UNIVERSITY OF MINNESOTA
NOV
FORESTRY LIBRARY

ERRATA

Central Hardwood Forest Conference II

"Effect of Land Use on Water Quality," Aubertin and Case, Page 228, line 11, -- 51.7 tons/acre/ -- to 51.7 tons/hectare/.

Page 228, line 15, -- 8.8 tons/acre/ -- to 8.8 tons/hectare/.

Page 233, paragraph 4, lines 9, 10, -- 13.0 tons/acre/year -- to 13.0 tons/hectare/year and -- 8.8 tons/acre/year -- to 8.8 tons/hectare/year.

Page 241, paragraph 2, line 5, -- 13.0 tons/acre/year -- to 13.0 tons/hectare/year.

"Influence of Pisolithus tinctorius on Northern Red Oak Seedlings with Nitrate Fertilization," Beckjord, Adams and Smith, Page 469, paragraph 2, line 10, omit - leaf area and green leaf area.

Page 473, paragraph 1, line 4, omit - leaf area and green leaf area.

"Effect of Genotype and Nutrient Regime on Growth and Elemental Concentration of Sycamore (*Platanus occidentalis* L.) Seedlings," Pope and Vasey, Page 497, table 2, A/W Ratio, 0.59a to 9.59a.

Page 502, table 5, each of the values indicated under "Dependent Variable" should be negative for the K and N "Regressor Variables."

"Patterns of Oak Wilt Mortality in Midwestern Oak Forests," Menges, Page 517, Equation 1-2 are from site 1, Dane County, Equation 3-4 are from site 2, Dane County.

Page 522, Equation p = (0.628 x LOG X) -0.980 to p = (0.628 x LOG d) -0.980.

RECENT HARDWOOD RESEARCH: RESULTS AND OPPORTUNITIES

Keynote Address, Central Hardwood Forest Conference, II

November 13, 1978, Purdue University, West Lafayette, Indiana

By

David T. Funk

North Central Forest Experiment Station

Carbondale, Illinois

I am pleased and excited to be able to talk to you here today. It is a real pleasure to return to Purdue and witness the recent progress made by the Department of Forestry and Natural Resources. The progress that I refer to is not merely the move to a separate Forestry Building, or the growth of the student body and faculty, although all these things have taken place. I am much more impressed with the overall sharpness of the students and the diversity of their backgrounds, the broadened and strengthened course requirements, the high quality of the research program, and the talent of the people who have joined the faculty in recent years. Having complimented the newer members of the faculty, I find as much or more pleasure in noting the continued presence of such veterans as Professors Kirkpatrick and Miller, whose excellence was recognized when I arrived here thirty-one years ago, and who continue to earn our respect and admiration for the talent and devotion that they bring to the campus every day.

I am excited not only because this is my first keynote speech, but also in reaction to the dynamic changes taking place in modern American forestry and their certain impact on the future of the Central Hardwood Forest. We can all think of solid examples of progress in forest management and forestry research, but I am also stirred by the questions that are being raised. We are quizzed by environmentalists who demand to know how we intend to practice 'excellent forestry'. At several locations around the country, a committee of scientists has been meeting to advise the Secretary of Agriculture on the wording of regulations to implement the 1976 National Forest Management Act. I am confident that many of their recommendations can be readily rephrased as questions--questions that urgently require answers before the act can be effectively implemented. And most stimulating of all, from my own more personal point of view, are the questions being posed by scientists in the various fields of forestry.

A few weeks ago I wrote several colleagues, soliciting examples of such questions. I asked them to suggest "...recent findings that cause us to smile, scratch our heads, and say, 'That's good'. I like it; but how does it work? What makes it so?'" More than twenty researchers responded, listing as many as a dozen items for consideration. May I take this opportunity to express my thanks and appreciation. I have built my talk on a few of these "head scratchers" that most appealed to me, and that furthermore represented a range of activities in central hardwoods research. I trust that those of you who went to the trouble to answer my request but do not find your suggestions among my examples will recognize the problems I faced in holding this talk to thirty minutes duration.

Head-scratcher number 1

For several years, Mel Larson of the Ohio Agricultural Research and Development Center has been studying factors that influence the vigor and physiological quality of hardwood nursery stock. He has recently shown that defoliating northern red oak seedlings in the fall, as late as September 23, can reduce shoot growth the following spring by 40 percent or more.[1] Furthermore, the effect is not related to reduced food reserves in the roots.

Mel hypothesizes that senescing leaves export something (perhaps a cytokinin) to the roots that is necessary for growth the following spring. The obvious next questions are, "Is a growth regulator really involved, and if so, what is it?" But a few other questions come to mind: what do these findings mean to the nurseryman who uses defoliant chemicals to induce dormancy? Should we take a closer look at diseases and insects that defoliate trees late in the growing season and that have been considered relatively harmless? Are they indeed of little consequence because the tree perhaps has time to respond to infection and export a growth regulator before losing its leaves, while Mel's pruners are much too quick? I foresee excellent opportunities to combine basic and applied research in pursuit of answers to these questions.

Head-scratcher number 2

In a recent Missouri study, black walnut root systems were examined by excavating trenches adjacent to eight trees on each of three sites which differed in several ways, including depth to bedrock.[2] The overall density of fine (< 2mm diameter) roots was found to be notably less on deep than on shallower soils when sampled at a distance of 50 cm from the tree bole. Furthermore, in the deepest soil (250+ cm) the fine roots were concentrated in the upper 30 cm of soil to a much greater extent than in the shallower soils (68 percent of total fine roots vs. 45 and 55 percent).

These findings prompt questions that verge on the teleological. Do black walnut trees produce a relatively constant number of fine roots regardless of soil depth? Does a tree concentrate its fine roots in optimal horizons and neglect to exploit the rest of the profile? Do mature walnut trees respond to good sites through increased shoot:root ratio rather than by overall increase in size?

---

[1]Larson, M. M. Effects of late-season defoliation and dark periods on initial growth of planted northern red oak seedlings. Can. J. For. Res. 8:67-72, 1978.

[2]Yen, C. P., C. H. Pham, G. S. Cox and H. E. Garrett. Soil depth and root development patterns of Missouri black walnut and certain Taiwan hardwoods. Paper presented at Symposium on Root Form of Planted Trees, Victoria, British Columbia, May 16-19, 1978.

Head-scratcher number 3

In his response to my inquiry, Bob Farmer described just-completed research in the eastern Tennessee Valley. Sawtimber-size yellow-poplar stands in four states were treated with 300 pounds/acre of ammonium nitrate and measured after five years. Nitrogen fertilization increased the annual volume growth rate from 4.3 percent to 5.2 percent and the value growth rate rose to 5.4 percent.[3] This solid biological response might be assumed to have good practical potential because of the short delay between the time of treatment and time of harvest. But no reasonable combination of stocking, interest rates, and stumpage prices could be put together that made fertilizer application a paying proposition.

Where does this leave us? Is intensive culture practical only for very short rotations or very high-value species? Will the situation ever change? I'll return to this subject briefly at the end of my talk.

Head-scratcher number 4

One of our studies that compares the development of black walnut trees grown with and without autumn-olive has begun to yield truly striking results. At each of five locations in Missouri, Illinois and Indiana, walnut in mixture with autumn-olive has outgrown walnut in pure stands; in two of the locations by a factor of more than 2 to 1 in terms of 9-year height, and almost 3 to 1 for diameter. These differences are not transitory; current annual height and diameter increment of walnut average more than 3 times as great in mixed as in pure plantations.[4] The results speak for themselves, and I have prepared a slide talk that begins with, "Autumn-olive is good for you". But we are hard-pressed to provide a comprehensive explanation.

We know that autumn-olive fixes nitrogen, that understory vegetation is reduced under the mixed plantings, that the soil temperature regime is moderated, and many other bits of information. But assuming that there is no single answer, how can we determine which environmental factors are separately or jointly limiting to walnut growth and that have been modified by the autumn-olive. We could use this sort of information to make preliminary evaluations of other potential nurse crop species prior to field tests; in our present state of ignorance we must proceed with a 'let's see what happens' approach.

---

[3]Farmer, R. E., W. B. Buckley, and S. M. Potts. Nitrogen fertilization of saw log yellow-poplar. Final report, 8 p. [1978]

[4]Funk, David T., Richard C. Schlesinger and Felix Ponder, Jr. Autumn-olive as a nurse plant for black walnut. Bot. Gaz. in press.

Head-scratcher number 5

Gene McGee, at the Silviculture Laboratory in Sewanee, Tennessee, submitted a suggestion that is so well phrased I should like to quote it intact.

> After studying most of the hardwood research that has been produced in recent years I am convinced that hardwood silviculture is easy; but that hardwood management is almost impossible. For example, good natural regeneration of hardwoods occurs in profusion in most places; all that is needed is a heavy or complete harvest cut. Yet when we set our goals to regenerate a specific species mix or to regenerate a stand identical to the one being harvested we often are disappointed. One of the most perplexing puzzles throughout the hardwood region is how to regenerate northern red oak on good sites. Good stands containing northern red are being replaced by good young stands but with the complement of red oak diminished. Clearcuts, shelterwoods, and partial cuts all seem to favor other species. Artificial regeneration of red oak does not at this time offer a really dependable and economic means for keeping the complement of red oak on our good sites. So it's easy to perpetuate good hardwood stands but it is most difficult to match natural conditions through man-made impositions.

All that remains is to state the few obvious questions. What are we doing 'wrong'? What is different about today's mature stands or environmental conditions that prevents us from returning to the situation of a century or so ago and reproducing these stands in the literal sense of the word? Is our problem the fact that we can't reproduce the original situation or that we aren't even sure what it was? I also hope to tie this problem into my closing remarks.

Head-scratcher number 6

Klaus Steinbeck at Georgia recommended that I include an item on short-rotation forestry, a topic which will receive considerable attention at this Conference in the soil-site/productivity and the intensive culture sessions. It doesn't seem necessary or appropriate for me to recite details of recent findings; you will soon hear them from researchers who are actively involved. Nevertheless, the prospects were neatly summarized in a recent talk by Claud Brown[5] who postulates yields of 15 tons of forest biomass (excluding foliage) per acre per year using genetically improved material on average or better sites in Georgia. These yields would be sufficient to fuel a 150 megawatt power unit, which could supply the electrical needs of a city of 150,000 people with the harvest from 41,000 acres. A plant located in the center of a tract of this size would require hauling of fuel biomass over a distance of less than 5 miles at the most.

---

[5]Brown, Claud L. Potentialities of forest biomass as sources of energy. Invited paper presented to Georgia Chapter, Soc. Amer. Foresters, Stone Mountain, Ga., August 9, 1978.

Head-scratcher number 7

Steve Boyce is one of my favorite forest philosophers, and I imagine that his ideas have provoked many of you to indulge in a bit of deeper-than-usual thinking. Tom McClintock of the Hardwood Research Council called my attention to Boyce's proposals for "custodial management" and Steve then followed up with several suggestions from Asheville. He points out that, (1) the quality of hardwood timber is increasing rapidly as diameters increase; we have more high quality hardwood trees now than at any time since 1920; (2) we can double the harvest of yellow-poplar now, and maintain the higher harvest rate indefinitely without intensive culture (my emphasis); (3) just as with Bob Farmer's study of yellow-poplar sawtimber fertilization, very few cultural practices can be economically justified in the hardwood forest;[6] (4) the need to obtain multiple benefits from the forest continues to intensify; it is essential to take a systematic approach toward accomplishing these goals;[7] (5) "Custodial management...is the cheapest way to manage forests. This is also the most logical way, because we cannot predict the future use of today's seedling." Custodial management includes minimum size harvest areas, cutting all trees larger than about 2 inches d.b.h. at the time of harvest, fire protection, and nothing more.

The philosophical questions raised by these hypotheses cannot be satisfactorily approached until we have considerably more broad based biological and economic information. The opportunity is at hand for the users of the Central Hardwood Forest to make serious errors of either Type I or Type II. First, if our Central Hardwoods are to become the fuelwood basket of the East, now is the time for intensive planning--by existing hardwood-using industries faced with unprecedented competition, by the multitude of other users who will find that hardwood forests managed for biomass production are partially or completely incompatible with game management and recreation, and by forest landowners and managers who will need to move quickly if they are to take advantage of this opportunity. On the other hand, if the opportunities are not real, or if practical considerations restrict them to only specialized situations, it is just as important to learn these facts as soon as possible and turn our attention to other more promising alternatives.

---

[6]Boyce, Stephen G. and Joe P. McClure. The harvest of yellow-poplar timber can be doubled. Yellow-poplar Symposium, Knoxville, Tenn. March 21-22, 1978.

[7]Boyce, Stephen G. Theory for new directions in forest management. USDA For. Serv. Tech. Pap. SE-__, in press.

You may perceive apparent discrepancies between these statements and the content of certain of the preceding "head-scratchers". I'll try to pull them together in my closing remarks.

Conclusions

If the following statements don't accomplish my objective of wrapping up the package, I'm more than willing to take the blame. If they do seem logical, may I once again acknowledge my debt to Steve Boyce and the many other colleagues who helped me with ideas for this paper.

The Central Hardwood Forest is a huge and wonderfully diverse resource. The productivity of many of our sites and the richness of our flora are world famous. Therein lie our opportunities and our challenge. We can and must intensify our efforts to understand this complex mosaic of forest cover types, each of them complex in its own right. To quote Boyce's letter one last time, "The most important research in silviculture is [to] develop knowledge of the biology of all organisms in the forest." Without this knowledge we can only speculate about the extent to which biological response equates with practical utility.

Thus, I close with the traditional plea for more and better, and especially for more fundamental research. May I emphasize that when I say fundamental I also mean broad. I do not admit to speaking equivocally when I maintain that we must deal with the natural regeneration problems so well stated by Gene McGee and the fascinating questions regarding endogenous growth regulators raised by Mel Larson. I am sure that the necessary answers will not be obtained by any sort of narrow approach--in the laboratory, greenhouse, or the forest itself. I trust that we shall be able to recognize the opportunities contained in the research results presented to this Conference. I look forward to three stimulating days with you.

INTRODUCTION

Scientists in the United States have been classifying and evaluating forest site quality for nearly six decades. As one would suspect, many methods have been employed, but, no one system applicable to all of the diverse sites, forest types, and forest conditions has been developed (Carmean 1975).

The importance of forest site classification has increased dramatically in the past 20 years, as evidenced by the number of papers devoted to this topic at North American Forest Soils Conferences (Bernier and Winget 1975). Additional evidence is found in the "high priority" ratings given research problems pertaining to site classification, productivity, and land use at the Southern Regional Working Conference in New Orleans, July 1977, and at the National Working Conference - National Program of Research for Forest and Associated Rangelands in Washington, D. C., January 1978.

Today forest managers are faced with the challenge of producing more wood from less forested land, so we have a critical need for site classification and productivity information. This paper establishes the need and the requirements for a site classification system, and defines the levels in the heirarchal system. Landtypes and forest management interpretations are discussed and examples given.

INTERIOR UPLANDS

The Interior Uplands include the Cumberland Plateau and the Highland Rim physiographic provinces (Fenneman 1938). The Cumberland Plateau extends from eastern Kentucky and southwestern Virginia through middle Tennessee and northwestern Georgia into northern Alabama. North of the Kentucky River this same geologic formation is called the Allegheny Plateau. Soils are derived from thick, nearly horizontal beds of sandstone and shale. Topography is characterized by dendritic drainage with winding narrow ridges and deep narrow valleys. The southern end of the Plateau in Alabama also is well dissected, but is less rugged. The Plateau is bounded on the east and west by prominent escarpments. At its southern extremity, the Plateau dips beneath Coastal Plain sediments.

The Highland Rim, called the Pennyroyal in Kentucky, lies west and north of the Cumberland Plateau, surrounds the Nashville Basin in Tennessee, and borders on the Bluegrass and Western Coalfields in Kentucky. Topography of the Rim is nearly level to rolling and sinkholes are common in some areas. Much of the Rim is covered with 2 to 4 feet of loess. Soils are derived from this loess and several strata of limestone of varying purity. Soils with fragipans are common on the Rim.

The Interior Uplands encompass 23.2 million acres and over one-half (13.2 million acres) is forest land. The Uplands have been settled for at least 175 years. Some of the area has been cleared, farmed, and abandoned several times. Some abandoned land now supports forests over 100 years old. Much of the steeper land was never cleared, but was logged, burned, and grazed repeatedly.

NEED FOR A SYSTEM

For the most part, existing forests of the Interior Uplands do not indicate site potential. A history of high-grading, fire, and grazing has resulted in thousands of acres of cull-dominated stands, so too few suitable stands exist to obtain a direct measure of site potential.

Very little tree-soil-site information is available; practically none is applicable to the Interior Uplands. What information is available was developed mostly by the factorial approach, which was not always successful. Often sample selection and statistical manipulation were much less sound than they appeared. Also products of these studies were graphs and equations, but the tools necessary for forest planning and management are maps and inventories (Stone 1978).

Less than 25 percent of Plateau and Rim counties have soil surveys published since 1967; less than 10 percent of the counties have surveys with Woodland Suitability sections. These recent surveys represent islands of soil and site information. We need to extrapolate from this data base to acreas lacking published information.

BASIS OF THE SYSTEM

Requirements

A site classification system for the Plateau and Rim should be relatively simple, practical, and applicable to all sizes and classes of ownership. The scale and intensity of delineations should be appropriate to meet a wide variety of management objectives.

From a practical standpoint there is little justification for making the usual medium-intensity soil survey (typical county survey) for most forest management activities. Bartelli and DeMent (1970) concluded that low-intensity surveys would provide a reasonable balance between cost and value of the survey for forest management purposes. Boundary lines in low-intensity surveys may coincide with natural features of the landscape.

Because landforms and topography are closely related to soil types a strong argument can be made for subdividing landscapes instead of mapping soils. In rugged terrain, landforms have as much as, or even greater significance than soils. Landforms can be recognized by foresters and other potential users without formal training in soil science. Recent attempts to classify forest land are a combination of soil and landform mapping (for example, Steinbrenner 1975).

Finally a site classification system should be heirarchal so it can be used at all organizational levels of planning -- project, regional, corporate, or national.

Description

This site classification system was adapted from Wertz and Arnold's (1975) Land System Inventory. The landscape is stratified on the heirarchal significance of physiography, geology, soils, topography, and vegetation.

The five levels of this site classification system are:

V. PHYSIOGRAPHIC PROVINCE -- A region of similar structure, climate, and geomorphic history (mapped at a very small scale); used for national and broad regional planning.

IV. REGION -- Represents the component parts of provinces and is defined by topography expression as influenced by structure, process, climate, and time (mapped at a scale of 1:500,000); used for regional planning and broad zoning.

III. SUBREGION -- Represents the component parts of regions and is the smallest land unit identified on the basis of geologic factors and climate as they are expressed over time (mapped at a scale of 1:250,000); permits the separation of areas having broadly differing resource potentials and natural hazards; used to identify specific planning relationships and resource allocation decisions.

II. LANDTYPE ASSOCIATION -- Represents the component parts of subregions and is the largest land unit controlled by soils, landform, and vegetation (mapped at scale of 1:60,000 to 1:125,000); used to summarize resource allocation decisions at the area-planning or working circle level.

I. LANDTYPE -- Represents the component parts of landtype association. Landtypes are visually identifiable areas that have similar soil and productivity and have resulted from similar climatic and geologic processes (mapped at scales of 1:10,000 to 1:60,000); used as the basic unit for overall land management.

Wertz and Arnold (1975) recognized two lower levels -- Landtype Phase and Site. Landtype phases are comparable to soil types and phases (mapped at scales of 1:20,000 and larger). Sites (generally not delineated on maps) represent a final integration of environmental factors as these occur at specific locations. These lower levels would be useful for detailed planning and for specific high-value forest operations like a seed orchard.

The proposed system can be described briefly as a process of successive landscape stratifications. Vegetation is not mapped but is considered in defining landtypes and in recognizing landtypes on the ground.

LEVELS OF CLASSIFICATION

Six regional guides that correspond to Level IV of the heirarchy have been proposed for classifying and evaluating forest sites of the Interior Uplands (Fig. 1). The first of these guides will cover the Southern Cumberland Plateau.[1]

Level V.--PHYSIOGRAPHIC PROVINCE

1. Cumberland Plateau
2. Highland Rim (Pennyroyal)

Level IV.--REGION

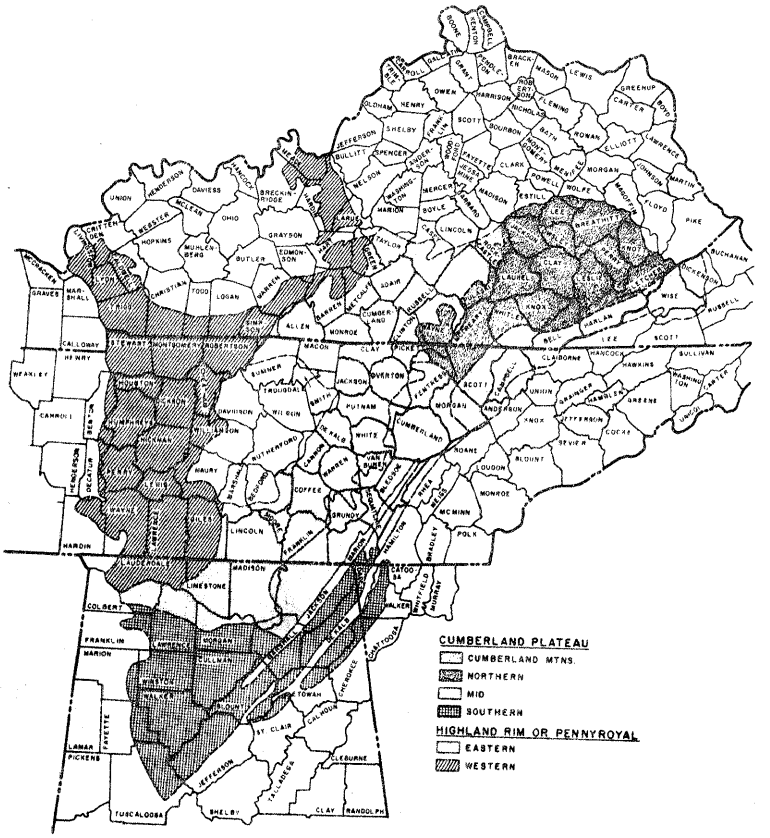
1. Cumberland Mountains
2. Northern Plateau
3. Mid Plateau
4. Southern Plateau
5. Eastern Highland Rim
6. Western Highland Rim

In the remaining description of the system, the Southern Cumberland Plateau will serve as an example. Four subregions are recognized (Fig. 2).

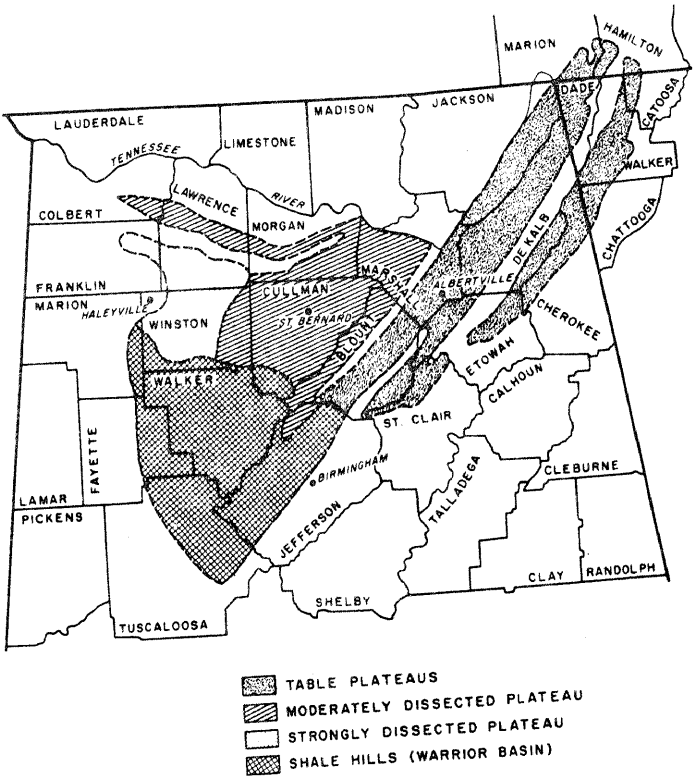
Level III.--SUBREGION

1. Shale Hills
2. Table Plateaus
3. Moderately Dissected Plateau
4. Strongly Dissected Plateau

1/ Smalley, Glendon. Classification and Evaluation of Forest Sites on the Southern Cumberland Plateau (manuscript in preparation).



1. Physiographic provinces and regions of the Interior Uplands.



2. Subregions of the Southern Cumberland Plateau.

These subregions correspond fairly well to the forest habitat regions delineated by Hodgkins and others (1976). The Shale Hills area is well dissected and soils are derived mostly from shale. Subregions 2, 3, and 4 are reasonably similar, varying mostly in degree of dissection. Soils are derived primarily from sandstone.

The Strongly Dissected Plateau was subdivided into three landtype associations:

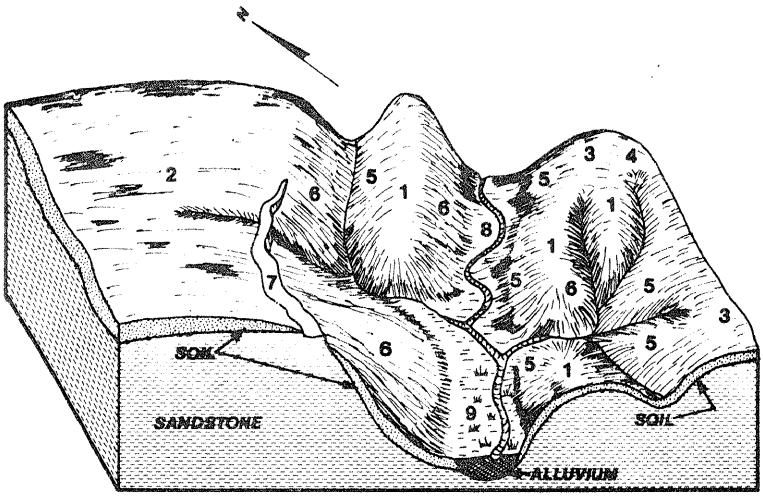
Level II.--LANDTYPE ASSOCIATION

1. Landtypes associated with drainages
2. Upland landtypes on the sides of the Plateau
3. Upland landtypes on top of the Plateau.

On top of the Plateau nine landtypes are recognized (Fig. 3). Landtypes 1 through 7 are on the uplands and Landtypes 8 and 9 are associated with drainages.

Level I.--LANDTYPES

1. Narrow ridges and convex upper slopes
2. Broad undulating uplands
3. Broad ridges -- north
4. Broad ridges -- south
5. North slopes
6. South slopes
7. Sandstone glades, rock outcrops, and shallow soils
8. Lower slopes, terraces, and streambottoms with good drainage
9. Terraces and streambottoms with poor drainage.



3. Landtypes on top of the Southern Cumberland Plateau where the caprock is mostly sandstone. Landtypes shown are (1) Narrow ridges and convex upper slopes, (2) Broad undulating uplands, (3) Broad ridges, north aspect, (4) Broad ridges, south aspect, (5) North slopes, (6) South slopes, (7) Sandstone glades, rock outcrops, and plateau edges, (8) Lower slopes, terraces, and streambottoms with good drainage, and (9) Terraces and streambottoms with poor drainage.

LANDTYPE DESCRIPTIONS

Each landtype is described in terms of nine elements (Table 1). The GEOGRAPHIC SETTING provides an overall description of the landtype, specifying both where it occurs on the landscape and its relation to other landtypes. Slope is classified according to Soil Conservation Service (SCS) standards (Soil Survey Staff 1951).

The most prevalent soil series are listed under DOMINANT SOILS. These series names reflect the most recent designations in soil classification and link this site classification system with county soil surveys published by the SCS. More detailed information is available in soil series descriptions issued by the SCS.

The kind of BEDROCK or SOIL PARENT MATERIAL and DEPTH TO BEDROCK are listed next. SOIL TEXTURE is described in terms of the 12 conventional classes (Soil Survey Staff 1951).

SOIL DRAINAGE is described in terms of the 7 conventional classes (Soil Survey Staff 1951). RELATIVE SOIL WATER SUPPLY of each landtype is rated in five classes: very low, low, medium, high, and very high. This qualitative rating is based on the available water holding capacity of the dominant soils, but allowances are made for the influence of soil drainage, topographic position, and aspect.

SOIL FERTILITY is described on the basis of seven classes: very low, low, moderately low, moderate, moderately high, high, and very high. Because soils of the Interior Uplands are fairly acid and derived from rocks with limited weatherable minerals, soils with high or very high fertility are not common (Francis and Loftus, 1977). The most common woody species in approximate order of abundance are listed under VEGETATION. Some distinctive herbaceous species are included. Species nomenclature follows the U. S. Forest Service Check List (Little 1953).

FOREST MANAGEMENT INTERPRETATIONS

Each landtype is evaluated in terms of productivity for selected species of trees and species desirability for timber production. Also, each landtype is rated for five soil-related problems that may affect forest management operations. The format for presenting forest management interpretations (Table 2) is similar to the one used by the SCS in Woodland Suitability sections of county soil surveys. This similarity should facilitate the integration of information contained in county soil surveys into this classification system.

Productivity

Productivity of commercially valuable species is expressed as site index and as average annual growth in cubic feet per acre. With few exceptions site indices for naturally occurring species are the means of values from Soil Survey Interpretations for dominant soils in each landtype. Interpretations are issued by the SCS as part of each soil series description. SCS personnel obtained height and age measurements in well-stocked, even-aged, essentially unmanaged stands that had not been damaged excessively by fire, insects, disease, or grazing. These stands were located on soils representing, as nearly as possible, the modal concept of each soil series. SCS personnel then used published site index curves to convert height and age pairs to site indices. Curves for most species are based on age 50 years, although younger base ages are common for fast-growing species or species grown in short rotations.

If data for a specific region or subregion are available, these will be used instead of the soil series averages. For example, in the Highly Dissected Plateau portion of the Southern Cumberland Plateau, site indices, base age 50 years, for upland oaks were derived from Smalley's (1967) soil-site study.

Average annual growth expressed in cubic feet per acre was calculated from available yield tables. Cubic feet was selected as a more versatile measure of volume growth than either cords or board feet. The yield tables represent either normal or fully-stocked conditions. Annual growth rates for all naturally occurring species or forest types were averaged over 50 years. This period seemed a reasonable compromise between short rotations for roundwood and long rotations for sawlogs. Because yields are not expressed in a common merchantability standard, care must be exercised in comparing average annual yields of species both within and between landtypes (see footnotes to Table 2).

Management Problems

For the most part management problems and ratings of slight, moderate, and severe follow SCS definitions.

PLANT COMPETITION rates the invasion of unwanted trees, vines, shrubs, and other plants after openings are made in the canopy. This competition can hinder establishment and normal development of desirable seedlings, whether they occur naturally or are planted or seeded. Competition ratings represent regional averages, and competition on a given landtype can vary considerably as a result of past land use.

SEEDLING MORTALITY is the loss of artificially established tree seedlings and is influenced by soils and topographic conditions; plant competition is assumed not to be a limiting factor.

EQUIPMENT LIMITATIONS are restrictions on use of conventional wheeled or tracked equipment for harvesting and planting trees, constructing roads, and controlling fire and unwanted vegetation. Soil and topographic characteristics such as slope, drainage, texture, stoniness, and rockiness influence equipment limitations, sometimes necessitating the use of different kinds of equipment and methods of operation, or restricting the season when equipment is used.

EROSION HAZARD is the degree of potential soil erosion that can occur during and after forest management operations that expose soil along roads, skid trails, fire lanes, and landing areas. The ratings assume that the forest is well managed and is protected from fire and grazing. Soil and topographic characteristics considered in rating hazard of erosion include slope, infiltration, permeability, water holding capacity, and resistance to detachment of soil particles by rainfall and runoff.

WINDTHROW HAZARD measures how soils affect root development and how firmly soils hold trees.

Species Desirability

Three categories are used for rating species desirability of species that commonly occur on each landtype. Most Desirable species are those that have potential for fast growth, high value, or both. Acceptable species are those with moderate growth rate or value. Least Desirable species are those with slow growth, poor quality, or both. These ratings represent the average situation for a region. The presence or absence of local markets could result in a species being assigned to another category.

USING THE SYSTEM

This system is designed to allow professional foresters, forest landowners, landuse specialists, forest researchers, and other resource professionals to make on-site determinations of site productivity and should provide a site-dependent framework for forest management planning and forest research.

To make on-site determinations of productivity on a particular tract of land users must first identify specific landtypes by referring to the Landtype Descriptions. Then users should refer to the appropriate table to obtain information about productivity, severity of management problems, and species desirability.

This site classification system provides a sound biological basis for forest management planning because it recognizes inherent site differences and soil-related hazards. When the system is adopted, landtypes become the basic unit of management. Continuous Forest Inventory or other forest inventory systems can easily be incorporated into this site classification system to obtain information on acreage, stocking, composition, and growth of forests by landtypes. Once productivity data are available for landtypes on a specific tract, they should be substituted for the regional values.

Users should be aware that there may be considerable variation in productivity within a landtype. This variation should be handled as a sampling problem dependent on the desired precision of the productivity information. To adequately sample some landtypes, users with existing inventory systems may be required to install new plots or points. Excessive variation in productivity within a landtype may indicate the need to divide the landtype into more homogeneous units.

A logical vehicle to transfer this site classification system into a valuable forest management tool is landtype maps (Fig. 4), which can be used in all phases of management from day-to-day activities to long-range planning. The number and scale of maps will depend on size of ownership and how intensively one wishes to manage. Landtypes can be mapped at scales of 1:10,000 to 1:60,000, and at these scales, areas as small as 2 acres can be recognized. Smoothness of the terrain will determine maximum size. In the Interior Uplands maximum size of landtypes probably will not exceed 20 acres. This size range compares favorably with Weyerhaeuser's soil-land form maps of their West Coast holdings (Steinbrenner 1975). The U. S. Geological Survey 7½ minute quadrangle sheets (1:24,000) make excellent base maps on which to delineate landtypes. Black and white or color aerial photos, particularly stero-pairs, can also serve as base maps. A reasonable amount of ground checking should be part of the mapping process. Owners or managers of large tracts should explore the advantages of computer-generated mapping of landtypes and other physical and biological feature of the landscape (Beeman 1978).

For forest researchers this site classification system provides a basis for stratifying study areas. The system also aids in identifying and isolating problems that need to be researched. For example, it became apparent in compiling site index and growth information that little mensuration data specific to the region was available. Finally, the system provides researchers with a vehicle for quick transfer of research results to the practitioner. Study results can be reported on the basis of their applicability to specific landtypes.

The development of this system is a continuing process. Additional research and experience in application will result in revision of productivity data, improved interpretation for timber management, and extension of interpretations to other forest resources.

For many years forest land management decisions have been made without knowledge of the productive capacity of the land. One does not have to look far before seeing mistakes resulting from this lack of information. With the application of this system, sounder management decisions can be made for Cumberland Plateau and Highland Rim forests.

LITERATURE CITED

Bartelli, Lindo J. and James A. DeMent. 1970. SOIL SURVEY -- A GUIDE FOR FOREST MANAGEMENT DECISIONS IN THE SOUTHERN APPALACHIANS. In Chester T. Youngberg and Charles B. Davey (ed.), Tree Growth and Forest Soils, Proc. Third N. Am. For. Soils Conf., p. 427-434. Oregon State University Press, Corvallis.

Beck, Donald E. 1962. YELLOW-POPLAR SITE INDEX CURVES. USDA For. Serv., Southeast. For. Exp. Stn. Res. Note No. 80, 2 p.

Beeman, Larry E. 1978. COMPUTER-ASSISTED RESOURCE MANAGEMENT. In Integrated Inventories of Renewable Natural Resour.: Proc. of the Workshop, p. 375-381. USDA For. Serv. Gen. Tech. Rpt. RM-55.

Bernier, B. and C. H. Winget (ed.). 1975. FOREST SOILS AND FOREST LAND MANAGEMENT. Proc. Fourth N. Am. For. Soils Conf., Laval Univ. Quebec. August 1973. 675 p. Les Presses de L'Universite' Laval, Quebec, Canada.

Broadfoot, W. M. 1960. FIELD GUIDE FOR EVALUATING COTTONWOOD SITES. USDA For. Serv., South. For. Exp. Stn. Occas. Pap. 178, 6 p.

Broadfoot, W. M. and R. M. Krinard. 1959. GUIDE FOR EVALUATING SWEETGUM SITES. USDA For. Serv., South. For. Exp. Stn. Occas. Pap. 176, 8 p.

Carmean, Willard H. 1975. FOREST SITE QUALITY EVALUATION IN THE UNITED STATES. Adv. Agron. 27: 209-269.

Fenneman, Nevin M. 1938. PHYSIOGRAPHY OF EASTERN UNITED STATES. 714 p. McGraw-Hill Book Co., N. Y.

Francis, John K. and Nelson S. Loftus. 1977. CHEMICAL AND PHYSICAL PROPERTIES OF CUMBERLAND PLATEAU AND HIGHLAND RIM FOREST SOILS. USDA For. Serv. Res. Pap. SO-138, 44 p.

Hodgkins, Earl J., Timothy K. Cannon, and W. Frank Miller. 1976. FOREST HABITAT REGIONS FROM SATELLITE IMAGERY: STATES OF ALABAMA AND MISSISSIPPI. A supplement to Southern Cooperative Series Bulletin 210, 2 p.

Little, Elbert L., Jr. 1953. CHECK LIST OF NATIVE AND NATURALIZED TREES OF THE UNITED STATES (INCLUDING ALASKA). USDA Agr. Handb. 41, 472 p.

McCarthy, E. F. 1933. YELLOW POPLAR CHARACTERISTICS, GROWTH, AND MANAGEMENT. USDA Tech. Bull. No. 356, 58 p.

Nelson, T. C., J. L. Clutter, and L. E. Chaiken. 1961. YIELD OF VIRGINIA PINE. USDA For. Serv., Southeast. For. Exp. Stn., Stn. Pap. 124, 11 p.

Schnur, G. Luther. 1937. YIELD, STAND, AND VOLUME TABLES FOR EVEN-AGED UPLAND OAK FORESTS. USDA Tech. Bull. 560, 88 p. (Reprinted 1961).

Smalley, Glendon W. 1967. SOIL-SITE RELATIONS OF UPLAND OAKS IN NORTH ALABAMA. USDA For. Serv. Res. Note SO-64, 6 p.

Smalley, Glendon W. and Robert L. Bailey. 1974a. YIELD TABLES AND STAND STRUCTURE FOR LOBLOLLY PINE PLANTATIONS IN TENNESSEE, ALABAMA, AND GEORGIA HIGHLANDS. USDA For. Serv. Res. Pap. SO-96, 81 p.

Smalley, Glendon W. and Robert L. Bailey. 1974b. YIELD TABLES AND STAND STRUCTURE FOR SHORTLEAF PINE PLANTATIONS IN TENNESSEE, ALABAMA, AND GEORGIA HIGHLANDS. USDA For. Serv. Res. Pap. SO-97, 57 p.

Smalley, Glendon W. and David R. Bower. 1971. SITE INDEX CURVES FOR LOBLOLLY AND SHORTLEAF PINE PLANTATIONS ON ABANDONED FIELDS IN TENNESSEE, ALABAMA, AND GEORGIA HIGHLANDS. USDA For. Serv. Res. Note SO-126, 6 p.

Soil Survey Staff. 1951. SOIL SURVEY MANUAL. USDA Agr. Handb. 18, 503 p.

Steinbrenner, E. C. 1975. MAPPING FOREST SOILS ON WEYERHAEUSER LANDS IN THE PACIFIC NORTHWEST. In B. Bernier and C. H. Winget (ed.), Forest Soils and Forest Land Management, Proc. Fourth N. Am. For. Soils Conf., p. 513-525. Les Presses de L'Universite' Laval, Quebec, Canada.

Stone, Earl L. 1978. A CRITIQUE ON SOIL MOISTURE-SITE PRODUCTIVITY RELATIONSHIPS. In W. E. Balmer (ed.), Proceedings Soil Moisture...Site Productivity Symposium, USDA For. Serv. Southeast. Area, State and Priv. For., Atlanta, Ga., p. 377-387. Myrtle Beach, South Carolina, November 1-3, 1977.

U. S. Forest Service. 1929. VOLUME, YIELD, AND STAND TABLES FOR SECOND-GROWTH SOUTHERN PINES. USDA Misc. Pub. No. 50, 202 p. (Slightly revised 1976).

Wertz, W. A. and J. F. Arnold. 1975. LAND STRATIFICATION FOR LAND-USE PLANNING. In B. Bernier and C. H. Winget (ed.), Forest Soils and Forest Land Management, Proc. Fourth N. Am. For. Soils Conf., p. 617-629. Les Presses de L'Universite' Laval, Quebec, Canada.

Winters, Robert K. and James G. Osborne. 1935. GROWTH AND YIELD OF SECOND-GROWTH RED GUM IN FULLY STOCKED STANDS ON ALLUVIAL LANDS IN THE SOUTH. USDA For. Serv., South. For. Exp. Stn. Occas. Pap. 54, 35 p.

Table 1.--An example of a landtype description. Landtype 1, Narrow Ridges and Convex Upper Slopes on top of the strongly dissected portion of the Southern Cumberland Plateau.

Geographic Setting - Shallow to moderately deep soils on gently sloping to steep narrow winding ridgetops and adjoining convex upper slopes. Slope ranges from 0 to 40 percent. Typically this landtype is no wider than 250 feet. Rock fragments, mostly sandstone, are common on the surface. Up to 50 percent of the soil mass may be coarse fragments. Along the western boundary of Little Mountain in Subregion B and in Subregion C in the transition to the Upper Coastal Plain ridgetops may be capped with a few inches to several feet of unconsolidated Coastal Plain sediments. If these sediments are extensive, this site classification does not apply.

Dominant Soils - Hartsells, Linker, Mountainburg, and Hector.

Bedrock - Predominantly sandstone and conglomerate with thin strata of shale or siltstone in places.

Depth to Bedrock - 40 inches or less.

Texture - Fine sandy loam, sandy loam, loam; often channery, flaggy, or stony.

Soil Drainage - Well-drained to somewhat excessively drained.

Relative Soil Water Supply - Low to very low.

Soil Fertility - Low.

Vegetation - White oak, southern red oak, scarlet oak, post oak, chestnut oak, black oak, shortleaf pine, Virginia pine, blackjack oak, hickories, and blackgum; occasional sweetgum and yellow-poplar. Dogwood, sassafras, sourwood, and huckleberries are common understory associates.

Table 2.--An example of forest management interpretations. Landtype 1, Narrow Ridges and Convex Upper Slopes on top of the strongly dissected portion of the Southern Cumberland Plateau.

PRODUCTIVITY				
SPECIES	SITE INDEX		AVERAGE ANNUAL GROWTH CUBIC FEET PER ACRE	
	NATURAL STANDS[1]	OLD-FIELD PLANTATIONS[2]	NATURAL STANDS[3]	OLD-FIELD PLANTATIONS[4]
Loblolly pine	70	55	104	133
Shortleaf pine	55	40	90	84
Virginia pine	60		53	
White oak	55 }			
Red oaks	60 }		38-45	
E. redcedar	35			

MANAGEMENT PROBLEMS				
PLANT COMPETITION	SEEDLING MORTALITY	EQUIPMENT LIMITATIONS	EROSION HAZARD	WINDTHROW HAZARD
Slight	Slight to Severe	Slight to Severe	Slight to Severe	Slight

SPECIES DESIRABILITY		
MOST DESIRABLE	ACCEPTABLE	LEAST DESIRABLE
Loblolly pine	White oak	Post Oak
Virginia pine	S. red oak	Blackgum
Shortleaf pine	Black oak	Hickories
	Chestnut oak	E. redcedar

FOOTNOTES FOR TABLE 2

1/ Site indices for each naturally occurring species, except those for upland oaks and those enclosed in parentheses, are the means of values from soil survey interpretations issued by the SCS for the dominant soils in each landtype (Beck 1962, Broadfoot 1960, Broadfoot and Krinard 1959, Nelson et al. 1961, and U. S. For. Serv. 1929). Site indices for white oak and red oaks were derived from Smalley's (1967) soil-site study and Schnur's (1937) site index curves. Estimated site indices are enclosed in parentheses. Base age is 50 years for all natural-grown species except cottonwood which is 30 years.

2/ Adapted from Smalley and Bower's (1971) site curves, base age 25 years.

3/ Annual growth of natural stands calculated from published yields at 50 years: Yellow-poplar -- (McCarthy 1933, Table 17), inside-bark volume to a 3.0-inch i.b. top; trees >4.5" d.b.h.; Sweetgum -- (Winters and Osborne 1935, Table 13), inside-bark volume to a 4.0-inch i.b. top, trees >4.5" d.b.h.; Upland oaks -- (Schnur 1937, Table 2, Column 12), outside-bark volume to a 4.0-inch o.b. top, trees >4.5" d.b.h.; Virginia pine -- (Nelson et al. 1961, Table 4), outside-bark volume to a 4.0-inch o.b. top, trees >3.5" d.b.h.; Loblolly and shortleaf pines -- (U. S. For. Serv. 1929, Tables 44 and 108), total volume outside bark, trees >3.5" d.b.h.

4/ Annual growth of loblolly and shortleaf pine plantations calculated from yields at 40 years assuming 1,000 seedlings planted per acre (Smalley and Bailey 1974a, 1974b), outside-bark volume to a 4.0-inch o.b. top, trees >4.5" d.b.h.