitude and timing of supplies of soil moisture and nutrients, the effective properties that control site quality (Stone 1984). Within the confines of necessary assumptions, stone's conception allows one to make some order out of the myriad of physical and chemical site factors shown to be related to site quality, i.e., they all affect the fundamental availability and supply of water or nutrients.

In retrospect, soil-site studies essentially provided a compilation of factors related to site quality, and were not readily applicable to the real management need for spatial delineation of repetitive units of the landscape, i.e., maps. The regression equations produced were often cumbersome and difficult for managers to use. The heterogeneity of forest sites made sampling difficult for practitioners. Researchers themselves ignored the variablility of soil properties within the experimental plots used to develop the equations (Powers 1987). Even if properly sampled, relationships between site quality and any given soil/site parameter were seldom linear (Fisher 1984). For all these reasons, experienced field foresters often had a better intuitive feel for site quality than could be obtained from rather complicated equations.

Use of Soil Surveys

The National Cooperative Soil Survey of the Soil Conservation Service (SCS) had been mapping soils in the South since the 1940s. With so many soil-site studies indicating relationships between soil properties and site quality, foresters naturally tried to utilize soil survey maps when available. However, they were generally disappointed. They found that SCS soil surveys too often pleased soil taxonomists but lacked the user orientation needed by forest managers (Grigal 1984, Smalley 1986).

Most studies found that site quality varied too widely within SCS soil series and mapping units to be of practical use to foresters (Carmean 1965; Van Lear and Hosner 1967; Broerman 1977). Not only was site quality poorly related to soil taxonomic units, response of the land to management was also unrelated. For example, Kushla and Fisher (1980) found that the response of slash pine to fertilization was related to soil drainage class and depth to and nature of the B horizon, but was not related to soil series. The reason for the lack of correlation between soil mapping units and site quality or response to management is obvious--those soil and site factors important to tree growth are often not the same ones considered in soil taxonomy and mapping.

Among the shortcomings of SCS soil surveys was the fact that they failed to incorporate knowledge that productivity is related to land-use history, landform, and climatic conditions, as well as to soil properties. Rowe (1984) suggested that the problem originated when pedologists began perceiving soils as natural bodies and things-in-themselves, rather than associating soils with their ecological significance.

SCS soil surveys are general purpose surveys. Soil surveys for forest management purposes should consider relationships between productivity and landform or moisture gradients (drainage) and soils should be mapped on the basis of properties known to be related to site quality and response to management. There is hope. Soil taxonomists increasingly recognize that the genesis and distribution of soils are best understood when studied in a landscape context, rather than at the level of individual pedons or classification units (Graham and Buol 1990). Arnold (1984) noted that while the recognition of soil individuals is the basis of the soil taxonomy used by SCS, there is a need for a similar type of definition of individual land areas that can be recognized and delineated as ecological response units.

For about the last 20 years, forest industries in the southeastern United States have been mapping their own forest lands. These companies chose either not to use published SCS county soil surveys or to refine them to better meet their special needs. Forest industries need an inventory of their soil resources and a site classification on the basis of productivity and

need for silvicultural treatment (Haines and Haines 1981). Their mapping emphasizes landscape features, such as shape of the landform, its geologic origin, and the position on the landscape. Special attention is given to the relationship between surface and subsurface soil properties and site quality (Everett and Thorp 1990). Industrial experience in the South indicates that foresters and soil mappers can work together to produce maps that better characterize forest land, not only for productivity but also to provide information on potential erosion hazard, regeneration potential, trafficability, and other management considerations for different soils.

Physiographic Classification

Physiographic classification represents an attempt to use physiography, i.e., the physical expression of geologic history, topography, soils, and climate of an area, to define broad land areas within which the local landscape can be subdivided into visually discrete landforms. The concept of physiographic land classification was first developed in Canada (Hills 1961). In 1975, Wertz and Arnold proposed a similar system for the United States to help standardize land classification and facilitate land-use planning, a topic of great public interest in the early 1970s.

In the South, the physiographic land classification concept was first used by Hodgkins et al. (1979) to map (scale of 1:1,000,000) and describe forest habitat regions and subregions of Alabama and Mississippi from landsat imagery. Upper level land classification units of province, region, and subregion were broadly defined by geology, topography, soil, and climate. Habitat regions are primarily useful for national and regional evaluations of forest resource conditions, and are not intended to be the basic units of operational land management where site specific decisions must be made. However, habitat regions do provide the foundation upon which the landscape can be further subdivided. Other southern states with completed habitat maps are Louisiana (Evans et al. 1983), Georgia (Pehl and Brim 1985), and South Carolina (Meyers et al. 1986).

Forest soil scientists often incorporated topographic features into their regression models during the heyday of soil-site studies. However, the practicality of using easily recognizable landforms in site classification systems in the South was slow in coming. Coile (1952), in his review of the relationship of soil and forests, briefly discussed the importance of topographic features to tree growth, but the concept of using landforms as the integrator of the landscape ecosystem (Rowe 1984) was not mentioned.

The term landform did not appear in early soil-site studies in the South, although its surrogate, drainage class, did. Turner (1938) first documented the relation betweeen drainage class and site quality of southern pines in Arkansas where excessively drained upland sands were poor sites and loamy soils in floodplains with good internal drainage were superior sites. In 1956, Beaufait related site quality for willow oak to topographic features such as ridges and flats (he did not call them landforms) and certain soil properties. In the mid 1970s, Weyerhaeuser Corporation developed a site classification system for the Coastal Plain of North Carolina in which soil features were stratified by landform (pocosins, flats, clay uplands) to yield regression equations which adequately predicted site index of loblolly pine (Campbell 1978). Until the data were stratified by landform, accuracy of equations for estimating site index was unacceptable.

The trend toward using landform (or drainage class) as the basic component of site classification systems gained momentum in the 1980s. Fisher (1981) described a site classification scheme for the Coastal Plain based on productivity differences which were related to drainage class, depth to and nature of the B horizon, and character of the A horizon. Drainage classes reflect, in part, subtle differences in elevation between lowlands and the Sandhills of the Coastal Plain. Responses to management activities such as site preparation and fertilization were related to site classes, an important feature in the increasingly domesticated forests (Stone 1975) of the Coastal Plain.

Switzer and Shelton (1984) divided the upland landscape of the Gulf Coastal Plain into five landform components: crest, shoulder, backslope, footslope and toeslope. Productivity was subjectively related to landform with the poorest sites on crests and shoulders and the best sites on the toeslopes. Differences in productivity among landforms were attributed to corresponding differences in nutrient and moisture regimes.

Between 1979-1986, Smalley (1986) developed a comprehensive and practical physiographic site classification system for the Cumberland Plateau and Highlands Rim provinces of the Interior Uplands of the Southeast. His hierarchal system progressively reduces complex landscapes to easily identifiable landforms called landtypes. Landtypes have resulted from similar climatic, geologic, and pedologic processes and are repetitive units of land with distinct potential for growing trees and/or similar management limitations and hazards. For each landtype, the geographic setting, dominant soils, depth to bedrock, soil texture, drainage, relative water supply and fertility, and general vegetation is described, as well as management interpretations.

Smalley's system is practical because it identifies discrete units (landtypes) of the landscape easily visualized by the forest manager and because it has mapping capability at a scale of delineation to meet most management objectives. It provides information concerning species suitability, competition, equipment limitations, erosion hazard, and other factors, as well as productivity. Vegetation is relegated to a position of minor importance because current vegetation was not considered to reflect site

potential and often did not coincide with site boundaries. Sites are further subdivisions of landtypes, but usually not mapped. In mountainous or steep terrain, site conditions often vary dramatically over short distances due to interactions between parent material, depth to bed rock, slope steepness and shape, aspect, terrain stability, vegetation, climate, and drainage and water supply from adjacent sites (Zahner 1984).

McNab (1987) published a first approximation of a site classification system for the Southern Appalachians similar to that of Smalley's for the Interior Uplands. Slope features, such as slope type, slope aspect slope position, slope shape, and gradient are incorporated into the system at different levels to divide the mountainous landscape into increasingly smaller units until landtype phases can be displayed on maps with a scale of 1:20,000 or larger. These landtype phases are the units appropriate for normal forest planning and management. As with Smalley's system, landtype phases are equivalent to an ecological site type if vegetation information is included in the description.

The transition from regression-based soil-site studies to multifactor physiographic site classification greatly increased understanding of forest-site relations and the feasibility of putting this knowledge to work in forest management. As Rowe (1984) pointed out, landform represents the most stable surface component of landscape ecosystems and, over long periods of time, becomes the primary correlate of soils and vegetation in areas of similar regional climate. Landforms are the prime cause of the repetitive patterns of soil and vegetation seen on the landscape. Thus, landforms with their associated soils and biotic communites are the logical basis on which site classification systems should be developed. If site quality varies too widely within landforms, than soil and vegetative features can be used to stratify the landform into units of more narrowly defined site quality.

Ecological Site Classification

Productivity concerns will always be an important part of site classification systems. However, because the forester is a steward of the land and all its resources, the public is increasingly demanding that equal consideration be given to other values of the forest, e.g., wildlife habitat, watershed protection, endangered plants and plant communities, etc. National forests are especially vulnerable to public pressures, but private forests will also come under closer public scrutiny in the future. There is no single site classification system currently in use by the U. S. Forest Service. However, the numerous systems in use by the agency all attempt to delineate and describe units of land that are fairly homogenous with respect to the relationships among vegetation, soil, and landform. The lack of a uniform system of classifying potential natural vegetation has hindered the full incorporation of vegetative components into a nationally standardized system (Larson and Schlatterer 1984).

The concept of ecological site classification was developed in Germany after World War II and has been the basis for their multiple-use management for decades (Barnes 1984). Ecological site classifications are similar to the multifactor physiographic site classification systems just described. However, in an ecological site classification system, the three components of the landscape ecosystem, i.e., landform, soil, and vegetation, are integrated simultaneously in the field. The local climax vegetation is identified and groups of species with narrow ecological amplitude, i.e., site specific, are determined and used to delineate site unit boundaries. Vegetation is given more consideration in delineating site classes than in the physiographic systems described previously.

In the South, ecosystem classification has been applied to a portion of the Coastal Plain in South Carolina (Jones, et al. 1984; Van Lear and Jones 1987). Late successional, near-climax hardwood communities were identified along a landform moisture gradient in the Hilly Coastal Plain province of South Carolina. Site types were identified by these late successional hardwood communities, including both overstory and understory species, that occupied specific landforms. Community identification was based on a relatively small number of character, or diagnostic, species which tend to occur on certain sites in conjunction with common species which have a wider ecological amplitude. In addition to the late successional hardwood communities associated with different landforms, earlier successional communities that precede them were also identified. In this regard, this system is similar to the habitat type approach developed by Daubenmire (1952) for the northern Rockies and now used extensively on national forests in the West (Pfister 1989). Jones (1989) has recently expanded this ecosystem classification system to the Piedmont of South Carolina.

There are numerous reasons why information about plant communities and successional trends should be included along with landform and soil components in land classification systems. By including vegetation, landscape ecosystem classification provides more complete information about ecosystem diversity and functioning. This information is essential if planners and managers are to stabilize and reverse the disturbing trend of landscape fragmentation of the landscape now so common throughout the South. It will be necessary to incorporate the best elements of land use planning and landscape ecology to preserve the landscape mosaic of wildlands (Brown 1989).

Inclusion of information about potential climax or late-successional vegetation and seral communities in a classification system gives insight about the composition and structure of old-growth communities that would prevail in areas protected from timber harvesting. Such areas often exceed 30 percent of the land base in Southern

national forests. In addition, if the seral communities preceeding late-successional communities are known, managers can decide which vegetative stage is desirable on various sites in the landscape. For example, the longleaf pine-wiregrass ecosystem of the Coastal Plain once covered up to 86 million acres, but now occupies no more than 5 million acres (Noss 1989). Accounts of early explorers suggest that much of the PreColumbian landscape of the Coastal Plain was in wet prairies and open savannahs, now rare communities that can only be created and maintained by frequent burning. It is important for ecological reasons to restore a portion of that original ecosystem. A landscape ecosystem classification describing successional sequences of vegetative communities on various site types with and without prescribed fire would aid in delineating those areas where restoration of this endangered ecosystem is best suited.

Forested wetlands commonly found along many coastal streams, rivers, lakes, and bays are among the most extensive types of forest sites in the southern United States. Although development of wetlands has slowed in the South in recent decades, the quality of wetlands continues to decline. To reverse this disturbing trend, wetlands must be delineated and their relationships to surrounding systems identified. Brown (1989) has proposed an landscape ecosystem classification system for wetlands which incorporates landscape position, nutrient availability, and hydrologic regime, in addition to successional trends, as a first step in protecting wetlands.

Riparian zones and streamside management zones throughout the South require similar consideration. Land-use planners and managers must give greater attention to the protection and functions of these sensitive and ecologically important ecosystems and how their management affects associated aquatic ecosystems.

No site or land classification system will satisfy all management needs or resolve all conflicts arising from opposing views on use of specific areas of land. As long as people have opinions and wants, there will be conflicts over land uses. All classification systems are contrivances of man to organize ideas in useful ways (Cline 1963). As such, they will never be perfect. However, classification systems that integrate the major ecosystem components of landforms, soils, and vegetation provide a relatively sound basis upon which individuals, companies, public agencies, and society can make long-term decisions about the land that make sense both ecologically and economically.

New Technologies

Maps have historically depicted the spatial relationships of land, including its characteristics and boundaries, and will continue to be important tools for storing and conveying spatial information. Unfortunately, as forestry became more sophisticated, the rate at which these maps became outmoded also increased. This problem can now be addressed through the use of digital computers and software for handling geographic data. Geographic Information Systems (GIS) and Digital Elevation Models (DEM) are increasingly used to input, store, manipulate, and display geographically referenced data to provide the current information needed by forest managers.

GIS and DEM are commonly used for land-use planning and resource inventory, but researchers are just recently discovering their potential for site classification. Several papers in this proceedings address this new technology, which has exciting possibilities for increasing our ability to map site and landscape features. Hammer (this proceedings) suggests that these new technologies can be used as research tools to generate new data, rather than as just hi-tech ways of producing maps and managing data. Certainly the future is bright for this new technology. Its potential for illustrating relationships between landforms, soils, and vegetation are almost unlimited, as is its potential for expanding our understanding of the values and functioning of these ecosystem components.

CONCLUSIONS

Forest site classification had its origins near the turn of the century shortly after forestry began in this country. The early history of site classification dealt with finding an appropriate expression of site quality, since it was generally recognized that productivity was a basic criterion for delineating sites. Site index, despite its problems, was selected and remains the most commonly used measure of site quality even today. In the South, decades of soil-site studies established the rather obvious fact that site quality was related to those soil and site features that affect the availability and supply of water and nutrients to forest trees. The compilation of factors related to site quality, while a necessary first step in the exploited forests of the South, did little to solve the problem of how to spatially delineate units of land with differing growth potential.

Foresters attempted to use general purpose SCS soil survey maps to delineate sites of different quality. However, these maps were generally not suitable for intensive forest management purposes. Site index varied widely within mapping units and responses to management activities often did not coincide with soil series. Soil and site features important to tree growth were obviously not the properties important to soil taxonomy. However, industrial forestry experience has shown over the past 20 years that foresters and soil mappers can work together to develop soils maps suitable for forest management purposes.

The importance of landform in classifying forest sites was not widely recognized in the South until the late 1970s. Landform naturally integrates climatic, hydrologic, soil, and vegetative variables, and forms the stable

repetitive feature of the landscape. Most importantly, landforms are readily mapped. Multifactor physiographic classification systems which separate landscape components on the basis of geology, topography, and soils into visually identifiable landtypes have greatly increased understanding of forest site relationships.

Ecosystem classification is similar to multifactor physiographic classification except it places greater emphasis on vegetation. Identification of late successional or near climax plant communities that occupy these repetitive landforms and the seral communities that preceed them is an integral part of the system. Such a system provides a broader ecological base upon which the patterns and processes of landscape ecosystems can be interpreted. However, it must be recognized that landscape ecosystem classification, nor any other system, is a panacea that will solve all land classification problems.

In the last decade, great progress has been made in the carteographic expression of geographic data using GIS and similar systems. Integrating site classification systems into these new technologies will improve our ability to manage forest land for maintenance and enhancement of productivity, and at the same time enable us to give due consideration to other values of the forest.

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