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To the Graduate Council:

I am submitting herewith a thesis written by Daniel D. Summers, entitled "Relationships of Soil, Site, and Time on the Changes in Forest Composition on Big Ridge Natural Study Area, Union County, Tennessee." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

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RELATIONSHIPS OF SOIL, SITE, AND TIME ON THE CHANGES IN FOREST COMPOSITION ON BIG RIDGE NATURAL STUDY AREA, UNION COUNTY, TENNESSEE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

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Master of Science

by

Daniel D. Summers

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ABSTRACT

The study was conducted on Big Ridge Natural Study Area in the Great Valley of East Tennessee. Fifth acre plots were established in 1936 forming strips of one-by-two chain plots across the steep ridge. Site, soil, and vegetation data were recorded on these plots, and compared to vegetation data from 1936. The data indicates that vegetation was significantly affected by openings in the stand due to logging prior to 1936 and the elimination of chestnut by *Endothia parasitica*.

Hickory, dogwood, red maple, chestnut oak, and blackgum maintained frequencies close to 100 percent between studies, while black oak, beech, and sugar maple increased in frequency.

Sourwood, hickory, scarlet oak, northern red oak, sassafras, and shortleaf pine declined in density between 1936 and 1967, especially in smaller stems, while red maple, sugar maple, blackgum, and beech showed sharp gains in density, especially in smaller stems. Sourwood, red maple, blackgum, Virginia pine, shortleaf pine, white oak, and scarlet oak increased in density as sites progressed from moist to dry, while sugar maple, beech, ash, and yellow-poplar showed the opposite relationship.

With the exclusion of chestnut from the data, basal area increased from 74.2 to 92.5 square feet per acre from 1936 to 1967. Black oak, chestnut oak, and hickory increased considerably in basal area between studies, especially on north ridges. Virginia pine doubled its basal area on south ridges.

No clear picture of forest types was indicated from the data, but considerable changes in type were recorded for individual plots between studies. Black oak was the primary type replacing chestnut.

Black oak importance values increased on upper slope positions, but showed a marked decrease below middle slopes. Chestnut oak was also important on upper and middle ridges, while hickory importance was greatest on middle north slopes. Beech importance increased from dry to moist sites.

Merchantable volumes and number of merchantable trees increased significantly over the 31-year period. Greatest volume was exhibited on south ridges, but north ridges had the greatest rate of volume increase. Chestnut oak and black oak increased significantly on all sites, while the greatest hickory volume increase was in hollows.

Canonical analyses indicated that heavy herbaceous ground cover, fine texture of B horizon, and slope directions approaching southwest were related to dry sites. On such sites shortleaf pine, Virginia pine, white oak, sassafras, sourwood, black oak, and scarlet oak, and red maple reproduction were most abundant. Mesic sites were indicated by dense shrub cover, more complete canopy closure, and high stone content of soil, and to a lesser extent, fine-textured, thick A horizons. Beech, ash, and hickory were highly related to these sites.

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CHAPTER I

INTRODUCTION

The objective of this study is to compare present vegetation data with that of a 1936 forest inventory which was conducted jointly by the Tennessee Valley Authority and the Appalachian Forest Experiment Station. Another objective is to relate soil-site factors to stand composition. The study area lies in the Great Valley of East Tennessee near the center of the Deciduous Forest of eastern North America.

The study area contains permanent sample plots which were established by the above agencies to observe the natural process over a period of years, such as growth and mortality, by forest types, sites, species associations in major forest types, and growth and development of reproduction. All natural features and native vegetation were to be preserved, with no cutting, road construction, hunting, introduction of foreign species, or fires permitted.

Since settlement of the region, the formerly forested valleys have been farmed and the ridges maintained in forests. Fire and grazing in the forests have been of common occurrence. Few uncut or otherwise undisturbed forests are left in the region. Although most of the study area was logged previous to the original study, no disturbances have occurred on it since. The study area is therefore important to the forest ecologist as a control forest to which the long term effects of various management practices in similar vegetation may be compared.

CHAPTER II

REVIEW OF LITERATURE

Succession

No plant community is completely stable. Its components vary with age and longevity, some are weak or overmature, some are always dying out. Other plants expand to fill the vacated space; "younger suppressed individuals, released from competition, may rapidly replace them, or the openings in cover and soil may allow establishment of new individuals, or even species, which were previously excluded." Thus, any plant community is characterized by constant change instead of stability (Cooper, 1926). This is the concept of succession.

Succession which begins on a bare area where no vegetation has grown before is called "primary" succession. "Secondary" succession results when the normal succession is disrupted by fire, cultivation, forestry practices, windthrow, or other disturbances which destroy the principal species of the established community. "To what extend the development of vegetation on the secondary area resembles primary succession is determined by the degree of disturbance" (Oosting, 1956).

During secondary succession, the effects of one stage, although not as striking as in primary succession, do influence the next stage. For example, on the Piedmont of New Jersey, Bard (1952) stated that it appeared that pioneer trees provided shelter for rodents which spread seeds, provided shade which restricted exacting heliophiles ("sunlovers"), and provided a reduction in soil temperatures which in turn reduced evaporation. These combined effects favored the establishment of oaks on the site. On the North Carolina Piedmont, similar findings have been reported by Billings (1938) studying shortleaf pine (*Pinus echinata*),[1] and by Coile (1940), working with loblolly pine (*Pinus taeda*). Baker (1950) warned, however, that the influence of the plants themselves has often been overrated.

Climax

Any discussion of plant communities and succession is incomplete without a discussion of the end result of succession--the climax. Selleck (1960) in "The Climax Concept" sites four definitions of climax:

1. Climax is development of vegetation and the formation of soil toward a definite end point determined and limited by climate (Braun-Blanquet, 1932).

2. Climax is a terminal community of succession which is controlled by climate; it is capable of reproducing itself and may not be replaced by other individuals as long as the climate remains the same (Oosting, 1956).

3. Climax is synonymous with vegetational formation, it is the ultimate terminating community, determined by climate (Weaver and Clements, 1929).

4. Climax is the final community in a successional series; it is self perpetuating and in equilibrium with the habitat (Odum, 1953).

These definitions indicate that climax is the last stage of succession on a certain given physiographic site in an unchanging climate. Selleck added, however, that a definition of climax should avoid terms of finality.

[1]Nomenclature after Harlow and Harrar (1958).

Several different types of climaxes exist. Cain (1939) attributed the variety of climaxes to differences in climate, topography, physiography, soil action and reaction, and ecological amplitude of biotic species.

Early in this century, many different names were assigned by various investigators to these formations. Clements devised an elaborate system of nomenclature with over half a dozen climaxes, such as pre-climax, post climax, and disclimax (Weaver and Clements, 1929). Since then, however, many of these terms have been disregarded (Selleck, 1960).

In his nomenclature of climaxes, Clements (Weaver and Clements, 1929) stated that any climatic region had only one potential climax, the most mesophytic community the climate could support. This climax would be found on the more intermediate sites, and both more mesic and xeric environments would normally be developing toward this condition. Although the term "regional climax" might be a better name, the redundancy "climatic climax" is the more commonly used term. Baker (1950) stated that the climatic climax was the last stage in succession and gave three cirteria by which climaxes could be recognized:

1. Climaxes are stable, their dominants replacing themselves. No new dominants can enter, except minor fluctuations of cycles due to climatic fluctuations.

2. Climaxes are correlated with mature soils, which, like the climax itself, are the product of the climate.

3. Climaxes are essentially uniform in species composition within the same climatic province. . . .

Although the climatic climax type covers large areas, one must always expect variations in associations within its region. Although the successional stages of vegetation and physiography may be progressing toward the regional climax, not all areas will ever reach it (Oosting, 1956). For this reason, other climaxes must be recognized.

When the stage immediately preceding the climax maintains itself over a long period of time, it is called a subclimax. The Subclimaxes are maintained by forces other than climate (Clements, 1916; Weaver and Clements, 1929; Tansley, 1935; and Baker, 1950). Oosting (1956), to give an example, considered the pine stands of the southeastern United States subclimax types, maintained for centuries by fire.

The physiographic climax is a climax maintained by permanent "natural barriers" such as dry ridges, swamps, or rock outcroppings (Nichols, 1923; Weaver and Clements, 1929; and Baker, 1950).

Edaphic climaxes refer to types dependant on some edaphic environment relatively little changed through climatic and physiographic cycles (Braun, 1950).

Climax On Upland Sites

In his classic study of the plant communities on the North Carolina Piedmont, Oosting (1942) concluded that the oak-hickory community was the climax type for that region, although combinations of the species varied. He found the principle type to be white oak (*Quercus alba*)-black oak (*Q. velutina*)-red oak (both northern red (*Q. rubra*), and southern red oak (*Q. falcata*), with scarlet oak (*Q. coccinea*) also present). The second principle type he found was white oak-post oak (*Q. stellata*). This type was characteristic of south and west exposure, dry ridges, and poorer soils. Oosting called it a variation of the climax type. Mockernut (Carya tomentosa) and pignut hickories (C. glabra) were present on both types. On the Duke Forest, the white oak-black oak-red oak type occurred 13 times as frequently as the white oak-post oak type.

The hickories were much more important in the white oak-black oak-red oak type than the other type. Carolina hickory (C. carolinae-septentrionalis) occurred here with mockernut and pignut hickories.

The occurrence of an occasional pine is probably normal even in the climax oak-hickory. Openings caused by catastrophies such as fire are often filled by pine. Oosting noted, however, that loblolly pine was restricted to the white oak-black oak-red oak type while shortleaf pine was restricted to the white oak-post oak type. Since the latter forest type was more open, much more pine was found in it than in the white oak-black oak-red oak type.

Principal understory species found by Oosting were dogwood (Cornus florida), blackgum (Nyssa sylvatica), red maple (Acer rubrum), and sourwood (Oxydendron arboreum), all common understory trees in upland oak-hickory types (Hawley et al., 1932). Billings (1938) reported an understory of dogwood and red maple in oak-hickory communities following shortleaf pine. He reported that the herb flora which developed in pine-hardwood stands persisted into the oak-hickory formations.

In the central states, somewhat similar results are obtained, although some of the species are different. Cain (1934) studied a virgin woods in Indiana, ungrazed, and unburned for over 100 years. He found four distinct strata, as follows:

1. A superior arborescent stratum over 100 feet tall; with almost complete coverage. Principal species were yellow-poplar (Liriodendron tulipifera), white oak, sugar maple (Acer saccharum), and blackgum.

2. An inferior arborescent stratum thirty to forty feet tall, composed of dogwood, blue beech (Carpinus caroliniana), and redbud (Cercis canadensis).

3. A shrub stratum, up to seven feet tall, composed of spicebush (Lindera benzoin) and elderberry (Sambucus canadensis).

4. A layer of vines, herbs, and low shrubs composed primarily of poison ivy (Toxicodendron radicans) and Virginia creeper (Parthenocissus quinquefolia).

Cain found more sugar maple and Fraxinus spp. saplings than trees in the overstory, and concluded that they would become more important in the future. On the other hand, just the opposite was found with yellow-poplar, leading Cain to feel that it would not be maintained in the climax.

In the same year (1934), Potzger and Friesner studied another virgin stand in Indiana. This formation of oak-hickory appeared more stable, but other results were similar.

Later studies indicate that oak-hickory can successfully reproduce itself in the central states, if grazing and fire are controlled (Minckler and Jensen, 1959; Minckler and Woerhide, 1965). Both studies indicate that oak-hickory can successfully regenerate itself in openings in the canopy when they occur. Oak was more abundant on the southern aspects and ridges (drier sites), but hickory was evenly distributed.

In the New Jersey Piedmont, Bard (1952) found few oak-hickory seedlings present, but contended that few were needed. He found many oaks over 200 years old, and predicted that many of them could live another 100 years. Therefore, not much reporduction would be needed to maintain the climax, and enough oak-hickory reproduction would be present to fill gaps in the canopy as they appeared.

The latter studies are significant in discussing the climax vegetation in much of the eastern United States. Braun (1935) stated that the distribution of plant communities was mainly controlled by slope exposure and soil. On Pine Mountain, Kentucky, in the Cumberland Mountains, she found immature soils supporting subclimaxes of pine and pine-oak, and physiographic climaxes of oak-chestnut, and oak. She found the "true" or "regional" climax in this area to be on mature soils and consisting of sugar maple, basswood (Tilia americana) and buckeye (Aesculus octandra). Braun stated that these species were the primary components in the "mixed mesophytic forest association" which was the center of the deciduous forest.

Tryon and Carvell (1958) found abundant oak regeneration under mature stands of oak in West Virginia. Later, however, Carvell and Tryon (1959, 1961) reported that oak-hickory could successfully regenerate itself on the southern, drier slopes, but on moister sites required disturbances in the canopy to maintain the type. Other studies support this conclusion (Korstian, 1927; Scholz, 1955; Weitzman and Trimble, 1957; and many others).

In a study of the oak-hickory climax, Braun (1964) described two centers of distribution; one on the Ozark-Ouachita uplands, and the other on the Piedmont. Oak-hickory is also climax throughout most of the region held by the "fire" subclimax shortleaf and loblolly pines in the South. On all other sites, Braun considered oak-hickory to be a physiographic climax, most of which are found on drier sites than the mixed mesophytic forest.

On the Piedmont of New Jersey, Buell and Small (1954) found the oak-hickory type[2] dominant, but stated "It appears obvious that these trees had their origin during a period of frequent fires."

Niering (1953) also in New Jersey, found chestnut oak (Q. prinus) to be the primary cover type in High Point State Park, although variations occurred within it. Pitch pine (Pinus rigida)-"scrub oak" dominated the ridges, pine-oak the slopes, and white oak-hickory the valley floors. All of these three types showed evidence of change, with oak replacing the pine on the xeric sites, and northern hardwoods replacing the oaks on the more mesic sites.

Some Natural Factors Affecting Stand Composition

Fire. After an extensive literature review of the ecological effects of forest fires, Ahlgren and Ahlgren (1960) concluded that fire has been a major factor in the ecology of the forests of North America,

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[2]Principally white oak, red oak (Q. rubra), black oak, and red hickory (Garya ovalis).

and also that fire had "undoubtedly been a major factor in determining the rate and direction of plant succession." Haper, Frank, and McQuilkin (1957) stated that "fire has been a major force in shaping the development and character of timberlands."

Oosting (1944) reported on the comparative effects of crown and surface fires in a thirty-five-year-old loblolly stand on the Duke Forest (North Carolina Piedmont). Changes in the herb and shrub cover were very temporary following the fires--after nine years very similar to previous composition. The crown fire destroyed 98 percent of the basal area of the pine overstory, which had the effect of releasing the oak-hickory understory. Pine reproduction, however, was good and Oosting felt that it might successfully compete with the hardwoods. The result would probably be a mixed pine-hardwood stand. The surface fire, on the other hand, killed only 2 percent of the pine overstory basal area. Hardwoods were much more severely damaged. The results of these burns showed that crown fires would hasten succession while surface fires would probably delay it.

Day (1935) cited the use of fire by the Indians in New Jersey. They used fire in village clearing, firewood, agricultural clearing, and hunting. The effects were magnified by the Indians' habit of seasonal moves. Day concluded that fire had had an important place in making the composition of the New Jersey forests.

Wildlife. In 1935 Hosley and Ziebarth studied the winter relations of white-tailed deer (*Odocoileus virginianus*) in the forests of north central Massachusetts. They found a preference for red maple as deer browse, followed by black cherry, white oak, and red oak. The use of these species for deer browse would tend to favor the growth of other species, affecting stand composition in the successional stages.

In northern hardwoods in New York, Webb, King, and Patric (1956) reported on plots inside and outside of four exclosures. Studying the effects of white-tailed deer they concluded,

> The effect of deer can be measured after fifteen years, but the differences are so small that it can be concluded that deer are not an important limiting factor in the establishment of any tree, shrub, or herbaceous species in this uncut mature northern hardwood forest.

Then a cutting operation was done on the area encompassing two of the enclosures. Nine years later, Tierson, Patric, and Behrend (1966) reported that the effect of deer browsing was plainly evident on the four principal species of the north-eastern region, sugar maple, beech, yellow birch (*Betula alleghaniensis*), and white ash (*Fraxinus americana*). Deer preferred the other species more than the beech, which they left. The result was beech reproduction, with a scarcity of reproduction of the other species.

In the Adirondacs of New York, Curtis and Rushmore (1958) concluded that deer have a marked effect on the number and composition of reproduction in a forest.

Korstian (1962) reported that deer browse changed with the season, sometimes by preference and often by necessity--especially in the winter. In the highlands of the Appalachians he reported that yellow-poplar, black cherry, red maple, white ash, pitch pine, hickories, white and red oaks have been heavily browsed, at one season or another.

Smaller wildlife also affect species composition. Oosting (1956) stressed that rabbit browse did not ordinarily have much effect on natural vegetation, unless periods of peak population come in a winter with a lot of snow. At these times rabbits do a lot of damage eating the bark of seedlings, or even "larger trees."

On the Norris Watershed of East Tennessee, Minckler (1941b and c) and Burton (1964) reported that hardwood stands failed to develop on seeded, abandoned fields because rodents ate the seeds.

In Massachusetts, mice and voles consumption of white pine seed was so great in study areas, that Herschel (1961) stated that all naturally disseminated seed except that overlooked by the predators was consumed.

Diseases and insects. Other biotic agents may alter the normal successional stages. Parasites can drastically alter the composition of forest stands (McCubbin, 1946). Chestnut blight, caused by the fungus _Endothia parasitica_, and described by Anderson and Rankin (1914), has virtually eliminated American chestnut (_Castanea dentata_). Chestnut blight killed one-third of the total volume of hardwood stands in the Appalachians (Jemison and Hepting, 1949). Oak, especially chestnut oak, replaced the openings left by the loss of the chestnut (Korstian and Stickel, 1927) and oak, hickory, and red maple are now dominant where oak-chestnut once occurred (Oosting, 1956; Shanks, 1956).

Dutch elm disease, caused by the fungus _Ceratostomella ulmi_, is another example of a parasite having tremendous effect on species composition. It is gradually spreading from New England southward, despite drastic procedures used to check it (Clinton and McCormick, 1936; Oosting, 1956). American elm (*Ulmus americana* L.) "may become a vanishing species unless the introduced Dutch elm disease is held in check" (Harrar and Harlow, 1958).

Insects may also seriously affect stand composition. For example, the balsam woolly aphid (*Chermes piceae*), accidentally introduced into the North America from Europe in the early 1900's, may eliminate Fraser fir (*Abies fraseri*) from the Southern Appalachians, and threatens balsam fir (*Abies balsamea*) throughout the Northeast. So far chemical control has proved too expensive to use, except in high-use areas such as recreation centers (U. S. Department of Agriculture and Interior, 1964). Biological control of the aphid appears to hold some promise (Lambert, 1967), and several predators from Europe and Asia have been tested, with plans for large scale release of predators if they exhibit the ability to control the aphid (Amman, 1961; Amman and Speers, 1965).

Light. It is common knowledge that light intensities change with stages in succession. Naturally, with no overhead canopy, abandoned fields receive full sunlight, but even here, weeds of varying heights shade the smaller plants.

Shirley (1945), however, stated that pioneer *woody* species seldom create enough shade to preclude invasion by others, although their shade and root competition might slow growth of invaders.

This shading pehnomenon increases in importance as the succession progresses toward the climax and is extremely important in maintaining the climax (Crafton and Wells, 1934; Billings, 1938). Plants in the lower strata must utilize light more effectively at low intensities to survive, since much light is intercepted by the canopy. Therefore, for the climax community to regenerate itself, it must be composed of species which can survive under conditions of low light intensity. Indeed, some plants have been found to grow receiving as little as 1 percent of full sunlight (Oosting, 1956).

Minckler, Plass, and Ryker (1961) in southern Illinois found that the size of opening in a forest stand had a "big" effect on composition, although Minckler and Woerheide (1965) reported that size of opening had little effect on the <u>number</u> of seedlings per given area found in an opening. The smaller the opening, the more seedlings of shade tolerant species found, such as red maple. Moreover, saplings on the south, east, and west edges of openings were found to be shorter than those on the north edge or in the center of the openings--a fact Minckler (1961) attributed to the amount of light the saplings received.

Shirley (1929) found that 20 percent of full sunlight was the minimum amount that most species could receive and still maintain maximum photosyntheseis. Light requirements varied with leaf thickness, length of stem, and root-shoot ratio. Below 20 percent of full sunlight, most plants increased in dry weight proportionally with the raise in light percentage. Shirley stated that light intensity was usually a limiting factor in the growth of plants under forest canopy, although light quality was not. Shirley, and Garner and Allard (1920) reported that flowering and fruiting could be delayed or curtailed when less than 20 percent of full sunlight was available, which would curtail reproduction under many canopies for some species.

<u>Temperature</u>. Shreve in 1924 studied the influence of altitude and slope exposure to soil temperature. He found insulation to be far more important than air temperature in determining soil temperature. Temperature of soil was usually higher on south-facing slopes than north aspects, and vegetation found on those slopes was correlated to the resulting conditions brought about by these temperature changes in the soil. Shreve also found that the temperature of the soil decreased with altitude, although higher slopes fluctuated. Temperature of the soil was less important than the ratio of evaporation to soil moisture in determining differences in vegetation on opposite slopes.

Minckler (1946) studied site conditions on the Norris Watershed in East Tennessee. He reported, "it was shown clearly that maximum surface soil temperature is dependent upon aspect and steepness of slope." On southerly slopes there was a rough relation of a four-degree (F.) rise of mean maximum surface soil temperature for each 10 percent increase in slope steepness.

Richardson (1958) found that the less vegetation on a soil, the higher the temperatures could get. Vegetation had an ameliorating effect on the temperature of the microsite.

<u>Soil Factors Affecting Site Quality and Stand Composition</u>

<u>Soil profile</u>. The depth of an A_1 horizon is considered by many to be one of the most important soil factors determining the quality of a site, which in turn determines the species found on it. In general, site quality increases as the depth of the A_1 horizon increases. Cooper (1942) found that site index for loblolly pine decreased 10 feet for each drop in grade of erosion in the A horizon. The classifications were:

0	No apparent sheet erosion
1	Less than 25 percent removed
2	25 to 50 percent removed
3	50 to 75 percent removed
4	Over 75 percent removed

Tryon, Beers, and Merritt, (1960) also found that the depth of the A_1 horizon, within limits, closely determines site quality for yellow-poplar, but question that this factor alone is adequate in predicting site quality. In Southern Arkansas, Zahner (1958) found that site index increased with depth of "A" horizon, up to 18 inches, which supports findings by Doolittle (1957). In a study of white ash and yellow-poplar on severely eroded old fields, Ryker (1958) found these species only about 2.6 feet in height; but with at least five inches of topsoil the average height was 7.9 feet for yellow-poplar and 4.0 feet for the white ash. The pines and red cedar grew about the same throughout the plots.

Soil texture of the A horizon is also an important factor in determining site quality. In planted red and white pine in Ohio, site index increased for both species as the texture of the A horizon became coarser (Gaizer and Merz, 1953). These general statements on the A horizons are supported by Allen (1960), Coile (1948), Dingle and Burns (1954), and Foster (1959), and others.

In the B Horizon, texture seems to be by far the most important variable in determining site quality. In northwestern Alabama, Allen (1960) considered a sandy loam or a loam subsoil a better loblolly pine site, while heavier clay subsoils under shallow surface soils characterized poorer sites. Site index for yellow-poplar was found to increase sharply with clay content from 3 to 30 percent, then level off with a peak of 36 percent, followed by a decline in site index with clay contents in excess of 40 percent (Phillips, 1966).

The effect of the C horizon is demonstrated in studies by Auten (1945), Meyers and Van Deusen (1960) and Allen (1953). They state that under similar conditions, tree growth in limestone-derived soils is superior to that in sandstone-and-shale-derived soils. In the Tennessee Valley, Burton (1964), reporting on an extensive series of plots of conifers and hardwoods, found limestone soils better than dolomite or shale soils for growth of almost all of the 14 different species tried. It is likely that other factors than parent material affected the few exceptions he found. Husch (1959), Carmean (1961), and others report that the number and size of roots in the C horizon increase with stoniness. In stoney soils, fine roots in B and C horizons concentrated around the surfaces of the stones. Apparently, moisture accumulated there.

Soil strucutre. According to Billings (1938), Berkmann (1913) was the first to point out that soil structure was appreciably changed by the roots of plants growing in the soil. Clay was more affected than sand. Bouyoucos (1924, 1927, 1929) emphasized the important influence that proper moisture conditions, favored by the forest environment, had on structure. Auten (1933) found that a large degree of soil porosity was acquired 20 to 25 years after forest trees had been established on cultivated land. The forest environment also produced soils platy in structure, with a characteristic greater moisture holding capacity than non-platy soils. Furthermore, forest litter protects soil aggregates from being beaten apart by rain (Buckman and Brady, 1960).

These findings show that soil structure is improved by succession as the forest replaces an abandoned field. As species composition is changed from conifers to hardwoods, less acid litter favors increased organic matter flocculation, which Meyer, Anderson, and Bohning (1960) have found give better granular (crumb) structure to the soil.

Soil moisture. Hirth in Connecticut reported in 1959 that the moisture content of a site increased with successional stages until forest was established (although moisture contents of microsites were similar in winter, regardless of successional stage).

Korstian and Coile (1938) found that trenched plots had significantly greater moisture contents during periods of stress than untrenched plots. The trenched plots usually had enough moisture during these stress periods for plants to maintain turgidity, the untrenched plots did not. Trenched plots also had more individual plants and species than the untrenched plots for two years. After two years, however, competition began to reduce the number of individuals in the plot. Mesic type plants were replaced by more zeric individuals. Establishment and growth of tree species was much better on trenched plots than on the control plots. Korstian and Coile stated that,

> It is believed that the study clearly demonstrates that competition between individuals of the forest vegetation for soil moisture is a highly significant factor in the growth, development, and reproduction of forest in the Piedmont.

Pomeroy (1949) found that loblolly pine germination depended on the availability of moisture to the seed. Kozlowski (1949) found that on the North Carolina Piedmont growth of seedling loblolly pine and overcup oak (*Quercus lyrata*) was seriously inhibited when soil moisture neared the permanent wilting point, although pine suffered more severely. Pine in high light intensities was found to absorb more water than in low light. Kozlowski stated that,

> It appears difficult, in view of the great reaction of pine to both light and water, to stress the overall importance of one while minimizing the other. It seems likely that, in the forest, ultimate failure of pine seedlings is caused by strong effects of both, and not by one factor independently.

In planted yellow-poplar, the inches of available water in the soil profile is strongly influenced by topographic factors "whose influence is not apparent in the physical properties of the soil" (Smalley, 1964). Coile (1935) found marked correlation between site index and water holding capacity of the B_1 horizon. In the poorer sites, site index decreased from 72 to 24 feet as water holding capacity increased from 26 to 45 percent; site index decreased from 72 to 67 feet as water holding capacity decreased from 26 to 20 percent.

Gaiser (1951), in the Central states, found that site index of white oak varied with total available water in the A horizon, but inversely with available water in the B horizon.

Billings (1938), Duncan (1939), and Coile (1939a) found that the moisture equivalent of soils, especially light-textured soils, was greatly increased by organic matter. Billings' correlation of 0.949 was highly significant. Coile further reported that the wilting percentages also increased with additional organic matter in light-textured soils, but at a lesser rate. Wilting percentages were not affected by organic matter in heavy-textured soils. He stated, however, that conditions which favor organic matter content in the soil make more water available. Thus, as organic matter accumulated on the forest floors, more mesic conditions are induced, which would generally favor climax species.

Available nutrients. Changes in local environment brought on by succession also affect the nutrient levels of forest soils, which furthermore affect resulting succession. Coile (1937a and b, 1940) studied the nutrient content of forest soils in depth. He found little change in total nitrogen in pine stands, although it was highest in old loblolly stands with hardwood understories of high calcium content. However, he did find highly significant differences in nitrogen and organic matter content (in the top five inches of soil) between a 115-year-old shortleaf pine stand, and a redgum-yellow poplar unevenaged stand. Nitrate content of the two stands was also highly significantly different; exchangeable calcium was significantly higher in the hardwood stand.

Coile (1939b) stated that,

> Forest stands influence the fertility level of surface soil through their effects on type of decomposition of organic debris which is periodically added to the soil surface. Tree species whose litter is high in bases favor more complete decomposition and incorporation of organic matter into the surface of the mineral soil.

Litter. Litter plays an important part in the process of stand composition and the determination of soil quality. Auten and Blair (1949) wrote that litter broke the impact of rain, retarded runoff, and filtered rain into the soil without disturbing soil structure. In dry weather it reduced evaporation. In cold weather it acted as a blanket mitigating low temperatures. In addition, the decay from litter provided mineral elements for plant growth, and sheltered microbiotic life and worms. Many researchers have found that humus, or litter, may preclude pine germination and early survival (Warming, 1909; Haig, 1936; Barrett, 1940; Brinkman and Swarthout, 1942; and Grano, 1949). Billings (1938) reported that the invasion of oak, after land abandonment, only occurred after enough litter had accumulated from pine and herbs to protect acorns from desiccation. He also reported a highly significant negative correlation (-0.973) between depth of litter and presence of herbs.

Lowdermilk (1930) found that forest litter greatly reduced superficial runoff, especially in saturated fine-textured soils, completely saturated. He found erosion to be much greater, and absorption much

In Indiana, Potzger (1939) reported a sharp zonation of forest types due to aspect. Beech, sugar maple, and yellow-poplar occupied the more mesic north-facing slopes while an oak-hickory forest occupied the south-facing exposure. North-facing surface soil had 30 percent more moisture than the south-facing slopes, and at a six-inch depth the north-facing slope had 28 percent more moisture.

In the Cumberland Mountains, Braun (1942) found oak-chestnut, oak-pine, or oak-hickory forest types on upper, south-facing slopes, and beech-white oak communities on lower slopes. Mixed mesophytic forests occupied coves and lower slopes on all exposures, extending to the upper north-facing slopes.

On the other hand, a study by Thor and Kring (1964) on an abandoned strip mine in the Cumberland Mountains of Tennessee recorded better growth of loblolly pine on a southern aspect than a north-facing slope. In fact, planted trees were 41 percent and seeded trees 88 percent taller after three years than those on a north aspect. However, although the south-facing slope was much drier, little competition was found from natural vegetation, whereas on the north-facing slope herbaceous and shrub vegetation competed for light and water. Also, the trees on the steep north slopes received less sunlight, and soil temperature was lower than on the south slope.

Silvical Characteristics Affecting Stand Composition

Seeding. Seed dispersal adaptations are a major cause in determining which species will become established in secondary succession

(Weaver and Clements, 1929). Light seeds are attached to wings, downy material, or other structures to aid in distribution by wind, although they are sometimes transported epizoically in mud adhering to the fur or feathers of birds or animals (Ridley, 1930). Examples of the light-seeded species are the pines, maples, and elms. The heavy-seeded species, such as the oaks, hickories, and walnuts, are distributed by gravity, birds, and other animals (U. S. Forest Service, 1948; Barrett, 1949). The importance of birds and other animals to the dissemination of seeds is enhanced by the findings of Krefting and Roe (1949), who experimentally demonstrated that the germination rate of seeds is often increased after ingestion by certain birds and mammals.

Another silvical factor making seeds important in the establishment of succession and composition was reported by Chepil in 1946 and by Oosting and Humphreys in 1940 in North Carolina. They found that seeds may be deposited several years before germination. Oosting and Humphreys took soil samples from current fields, and fields abandoned at many different ages one to 112 years. They reported that germination tests showed "a succession of species, as do the plants above the ground, and in general, they are indicative of that same succession." They found, however, some germination of several species where no parent plants were found, indicating the seeds "were viable a long time." They also found that forest seeds apparently needed forest conditions to remain viable. The most germination was found from the one-year-old field, but the most species from the five-year field.

Varying requirements for germination of seeds of different species affect stand composition. Minckler and Jensen (1959) reported on upland central hardwoods. Yellow-poplar required moist, northerly sites for reproduction, oak-hickory drier, warmer sites. Hickory reproduced better on thick litter on drier sites. Oak was not affected by litter depth, but yellow-poplar was extremely sensitive to thick litter. On the moist sites, all but the oak reproduced better the less the litter thickness.

Other silvical characteristics have been found to affect stand composition. Wahlenberg's (1949) study on the Piedmont showed that one of the factors favoring hardwood composition was the ability of hardwoods to sprout. Most pines do not. Oak and hickory sprouting has been reported by Johnston (1941), Liming and Johnston (1944), and Merz and Boyce (1956).

Light. Toumey and Kienholze (1931) reported on some trenched plots under a 41-to-60-year-old white pine stand. White pine (Pinus strobus) and some hemlock became established and grew well for several years. After eight years, however, growth was declining, a fact they attributed to competition of the overstory pines within the plots. Twenty-one years later, Lutz (1945) reported that all the white pine reproduction was dead, while the hemlock had increased in number and size. He said that "if moisture supply was too low for the pine it is difficult to believe it was sufficient for hemlock, yet the pine died and the hemlock flourished." Since the hemlock survived, he concluded that light intensity was too low for the relatively shade-intolerant white pine, but "favorable" for the shade-tolerant hemlock.

Oosting and Kramer (1946) also questioned that moisture alone was the only reason why pine seedlings failed under the forest canopy while most hardwoods were successful. They ran a transect from within a forest stand out into an adjacent abandoned field. They found pine reproduction abundant in the field, and on the edge of the stand, despite the fact that competition for moisture was similar to that within the stand, where there was practically no pine reproduction. They concluded that pine seedlings fail under forest stands because with low-light intensities they are not able to produce enough "food" to develop root systems adequate to compete with the roots of the overstory trees. Therefore, they deduced that light was more important than moisture in precluding shortleaf and loblolly pine reproduction under a forest canopy.

The shade intolerance of pine, with the corresponding shade tolerance of most hardwoods, is in a large measure responsible for the replacement of pine by hardwoods. Kramer and Decker (1944) found that loblolly pine was able to produce maximum photosynthesis only in full sunlight. Chapman (1945) stated that "overhead shade of low hardwoods is fatal to loblolly pine seedlings" and that they would "inevitably" die unless released within five years. He added that if the overhead shade was high, with intermittent sunlight, the loblolly seedlings might survive ten to 20 years, although they were vulnerable to drought and fires. He also stated that loblolly seedlings growing in full sun were more resistant to drought than those growing in shade.

Kozlowski (1949) believed that the difference in pine versus hardwoods in ability to survive in shade was formed by heredity, especially as it influenced the root-shoot ratio, and photosynthesis rate. Using two-year-old stock, he found that overcup oak seedlings had higher absolute rates of photosynthesis than loblolly pine at all higher light intensities, whether expressed in milligrams of carbon dioxide per unit of dry weight of foliage, per unit of leaf area, or per unit of total dry weight of plant. Comparing the effects of light, he found that both oak and pine growth was reduced by shading, but the pine much more so. Loblolly pine showed consistent increase in photosynthesis rate up to the equivalent of full sunlight. On the other hand, the more tolerant red maple reached maximum, or near maximum, photosynthesis rates at relatively low light intensities. Pine in full light had greater height growth, greater dry weight of foliage, stems, roots, and total dry weight, and greater root growth in proportion to shoot growth than pine in the shade.

The reproduction of yellow-poplar, another pioneer species on better sites, has also been studied under a forest canopy by Sims (1932). He found a regular turnover of yellow-poplar seedlings, and attributed the lack of survival to the shade intolerance of the species.

A general trend of succession may be seen by considering the tolerance of species. Using Baker's revised tolerance table (1949) it is seen that the pioneer trees such as eastern redcedar, shortleaf pine, loblolly pine, Virginia pine, yellow-poplar, sweet gum, and black cherry, are classed as intolerant. Intermediate in tolerance are most of the

CHAPTER III

DESCRIPTION OF THE AREA

Location

The Big Ridge Natural Study Area is in Big Ridge State Park near the center of Union County, Tennessee, about 25 miles north of Knoxville (see Figure 1). The study area lies on Pinnacle Ridge, on the portion which forms a peninsula extending into Norris Lake. The northern end of the ridge lies along the Clinch River and was drained by it until formation of Norris Lake in the early thirties.

Geology

The Big Ridge area is part of the Great Valley of East Tennessee, which is a part of the Ridge and Valley Province of the Appalachians. In East Tennessee the Valley is about 40 miles wide. The regular open folding found in the northern part of the Great Valley, gives way in the Tennessee section to "closer folding, overturning toward the northwest, and thrust faulting. In the southern section almost every fold is broken by a thrust fault dipping toward the southeast" (Fenneman, 1938).

Great differences in hardness occur among the 30,000 to 40,000 feet of stratified Paleozoic rocks involved in the folding.

> As selective erosion is particularly conspicuous in this region, and as folding may bring the same stratum to the surface repeatedly, a small number of strong formations suffices to make a great number of ridges. (Fenneman, 1938.)

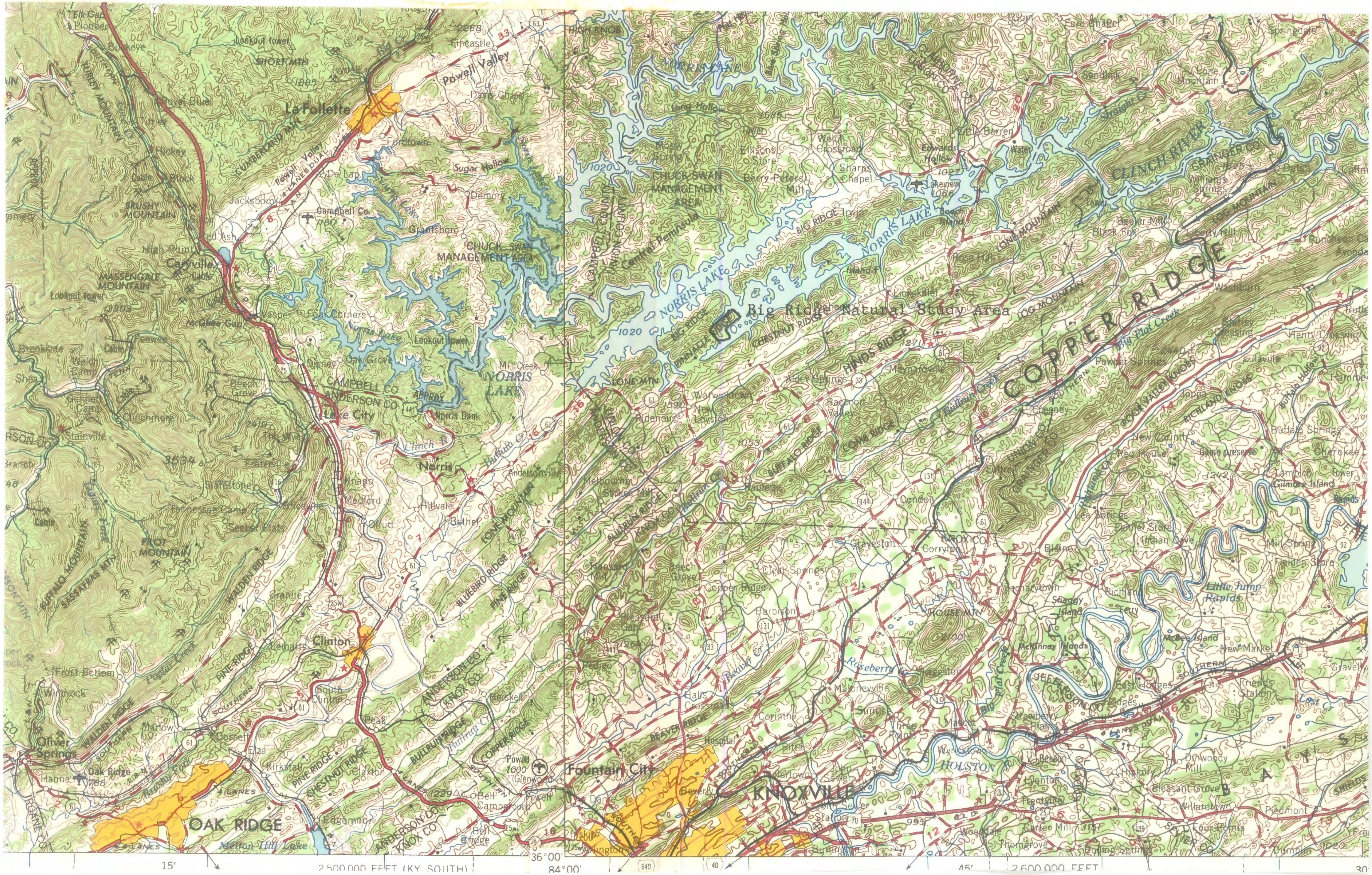

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Figure 1. Area around Big Ridge Natural Study Area, Union and adjacent counties, Tennessee.

Rodgers (1953) noted that the ridges and valleys are parallel and are orientated in a northeast and southwest direction. He stated that the ridges are numerous, and exhibit overall uniformity throughout their length, despite differences in height, sharpness of outline, and other features. Around Knoxville, the local relief is 300 to 400 feet (Fenneman, 1938). Pinnacle Ridge rises about 300 feet above Norris Lake. Big Ridge to the northwest, and Chestnut Ridge to the southeast, both rise over 500 feet (to over 1,500 feet elevation) above the lake.

Drainage patterns in the Valley coincide with ridge and valley trends and streams follow the soft rock of the valleys, crossing the hard belts of rock (ridges) through "water gaps" by the most direct routes; i.e., at right angles. Figure 1 shows the truncated end of Pinnacle Ridge cut by the Clinch River.

Pinnacle Ridge is underlain by interbedded sandstone and shale, which dips to the southeast (Rudolph *et al.*, 1953). Sandstone is the dominant rock on the ridge, but shale is exposed in a narrow strip on the northwest side, and on the lower ridges of the southeast side.

Topography

Elevation above mean sea level on Pinnacle Ridge now ranges from 1,020 feet at the Norris Lake mean pool level to 1,340 feet. The ridge could be descriptively called "comby" (Safford, 1869) because of the peaks and hollows along the ridgetop. In the mile of ridge covered in the study, five separate knobs may be seen with hollows of about 80 feet separating them. In places on the ridge, 300 feet in elevation may be gained in less than a quarter of a mile. Slopes on Pinnacle Ridge average 54 percent on the study plots.

Pinnacle Ridge, like most ridges of the Great Valley, lies in a northeast-southwest direction. Most spur ridges extend from the main ridge at nearly right angles. On Pinnacle Ridge plots, almost 25 percent of the slopes faced from magnetic northwest (315°) to northeast (45°) and about 23 percent of the slopes faced from south (180°) to west (270°).

Burrage (1946) reported a well-developed system of drainage in the area. Subterranean drainage was good, and poor drainage was an exception. On the steep slopes of the study area (with coarse soils) drainage was considered adequate to excessive.

Throughout the region, short tributary streams are common, and intermittent streams occur very frequently. On the study area, no all-weather streams were found, although "wet weather" streams were found in every well-developed hollow.

Soils

The soils of the Norris area, including all of Union County, are underlain by limestone, dolomitic limestone, shale, and sandstone (Born, 1936).

> These soil series were derived principally from limestone (Dewey and Talbott), shale (Montevallo and Armuchee), and dolomite (Fullerton and Clarksville). Fullerton and Clarksville cherty silt loams were predominant and generally occupied the ridge crests. (Minckler, 1946.)

Of the 24,000 acres in the Norris area, Rudolph (1953) estimated that

Clarksville cherty silt loam occupied 23 percent, and Fullerton cherty silt loam 22 percent of the area. This would leave 45 percent of the Norris area covered with Fullerton and Clarksville cherty silt loams.

The surface soils of the Norris area have been reported to have a high infiltration capacity. Furthermore, even though these soils absorb water readily, water is not retained in them because of steep slopes and porous, light-textured topsoil (Rothacher, 1953).

Minckler (1941a) dug 120 soil pits on upper, middle, and lower slopes of the Norris Watershed. He reported that mechanical analysis indicated a "surprising uniformity in the soils as a whole."

Rudolph (1953) classified most of Pinnacle Ridge as Lehew fine sandy loam, steep phase (Figure 2). He reported that Lehew soils are on steep, sharp-crested valley ridges underlain by purple, red, and green interbedded sandstone and shale. They are predominantly fine sandy loams, shallow, and infertile. Moisture conditions are not good because surface and internal drainage is very rapid. Therefore, Lehew soils are not suitable for crops or pasture. Rudolph described the "representative" profile to be:

> Zero to eight inches, pinkish-gray or light purplish-brown loose fine sandy loam; eight to 30 inches, purplish-red fine sandy loam mixed with partly weathered red, purple, and green shale and sandstone fragments; 30 inches plus, red and purple thin-bedded sandstone and shale.

The lower southeastern edge of the ridge, most of which is out of the study area, Rudolph classified as Montevallo shaly silt loam, steep phase (Figure 2). The Montevallo soils are brownish-gray thin shaly soils on hilly and steep knobs underlain by green, yellow, purple, red,

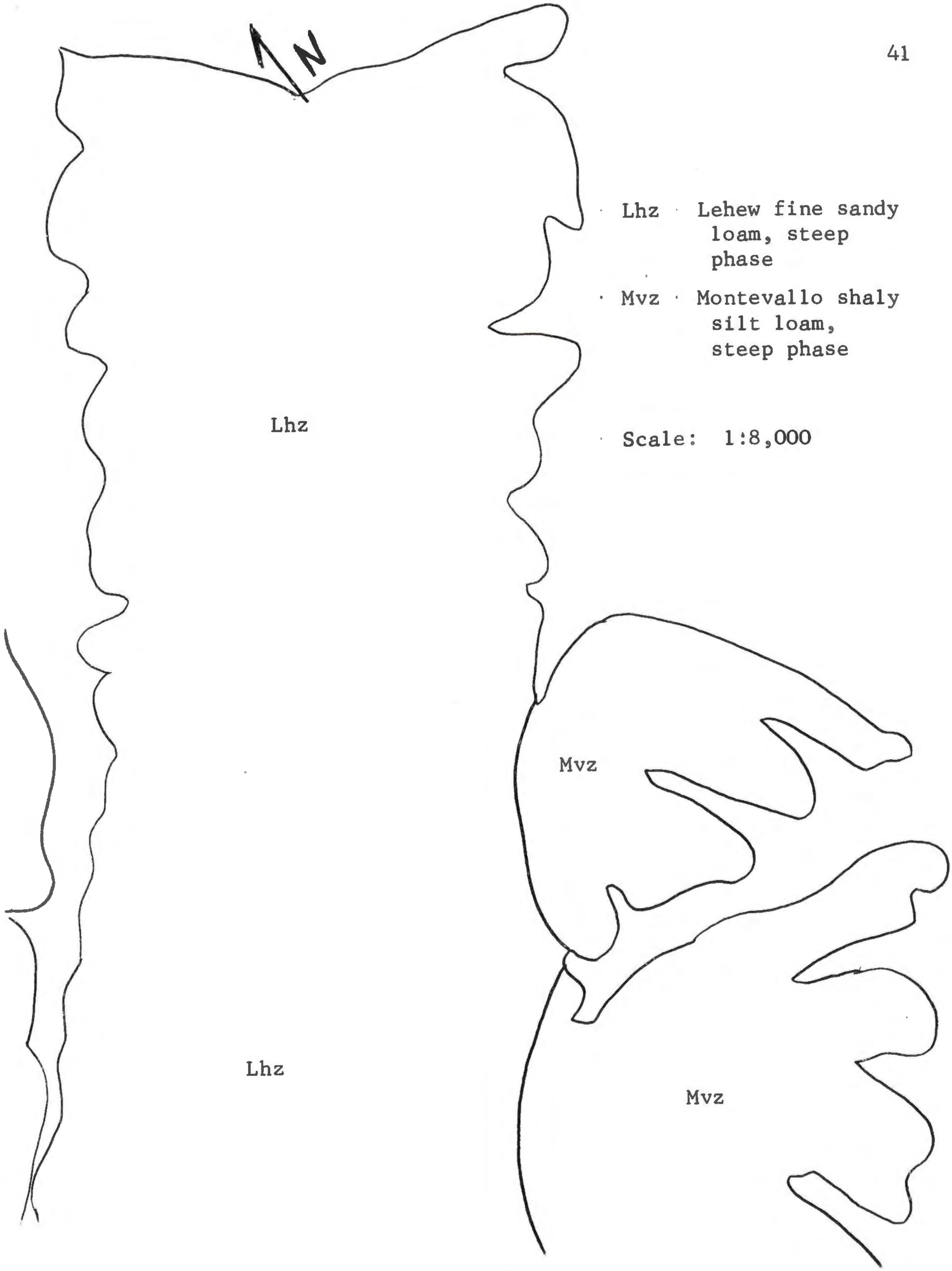

Figure 2. Soil classification of Pinnacle Ridge Area.

Source: F. Rudolph. 1953. Soil survey of the Norris Area, Tennessee. U. S. Dept. Agr. Soil Survey Series 1939 No. 19. 173 pp.

and gray fissile acid shale. They are strongly acid, and low in organic matter. Drainage is good, and moisture conditions may be poor for plant growth because the soil has low moisture-absorbing and retaining properties. Rudolph gave "a profile description representative" of much of the soil:

> Zero to four inches, light brownish-gray or yellowish-gray loose shaly silt loam; four to 18 inches, yellowish-brown silt loam mixed with partly weathered red, green, purple, yellow, and gray shale fragments; 18 inches plus, varigated red, green, purple, yellow, and gray acid fissile shale.

Under the new scheme of soil classification, Kellogg and Smith (1960) included the Red-Yellow Podzolics of this area within the Ultisol Order. This would include Dewey, Talbott, Fullerton, and Clarksville soil types. Armuchee and Montevallo soil types in this area would be classed in the Entisol Order as true lithosols, in which erosion removes the topsoil almost as fast as it is formed (Rudolph *et al.*, 1953).

Climate

Weather data compiled for White Hollow Watershed from 1941 to 1965 are summarized in Figure 3. Mean annual precipitation was 46.24 inches for the period. Mean monthly precipitation was 3.75 inches, with high periods of precipitation in winter (about 5 inches), and a sharp peak in midsummer (4.47 inches). Early spring and late summer-early fall had less than average precipitation, especially October (2.38 inches).

Climatological data (28-year record), taken at Tazewell, in Union County, show an average growing season of 174 days. Mean January

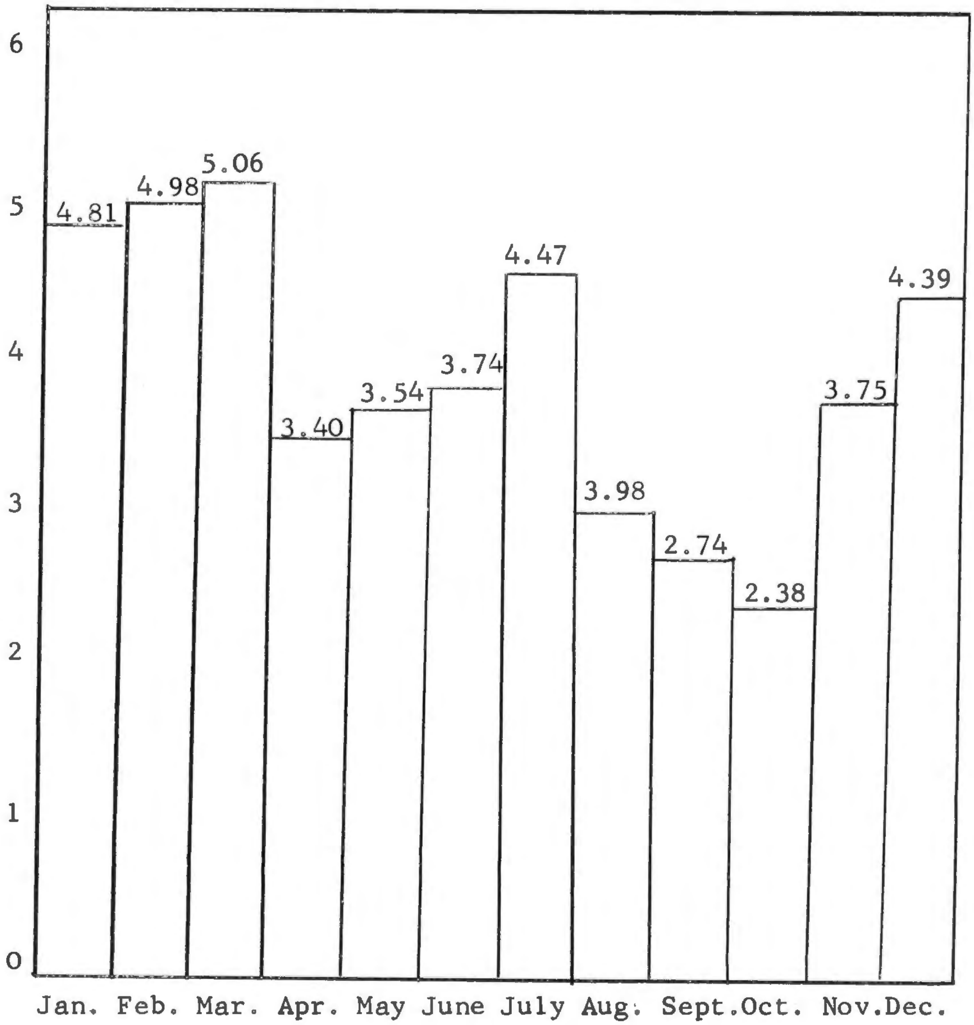

Figure 3. Monthly precipitation means (inches) recorded from 1941-1965 at Central Peninsula, Union County, Tennessee.

Source: Tennessee Valley Authority, Hydraulic Data Branch.

temperature was 35.2°F. During this period a maximum temperature of 106°F. and a minimum of -29°F. were recorded (Minckler, 1946). Less than 50 miles south of Big Ridge, in Roane County, Swann _et al._, (1942) reported an average frost free period of 196 days.

The Unaka Mountains to the east and the Cumberland Plateau to the west have a mitigating effect on the climate in the Great Valley of East Tennessee. The former divert the hot, southerly winds caused by high pressure systems developing along the Atlantic Coast. The Cumberland Plateau on the west weakens the force of cold air masses from the northwest and the hot summer winds from the west. Prevailing winds are from the west and northwest, but inclement weather usually comes up the Great Valley from the southwest (Dickson, 1960).

Snow, glaze, hail, and early and late freezes occur occasionally, and may be quite damaging. Hailstorms occur two or three times a year on the average, and damaging glazestorms average once in every five or six years. Mean annual snowfall varies from four to six inches in most of the Great Valley, although the Plateau or mountains on either side may receive ten inches per year (Dickson, 1960). Rudolph _et al._ (1953) reported a mean annual snowfall of 10.4 inches in the Norris area.

Vegetation

The forest of East Tennessee has been typed oak-chestnut-yellow-poplar by Shantz and Zon (1936), and as a part of the Appalachian Oak Forest by Kuckler (1964).

Braun (1942) considered the Cumberland Mountains, about 50 miles north of the study area, to be the center of distribution of the mixed mesophytic forest. However, away from its center of development, the mixed mesophytic formation is restricted to coves, valleys, revines, and north-facing or protected slopes. MacDonald (1964) and Martin (1966) in the southern Cumberlands, and Caplenor (1965) and Sherman (1958) on the western edge of the Cumberland Plateau, have found the mixed mesophytic forest on protected sites. Whittaker (1956) found the cove hardwoods of the Great Smoky Mountains at the eastern edge of the Great Valley very similar to the mixed mesophytic forest of the Cumberlands.

Braun (1964) recognized, furthermore, that the drier sites in the Cumberlands, the Ridge and Valley Province, and in the Blue Ridge Province, were dominated by oak-chestnut and oak-pine. Since the death of chestnut, these types have been replaced by oak-hickory or mixed oak.

In the Ridge and Valley Province adjacent to the Cumberland Mountains Braun (1964) says:

> . . . there is some evidence of segregation into communities comparable to the association-segregates of the Cumberland Mountains--beech-maple-basswood-buckeye, white oak-beech-maple, white oak-chestnut, and higher slope chestnut communities.

Typical sites were dominated by chestnut (before its elimination), with northern red oak and white oak the principal associates. Sheltered coves and slopes were occupied by segregates of the mixed mesophytic forest.

On Chilhowee Mountain, lying between the Ridge and Valley and the Blue Ridge Provinces (about 50 miles southeast of Big Ridge) Thomas (1966) reported that the distribution of cover types was more closely related to "site exposure" and depth of soil than to soil types, geological formation, or altitude. The most abundant cover types on the mountain were mixed oak and oak-pine. Thomas stressed that past logging affected cover types by decreasing "choice" species and increasing "less desirable" hickories. On Chilhowee Mountain he found that chestnut had been replaced by chestnut oak, red oaks, and white oak, which are classified "mixed oaks."

On English Mountain, a part of the Chilhowee group, Chapman (1957) also found "site exposure" the most important factor in determining cover types, with depth of soil and closeness of bedrock to the surface next in importance. The most exposed sites, south, southwest, and western aspects were dominated by oaks and pines (chestnut oak, Virginia pine, table mountain pine (_Pinus pungens_), and pitch pine). Less exposed sites were dominated by chestnut oak, chestnut oak-pignut hickory, chestnut oak-red oak-hickory, and chestnut oak-mixed hardwoods, arranged in order of increasing moisture. Protected sites contained some cove hardwoods, with a wide variety of dominants. Some logging and local repeated fires have occurred on the mountain.

Wolfe (1956) recorded vegetation for Hawkins County, about 30 miles northeast of the study area, also in the Ridge and Valley Province. Originally, the forests of the coves and lower north slopes were primarily yellow-poplar, sugar maple, beech, white ash, and northern red oak. Also found in the coves were American elm, sweet birch, umbrella magnolia (_Magnolia tripetala_), Fraser magnolia (_M. fraseri_), hemlock, buckeye, and basswood. Chestnut oak, northern red oak, pignut hickory (*Carya cordiformis*), and red maple were found higher on the north slopes.

Originally, the drier southern slopes, higher north slopes, and ridgetops supported chestnut, white oak, southern red oak, scarlet oak, chestnut oak, black oak, shagbark hickory (*Carya ovata*), pignut hickory, black gum, sourwood, redcedar, chinquapin oak (*Quercus muehlenbergii*), post oak, hophornbeam (*Ostrya virginiana*), and shortleaf pine. Some Virginia pine, table mountain pine, blackjack oak, and sand hickory (*C. pallida*) were also present. Chestnut was a dominant member of many of these stands.

In 1946 Minckler reported that forest type differences for the Central Peninsula area were related to slope exposure and steepness. The southerly slopes supported yellow-poplar, yellow-poplar-shortleaf pine, and oaks and hickories.

A forest inventory by TVA (1963) of the Clinch-Powell Watershed using mechanically spaced samples revealed 67 percent in upland hardwoods, 11 percent in Virginia pine, 7 percent in shortleaf pine, 5 percent in pine-hardwoods, and 9 percent in other forest types. Cowan (1958) characterized present forest areas of the Central Peninsula State Forest as shortleaf pine, 18 percent, pine-hardwoods, 39 percent, hardwood, 35 percent, and shortleaf pine plantations, 8 percent. Shortleaf pine, northern red oak, and yellow-poplar made up the greatest percent of sawtimber volume.

Further vegetational studies of the area have been made by Burrage (1937), McQuilken (1937), Shanks (1948), and TVA (1961).

Although no quantitative data are available, vegetation on the study area is no doubt affected by a high deer population. Well-traveled trails, well-used beds, and droppings are numerous. Several deer were sighted by the inventory workers in the field.

Human History

French pelt traders visited East Tennessee, including the Clinch River area, as early as 1700 (Williams, 1937). Williams also reported that the Clinch was mapped by 1733 as the "Pelesipe" by the French, which would indicate the French had traveled up the river.

When white men first discovered this area they found a land of majestic trees and abundant game. Deer, buffaloes, bears, turkeys, panthers, volves, and many smaller animals abounded (Hale, 1899). A "combination of circumstances" freed the area of Indians and thus favored the rapid settlement of the best land (Killebrew and Safford, 1874).

The area in the vicinity of Big Ridge was settled about 1796 (Rudolph, 1953). The first settlers were migrants primarily from Kentucky, Virginia, South Carolina, North Carolina, and other sections of Tennessee. Farms were established at low density on the best land throughout the region. Settlement was very sparce on the "Central Peninsula" formed by the junction of the Clinch and Powell Rivers (see Figure 1, page 37).

Dry sites and infertile soils kept crop yields low even in the last century. Killebrew and Safford (1874) reported that farmers in

Union County averaged about 30 bushels of corn and ten bushels of wheat per acre. Corn, wheat, oats, and clover were regarded the most valuable crops, although many others were grown. A large quantity of untillable land was reported, "owing to the mountains and ridges which run through" the area which were considered "scarcely fit for anything except it be for raising fruit and grazing sheep." The prevailing timber mentioned was "poplar," pine, oak, and chestnut. The people were described as "industrious and provident, while they are law-abiding and orderly."

Lumbering of the Norris Watershed area occurred about 1900, but declined as soon as the old-growth stands were depleted. As late as 1936, however, the Southern Forest Survey reported that "a material part of the farm cash income" was from timber products, and that forest industries ranked third in the area as a source of employment.

In 1935 and 1936 the Tennessee Valley Authority purchased the land between the Clinch and Powell rivers known as the Central Peninsula. Large acreages of abandoned farmland were designated for experimental use. McQuilken (1937) conducted preliminary investigations of the "herbaceous and shrubby" vegetation of the area as a record of existing conditions, and to relate these conditions to site factors. In another study of the same area Burrage (1937) detected changes in vegetation. Permanent plots were established to monitor changes over several study periods. Minckler (1941b) investigated the edaphic factors including temperature and moisture relations. Later, in 1948, Shanks studied the permanent sample plots to compile a comprehensive species composition list.

Agriculture is the chief industry of Union County. In 1946, Minckler reported that corn and tobacco were the major crops, most pastures were unimproved, and small grains and hay were "unimportant." "Woodland grazing, burning, and bad cutting practices have been common." Varying degrees of erosion are prevalent on the old fields. Currently small livestock farms are the primary agricultural venture, and pasture and small grains are the chief crops. Tobacco is a supplemental cash crop (Bates, 1967).

The harvesting of timber products is only a minor activity, despite a market for pulpwood, because the merchantable timber has been depleted. Remaining timber products are of low value and poor quality.

Of the established plots on the study area, 45 are on abandoned farmland, most of which are located on lower slopes. Twenty-five of these were abandoned very shortly prior to the original study, while the other 20 plots obtained enough pole-sized trees to be considered "forested."

Although field observations indicate that small, isolated fires have occurred on the study area, no major fires have been reported.[4]

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[4]Personal communication with Mr. Jim Robb, Superintendent of Big Ridge State Park.

CHAPTER IV

METHODS

Original Study

The original study was conducted in March and April of 1936 under the supervision of Tennessee Valley Authority personnel working in cooperation with the Appalachian Forest Experiment Station, at Asheville, North Carolina. The Appalachian Station formulated the basic plan for the study, which was also conducted in similar form at Coweeta and Bent Creek in western North Carolina; and at Tacoa in northern Georgia. Other studies occurred in the Southern Appalachian area (MacKinney, 1935; Richards, 1935). Civilian Conservation Corpsmen were assigned to assist in the establishment of plots and the collection of data.

Establishment of plots. The study of Pinnacle Ridge was designed to contain eight strips of plots, ten chains apart, lying roughly perpendicular to the main ridge. Figure 4 shows the established layout of the plots. Since the strips were run from the northwest side, the strips run on a bearing of S30°E, with the exception of strip number three, which for some unexplained reason bears about five degrees farther south than the others. The strips were laid off with a transit, tape, and field stakes.

Stakes were placed along the baselines at two-chain intervals, and a right angle was turned at the transit to establish stakes taped

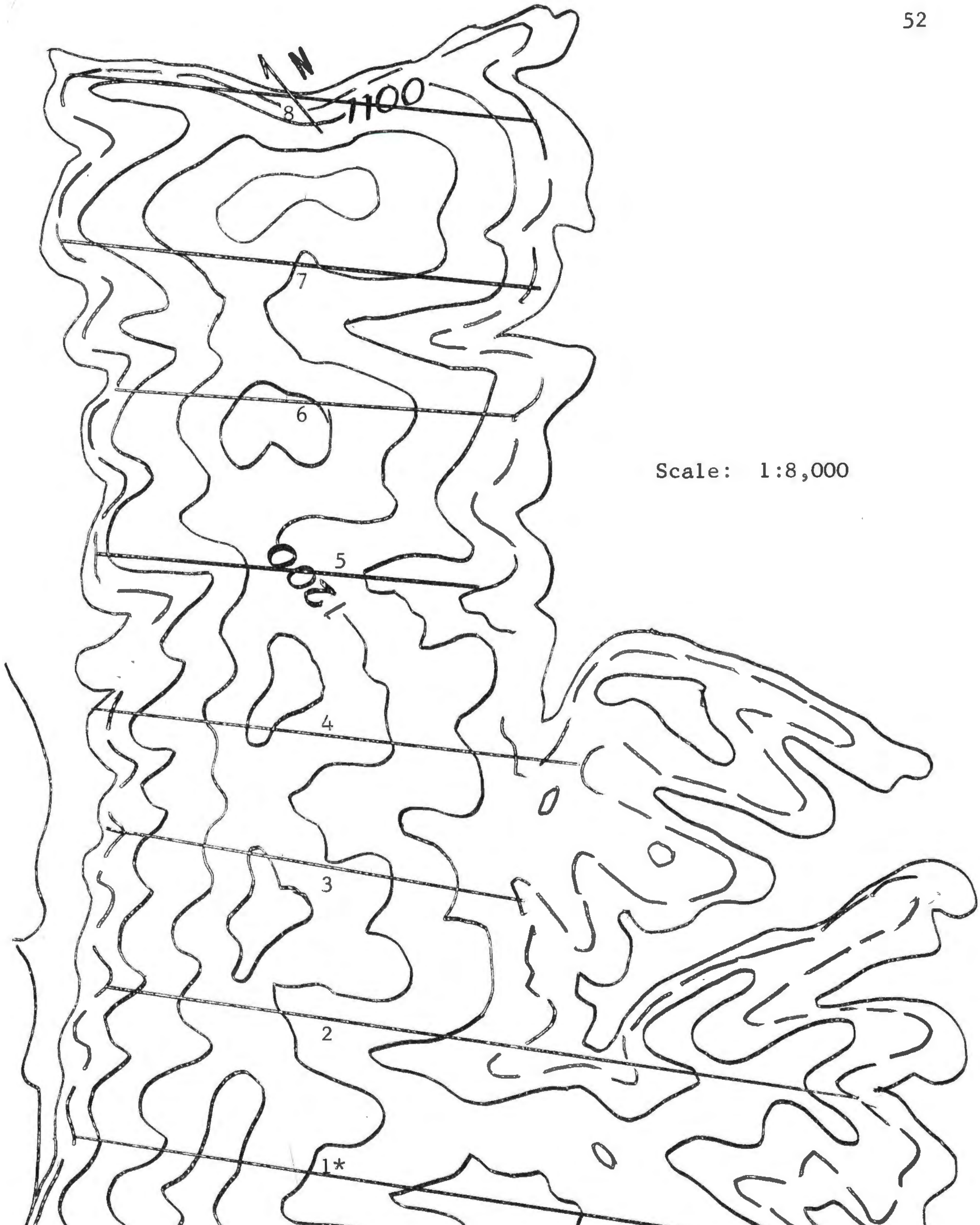

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Figure 4. Big Ridge Natural Study Area showing location of strips.

*Numbers represent strip numbers.

one-half chain on either side of the baseline. These stakes formed the corners of plots, one chain in width, and two chains in length. Cedar posts were packed in by mule. Posts were also placed at the beginning and end of each baseline and usually numbered to identify the strip. Although badly rotten, most all of the posts were still intact in 1967.

Starting from the northwest, the stake identifying plot number one for the strip would be at the far left end of the plot. An exception to this was noted on strip four, where the first left corner stake was numbered, and 18 plots were shown on resulting maps and the vegetational tally sheets. However, only 17 plots were established on this strip. Apparently plot six in the original study is a duplication of plot five, since the data from these plots are almost identical.[5] Also, striking correlations on almost all the other plots occur between the original study and the current study, when data from plots five and six in the original study are considered to be the same. Therefore, data from plot number six of the original study was discarded, and original plot seven data compared with data from plot six in the current study; original plot eight data were compared with data from plot seven in the current study, and so forth throughout the rest of the strip.

On the numbered corner posts, two numbers were cut into the heartwood near the top of the post. An upper number identified the strip, and a lower number identified the plot on the strip. To establish

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[5]This assumption was verified in a personal communication by Mr. B. H. Corpening, formerly with the Appalachian Experiment Station.

plot boundaries for vegetation studies, the plot boundaries were marked by stringing twine from one stake to the next on the corners of the plot.

Vegetation data. In the original study, trees and shrubs over "one inch" in diameter were tallied. Any diameter from 0.6 to 1.5 was tallied as "one inch." Tallies were recorded in one-inch classes, except for the tally of trees one-to-three inches in dbh which were lumped. Stems were tallied by species and by diameter class in the original study for each plot.

A "Forest Condition Class" map was also constructed of the study area. Only four plots were classified as "old growth sawtimber stands." Forty plots, of the 145, were located in areas called "new growth sapling stands," with the rest of the plots in areas labeled "second growth pole stands." No doubt the predominance of this latter condition class prompted the use of the tally of "stumps" on the vegetational tally sheet.

Current Study

Although the edges of the plots were marked with a string in the original study, that was not considered necessary for the reinventory. Edges were marked by dragging a foot through the litter between posts. Trees considered to be on the line were alternately counted in and out. In a few cases, such as on the crest of a ridge or when a post was missing, a hand compass was used to point the direction of the line.

When the next corner was located, the duff mark could be made back to the previous stake.

Site data. Site data for each plot was recorded on a Continuous Forest Inventory Plot Tally Sheet, developed by MacDonald (1966) of The University of Tennessee. Not all of the categories considered by MacDonald were recorded in this study. These sheets had been prepared so that data may be key punched for computer analyses directly from the field copy. The key to the code (see Appendix A) can be taken into the field permitting the coded data to be recorded directly.

Field work on the Norris Area Soil Survey was completed in 1939 and reported by Rudolph (1953) (see Figure 2, page 41). In the soil survey map of Pinnacle Ridge, soils were classified as fine sandy loam and fine silty loam, and were so coded on the tally sheets. The break in soil types on the map was distinct enough to assign to individual plots.

Slope direction, steepness percent, position on slope, and form of slope are arranged in the code from moist to dry conditions. Slope direction was obtained with a hand compass. In some locations, such as ridge tops or hollows, opposite directions might be represented on the same plot, but the larger slope was recorded. Steepness was determined by a "Sunto" clinometer to the nearest percent. Position on slope and form of slope were determined by ocular estimate.

In a study of the nearby White Hollow Watershed, Bates (1967) found that the pH of topsoil and thickness of humus layer were only slightly correlated with species or growth of trees. Therefore, these factors were left out of the Big Ridge study. Instead, an erosion factor was considered (in column 22). It should be noted, that despite sheet erosion, some sites had very deep A horizons. These sites were usually near the bottom of deep hollows with very steep sides.

To determine soil depths and textures, two to four soil pits were dug with a sharp spade on each plot. If the soils appeared similar in depth and texture, only two pits were dug per plot. However, if soils appeared variable in depth and texture, three pits were dug. In a few cases, when no clear picture of the soils was evident after three pits had been examined, a fourth was dug. Depth of the pits depended on the depth of the A horizon. Pits were dug only deep enough to be sure that the B texture could be determined.

Thickness of the A horizon was coded from shallow to deep, and recorded in two-inch classes. Often, no clear line of demarkation by color or texture was evident between the A and B horizons. Thus, the exact depth of the A horizon was often difficult to determine, despite the use of texture, structure, and color characteristics. The A_1 horizon was darker than the A_2 or A_3 layers, the latter two layers were often not present.

Texture of the A and B horizons in each pit was determined by rubbing a sample of moist soil between the thumb and forefinger and identifying its texture class by the feel, as described by the Soil Survey Staff (1951) and Robinson and Breinig (1962). The feel method was practiced on some known textural samples before the field work was started. Bates (1967) used the feel method of textural analysis on his study on the White Hollow Watershed.

Laboratory textural analysis of eighteen topsoil samples selected at random from 109 samples indicated that ten of the field estimates were correct; six had a difference of only one textural grade; and two had a difference of two textural grades.

Somewhat similar results were obtained in a study by Allen (1960).

Soil samples from about 25 plots (50 samples) were brought into the lab. Analysis of 16 of these samples were run by the hydrometer method of particle-size analysis, as described by Black (1965). A calibrated hydrometer was used to record the concentration of the suspension from 30 seconds to 720 minutes, and textural class calculated. The remaining samples were typed by the feel method by Dr. Max Springer, of The University of Tennessee Department of Agronomy. His designation of the textural classes were, in general, consistent with those of the researcher.

Depth to rock or pan was considered to be deep enough on the study area that it would not be a pertinent factor in relation to stand composition except on a few plots on the ridge crest. Soil pits were arbitrarily placed to avoid rock outcroppings or large rocks. Small rocks, nevertheless, were encountered in digging the pits, and were estimated in relation to percent of total soil and rock removed. The volume of rock in the total soil mass of A and B horizons was estimated in 20 percent classes.

Because of the coarse texture of most of the soils, and the steepness of the slopes, soil drainage was not recorded in this study. No mottling was found in any of the soils.

Vegetation data. Canopy closure by trees, shrub cover, herbaceous ground cover, and most important element in ground and shrub cover was recorded for the entire plot by ocular estimate. Admittedly, these observations were not entirely accurate, but they give an indication of relative density of cover and canopy closure.

As in the original study, any tree or shrub over "one inch" in dbh was tallied. Diameters were recorded as in the original study.

These data were put on The University of Tennessee Computing Center data sheets, for key punching on computer cards. To reduce the number of size classes to a more manageable form, the separate diameter classes were divided into three groups, one-to-three inches, four-to-eight inches, and nine-or-more inches.

The 80 columns of the sheet allowed only 38 species to be entered, and this number was later reduced to 33 for analysis because of computer storage problems. Sweetgum, hackberry, black locust, redbud, and witch hazel were omitted, because they had the least tally of the trees represented.

Statistical Analyses

Frequency, the percent of occurrences by plot, was determined by calculator for each species.

The density of the forest vegetation by species was computed both in number of trees per acre by computer, and in basal area by calculator. Per acre density was determined by class diameter (one-to-three inches, four-to-eight inches, and over eight inches). Densities found in the two studies was compared by species. Furthermore, the main ridge of the study area was divided into four site and exposure classes, North Ridge (35 plots), North Hollow (25 plots), South Ridge (43 plots), and South Hollow (17 plots). Number of stems by species and diameter classes were also computed for these different site groups.

Basal area of all trees "one inch" diameter breast height or more in both studies was determined by plot for each species. Totals were then figured for each species found on the plot. Forest types were then assigned to plots by listing species in descending order until 50 percent of the basal area on each plot was accounted for. The basal area was also broken into the four site groups for analysis. A large variation occurred in types, so comparisons were made by counting the number of times a species occurred in type names of the plots. For instance, black oak was found in type names nine times in 1936, compared to 24 times in 1967.

Volumes were determined for both studies and compared. Species, dbh, and "merchantable" height were recorded for trees meeting the "merchantable" class requirements of the original study. Trees contained at least one eight-foot log that was 12 inches in diameter at breast height, and at least eight inches at the small end. No deduction was made for defect or crook. Volume was computed by species for each site group using a table of cubic volume of merchantable wood for eastern hardwoods, form class 77, prepared by Mesavage (1947). For half logs, 45 percent of the volume of one log of an equal diameter was used.

Soil-site-stand composition relationships were studied by canonical analysis. Two sets of variables were determined from the data. Site factors were considered the independent (predictive) variables with the different species considered to be the dependent variables.

A problem arises, however, in correlating site factors to species, because the site factors and the species themselves are interacting and interdependent. Canonical analysis has the advantage of showing "how the two sets of variables are related to each other and how the variables within each set contribute to this relationship" (Bishop, 1966).

A canonical correlation, the maximum correlation for the sets of variables, was computed from a combination of linear equations weighting both the dependent variables on one side of the equation, and the independent variables on the other side of the equation. This correlation was done by diameter groups for both studies.

Results of canonical correlation on the Big Ridge study are ranked in descending order according to weight, regardless of sign. Variables with weight less than plus or minus .1000 were not listed.

CHAPTER V

RESULTS AND DISCUSSION

Frequency

Frequency data of the vegetation on Big Ridge Natural Study Area indicate that few species are becoming more widely distributed (Table 1). Only black oak, beech, and sugar maple show significant increases in frequency; ash and Virginia pine are spreading at a much lesser rate. Black oak, while only intermediate in light tolerance, is still a member of the climax forest on upland sites in East Tennessee. Very tolerant beech and sugar maple, climatic climax components of the mixed mesophytic forest, gained in distribution on all site groups. Beech showed a marked increase in frequency on southern ridges, although on these sites it was usually restricted to the subordinate crown classes. Sugar maple in both studies increased in frequency from the relatively hot and dry south ridges to the more cool and moist north hollows, but had the largest gain on north ridges over the 31-year period. Sugar maple occurred on 92 percent of the plots in north hollows in 1967.

Hickory, dogwood, red maple, chestnut oak, and blackgum had a frequency close to 100 percent in the original study, and changed little in frequency during the 31-year period. All are components of upland oak-hickory forests, although tolerance to light varies from tolerant to intermediate among these species.

TABLE 1. Frequency (in percent) of 18 most abundant species by sites ranked from original data

Species	Study	South Ridge	South Hollow	North Ridge	North Hollow	Mean*
hickory	1936	98	94	100	96	98
	1967	98	100	97	100	98
	Dif.	0	6	-3	4	0
sourwood	1936	100	94	97	92	97
	1967	93	82	86	64	83
	Dif.	-7	-8	-7	-28	-14
dogwood	1936	91	100	100	92	95
	1967	100	94	94	96	97
	Dif.	9	-6	-6	4	2
red maple	1936	98	94	94	88	94
	1967	98	94	94	80	93
	Dif.	0	0	0	-8	-1
chestnut	1936	91	88	91	72	87
	1967	19	18	9	8	13
	Dif.	-72	-70	-82	-64	-74
chestnut oak	1936	77	76	86	88	82
	1967	93	71	83	76	83
	Dif.	16	-5	-3	-12	1
sassafras	1936	84	71	80	84	81
	1967	81	71	69	60	72
	Dif.	-3	0	-11	-24	-9
black gum	1936	91	88	83	84	87
	1967	95	82	77	76	84
	Dif.	4	-6	-6	-8	-3
white oak	1936	81	76	71	64	74
	1967	72	41	66	56	63
	Dif.	-9	-35	-5	-8	-11
scarlet oak	1936	84	71	80	44	73
	1967	60	41	37	12	41
	Dif.	-24	-30	-43	-32	-32

TABLE 1 (continued)

Species	Study	South Ridge	South Hollow	North Ridge	North Hollow	Mean*
black oak	1936	74	88	60	44	66
	1967	81	88	94	84	87
	Dif.	7	0	34	40	21
beech	1936	37	65	40	80	57
	1967	58	71	48	88	70
	Dif.	21	6	8	8	13
shortleaf pine	1936	72	41	40	8	57
	1967	65	53	31	4	49
	Dif.	-7	8	-9	-4	-8
yellow-poplar	1936	33	47	54	76	50
	1967	35	35	43	72	45
	Dif.	2	-12	-11	-4	-5
ash	1936	28	35	57	84	49
	1967	28	53	66	92	56
	Dif.	0	18	9	8	7
sugar maple	1936	26	35	51	76	45
	1967	33	47	83	92	62
	Dif.	7	12	32	16	17
Virginia pine	1936	56	53	40	12	42
	1967	70	59	37	12	47
	Dif.	14	6	-3	0	5
northern red oak	1936	14	29	46	60	35
	1967	9	6	14	28	14
	Dif.	-5	-23	-32	-32	-21
means	1936	63	63	66	65	66
	1967	65	61	62	61	63
	Dif.	2	-2	-4	-4	-3

*Weighted mean for 120 plots.

Chestnut, scarlet oak, northern red oak, sourwood, white oak, and sassafras declined considerably in distribution; shortleaf pine and yellow-poplar declined at a lesser rate. Chestnut was eliminated by chestnut blight. Sassafras and sourwood are pioneer species which would respond to logging disturbance and openings from dying chestnut. They declined as light deminished under the closing canopy. Intolerant sassafras is one of the first trees of the forest to die when overtopped (Fowells, 1965). The decline in distribution of scarlet and northern red oaks is believed to be a case of misidentification.

The decrease in frequency of white oak is surprising. Although considered intermediate in light tolerance by Baker (1949), white oak has the ability to live for long periods as an overtopped tree responding quickly to release (Fowells, 1965). Trees in the small diameter class, one-to-three inches dbh, account for the decline in white oak. Frequency of one-to-three inch white oak in south hollows declined from 53 to 18 percent in the 31 years between studies, and a lesser amount on all other sites.

Density

From 1936 to 1967 several changes have taken place in density of the vegetation of the study area. These changes are reflected in Table 2, which lists the 18 most abundant tree species in the 1936 study, and shows how number of stems per acre changed from 1936 to 1967. Twenty-five of the 145 plots on the area were established in old fields; data from these plots were excluded from Table 2. Table 3 presents the

TABLE 2. Ranking and changes by stems per acre in diameter class group of the 18 most abundant species on Big Ridge Natural Study Area (to nearest whole number)

Species	Study	Stems per acre 1-3"	4-8"	8"	Total	Ranking 1936	1967
hickory	1936	111	16	8	135	1	2
	1967	72	24	7	103		
	Dif.	-39	8	-1	-32		
dogwood	1936	110	5	0	115	2	3
	1967	83	6	0	89		
	Dif.	-27	1	0	-26		
sourwood	1936	88	9	0	97	3	4
	1967	45	8	0	53		
	Dif.	-43	-1	0	-44		
red maple	1936	87	6	1	94	4	1
	1967	112	14	1	127		
	Dif.	25	8	0	33		
chestnut	1936	57	20	8	85	5	18
	1967	1	0	0	1		
	Dif.	-56	-20	-8	-84		
chestnut oak	1936	23	8	5	36	6	8
	1967	16	12	9	37		
	Dif.	-7	4	4	1		
scarlet oak	1936	24	8	4	36	7	17
	1967	1	3	4	8		
	Dif.	-23	-5	0	-28		
beech	1936	25	6	5	36	8	6
	1967	34	8	5	47		
	Dif.	9	2	0	11		
Virginia pine	1936	24	9	3	36	9	9
	1967	15	12	6	33		
	Dif.	-9	3	3	-3		
sassafras	1936	28	3	0	31	10	11
	1967	16	4	0	20		
	Dif.	-12	1	0	-11		

TABLE 2 (continued)

Species	Study	Stems per acre 1-3"	4-8"	8"	Total	Ranking 1936	1967
blackgum	1936	24	3	1	28	11	7
	1967	41	4	1	46		
	Dif.	17	1	0	18		
sugar maple	1936	21	2	1	24	12	5
	1967	43	6	1	50		
	Dif.	22	4	0	26		
shortleaf pine	1936	9	7	5	21	13	13
	1967	1	3	6	10		
	Dif.	-8	-4	1	-11		
ash	1936	17	2	0	19	14	12
	1967	13	3	1	17		
	Dif.	-4	1	1	-2		
black oak	1936	10	4	4	18	15	10
	1967	9	8	8	25		
	Dif.	-1	4	4	7		
northern red oak	1936	5	2	1	8	16	14
	1967	0	0	1	11		
	Dif.	-5	-2	0	-7		
white oak	1936	11	2	2	15	17	15
	1967	5	3	2	10		
	Dif.	-6	1	0	-5		
yellow-poplar	1936	8	3	1	12	18	16
	1967	3	4	2	9		
	Dif.	-5	1	1	-3		
Totals	1936	782	115	49	1046		
	1967	510	122	54	786		
	Dif.	-272	7	5	-260		

TABLE 3. Percent of total stems by diameter groups and change in total number of stems for 18 species

Species	Diameter Group*	Original Study Percent	Current Study Percent	Percent Difference	Change in Number of Stems
shortleaf pine	1	43	10	-33	-185
	2	34	31	-3	-94
	3	23	59	36	31
Virginia pine	1	68	46	-22	-202
	2	22	35	82	82
	3	8	18	10	86
black oak	1	59	37	-22	-22
	2	20	30	10	99
	3	20	33	13	117
northern red oak	1	55	22	-33	-101
	2	28	34	6	-44
	3	18	44	26	-21
scarlet oak	1	66	18	-48	-533
	2	23	13	-10	-134
	3	11	51	40	0
chestnut oak	1	64	43	-21	-178
	2	22	32	10	96
	3	15	25	10	95
white oak	1	73	47	-26	-151
	2	13	30	17	23
	3	14	25	8	3
blackgum	1	86	89	3	414
	2	9	8	-1	23
	3	5	3	-2	2
red maple	1	93	88	-5	585
	2	6	11	5	195
	3	1	1	0	8
sugar maple	1	90	86	-4	513
	2	6	12	6	106
	3	4	2	-2	0

TABLE 3 (continued)

Species	Diameter Group*	Original Study Percent	Current Study Percent	Percent Difference	Change in Number of Stems
yellow-poplar	1	64	35	-29	-100
	2	23	40	17	26
	3	13	24	11	19
beech	1	69	73	4	232
	2	18	16	-2	30
	3	13	11	-2	8
dogwood	1	96	93	-3	-630
	2	4	7	3	40
	3	0	0	0	0
hickory	1	82	70	-12	-947
	2	12	24	12	203
	3	6	7	1	-31
sourwood	1	91	85	-6	-1041
	2	9	15	6	-31
	3	0	0	0	0
sassafras	1	90	80	-10	-278
	2	10	19	9	22
	3	0	1	1	1
chestnut	1	66	96	30	-1291
	2	24	4	-20	-477
	3	10	0	-10	-192
ash	1	87	77	-10	-94
	2	11	20	9	25
	3	2	3	1	3

*Diameter groups are coded:

1 1-3 inch diameter breast height stems
2 4-8 inch diameter breast height stems
3 over 8 inch diameter breast height stems

changes in size classes which have taken place in the period between the two studies.

The 1936 study classified about two-thirds of the area (96 plots) as "Second Growth Pole Stands" indicating that logging had occurred on the area. Another 20 plots considered forested were designated "New Growth Pole Stands," which would indicate abandoned farmland. Only four plots were located in old growth. Chestnut was being killed by the chestnut blight at the time of establishment of the original study. In 1936, chestnut still had more large trees than any other species (number of trees over four inches dbh). With the death of these trees, large openings were created in the forest canopy.

Therefore, it would be expected that the 1936 inventory would include more pioneer trees than the current study 31 years later. This is the case. The trees which did increase in number, red maple, sugar maple, blackgum, beech, and black oak, are all components of climax forests. Red maple and blackgum are capable of thriving on a wide variety of sites; their number increased as the oak-hickory forest moved toward a climax. Red maple is a good seeder and regenerates well under closed stands (McDermott, 1953). Although blackgum is rated intolerant by Baker (1949), and appears to require nearly full light for optimum early growth, it may survive despite overhead competition. It is commonly an intermediate in the crown canopy (Fowells, 1965). Sugar maple and beech reproduction increased in number as canopies closed; in 31 years, however, number of dominant trees (over four inches diameter breast height) scarcely changed.

The oaks would be expected to increase in density because they can reproduce under closed canopies and through leaf litter becoming components of the climax on upland sites. Black oak responded in this way. The total number of chestnut oak, however, remained about constant, due primarily to a loss in reproduction (one-to-three inch diameters). Table 3, page 67, shows that both black oak and chestnut oak stems over four inches in diameter are increasing in number and percent.

Chestnut, sourwood, hickory, scarlet oak, dogwood, sassafras, shortleaf pine and northern red oak declined greatly in number. The total number of white oak, ash, yellow-poplar, and Virginia pine declined much less over the 31-year period. Due to the influence of closing canopies after previous logging and dying chestnut, the pioneer species such as sourwood, sassafras, ash, shortleaf and Virginia pines, and yellow-poplar declined in total number, although in trees over four inches in diameter the pines and yellow-poplar increased in number (Table 3). Number of stems of hickory reproduction (one-to-three inches dbh) was markedly reduced between the studies, while the number of trees over four inches diameter breast height increased.

Tables 2 and 3, pages 65 and 67, respectively, indicate that much oak reproduction was obtained while the stand was open following logging and the dying of chestnut. With the closing of the stands over the following 31 years, oak reproduction became less dense. The larger black and chestnut oaks increased in density. The writer believes that an identification problem is partially responsible for the decrease in scarlet and northern red oaks on the area. The 1936 study was done in

March and April, before the trees leafed out. It is questionable that a CCC crew could have distinguished between scarlet, northern red, and black oak without leaves to aid in their identification.

In both studies sourwood, red maple, blackgum, Virginia pine, shortleaf pine, white oak, and scarlet oak showed definite increases in density as sites grew progressively drier (Table 4). For red maple and blackgum this site effect was accentuated by 1967, as largest gains in density were exhibited on southern sites. The trend in Virginia pine was confusing in the original study, where north ridges had considerably more stems than the south hollows. Larger openings in the canopy on the north ridges could account for the break in the pattern.

In both studies sugar maple, beech, ash, and yellow-poplar showed increases in density from south ridges to north hollows. Sugar maple distribution was opposite that of red maple (Figure 5), with sugar maple density increasing on moist sites, and red maple on drier sites. The differences in density have been greatly accentuated over time.

Sassafras density increased on the more moist sites in the original study, but decreased on such sites in 1967 (Figure 6). It is probable that the more moist sites were logged heavier than drier sites, because more valuable trees would have been found there. This heavier cut in moist sites would have left larger openings than on drier sites, resulting in more abundant reproduction. In the absence of disturbance, during the 31-year period between studies, the mesic sites would close more completely than dry sites, allowing less light to reach the

TABLE 4. Stems per acre by topographic sites of the 18 most abundant species

Species	Study	South Ridge	South Hollow	North Ridge	North Hollow	Mean
shortleaf pine	1936	34	27	14	0	19
	1967	19	13	5	1	10
	Dif.	-15	-14	-9	1	-9
Virginia pine	1936	57	21	33	10	30
	1967	57	40	13	18	32
	Dif.	0	19	-20	8	2
black oak	1936	25	17	16	5	16
	1967	29	21	31	13	24
	Dif.	4	4	15	8	8
northern red oak	1936	2	4	14	14	9
	1967	0	1	2	2	1
	Dif.	-2	-3	-12	-12	-8
scarlet oak	1936	55	22	38	9	31
	1967	15	6	7	1	7
	Dif.	-40	-16	-31	-8	-24
chestnut oak	1936	27	29	57	29	36
	1967	33	31	55	25	36
	Dif.	6	2	-2	-4	0
white oak	1936	17	12	20	6	14
	1967	12	3	14	5	11
	Dif.	-5	-9	-6	-1	-3
blackgum	1936	34	25	24	25	27
	1967	65	55	37	20	44
	Dif.	31	30	13	-5	17
red maple	1936	101	95	104	66	78
	1967	161	146	128	52	122
	Dif.	60	51	24	-14	44
sugar maple	1936	11	9	35	40	24
	1967	12	20	72	102	52
	Dif.	1	11	37	62	28

TABLE 4 (continued)

Species	Study	South Ridge	South Hollow	North Ridge	North Hollow	Mean
yellow-poplar	1936	5	8	18	17	12
	1967	5	9	10	19	9
	Dif.	0	1	-8	2	-3
ash	1936	5	13	27	38	21
	1967	9	11	22	25	14
	Dif.	4	-2	-5	-13	-7
beech	1936	25	31	39	53	37
	1967	35	49	48	64	49
	Dif.	10	18	11	11	12
dogwood	1936	94	103	135	128	115
	1967	89	112	90	75	92
	Dif.	-5	9	-45	-53	-23
hickory	1936	118	126	161	137	136
	1967	98	92	133	78	100
	Dif.	-20	-34	-28	-59	-36
sourwood	1936	130	121	81	47	95
	1967	74	75	44	12	51
	Dif.	-56	-46	37	-35	-44
sassafras	1936	24	25	30	46	31
	1967	26	19	18	13	19
	Dif.	2	-6	-12	-33	-12
chestnut	1936	108	82	88	31	77
	1967	1	1	1	1	1
	Dif.	-107	-81	-87	-30	-76
mean	1936	48	43	52	38	40
	1967	41	39	41	29	38
	Dif.	-7	-4	-11	-9	-2

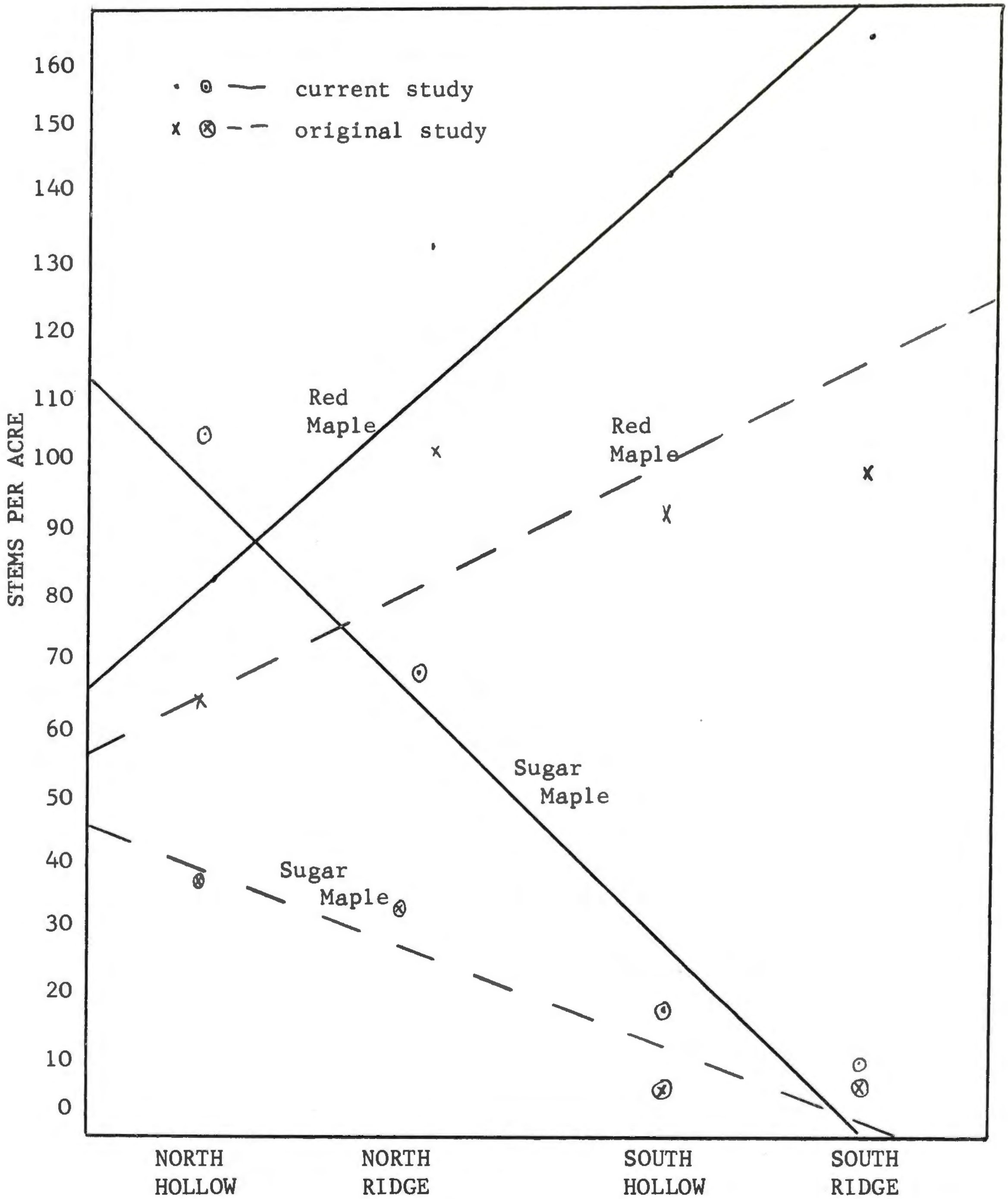

Figure 5. Original and current stems per acre of red maple and sugar maple by topographic sites.

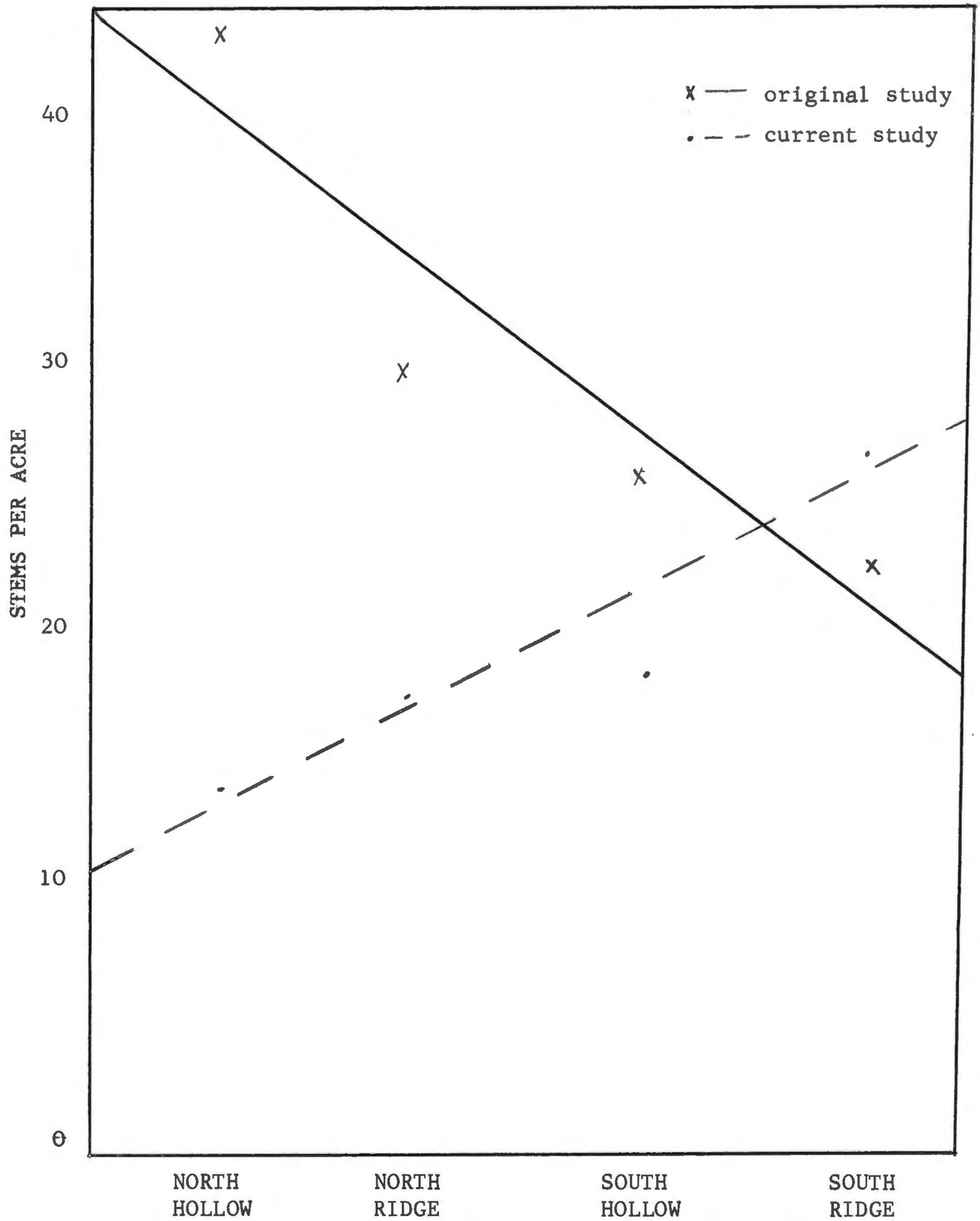

Figure 6. Original and current stems per acre of sassafras by topographic sites.

understory. This would account for the decrease in density of understory species such as dogwood, and sassafras.

Basal Area

Although the timing and intensity of the logging done on the study area preceding the first inventory in 1936 are unknown, basal area figures indicate the combined effect of logging prior to 1936 and the loss of chestnut. Table 5 shows the increase in total basal area, as would be expected as the stands mature, despite the reduction in number of stems.

A few species did, however, decrease in basal area. The understory trees, sourwood and dogwood, lost basal area. Both species are common pioneer trees in old fields or forest openings, and while they remain as understory components under closed canopies, basal area would be expected to decrease as stands close.

The reduction in basal area of northern red oak and scarlet oak, combined with the very sharp rise in black oak, is attributed partially to a problem of identification, as mentioned earlier. The oaks would normally be expected to increase in basal area on the upland. While black oak would be expected to increase in basal area, some of the observed increase may be attributed to the reduction of basal area in northern red oak and scarlet oak probably caused by identification errors in 1936. Black oak showed the greatest increase on north ridges. A similar problem was experienced by Nelson (1955) at Coweeta Watershed in western North Carolina. In a study similar to that at Big Ridge, initiated in 1934 and reinventoried in 1941 and 1953, Nelson found black

TABLE 5. Ranking and changes in basal area per acre by site group of the 18 most abundant species

		Basal Area (square feet per acre)											
		South				North						Ranking	
Species	Study	Ridge	Change	Hollow	Change	Ridge	Change	Hollow	Change	Mean[a]	Change	1936	1967
chestnut	1936	17.4	-17.3	11.8	-11.8	10.8	-10.8	5.8	-5.8	12.3	-12.2	1	18
	1967	0.1								0.1			
hickory	1936	9.2	1.7	11.9	1.2	11.4	2.6	17.9	-0.8	12.1	1.3	2	2
	1967	10.9		13.1		14.0		17.1		13.4			
chestnut oak	1936	8.3	2.1	9.0	6.7	12.2	9.2	7.7	1.3	9.4	4.7	3	1
	1967	10.4		15.7		21.4		9.0		14.1			
scarlet oak	1936	10.5	0.3	4.0	0.5	5.2	-0.2	3.4	-1.6	6.6	-0.3	4	7
	1967	10.8		4.5		5.0		1.8		6.3			
white oak	1936	5.6	-0.3	9.4	-5.2	6.4	1.5	3.1	2.6	5.8	0.2	5	8
	1967	5.3		4.2		7.9		5.7		6.0			
beech	1936	3.5	1.9	4.4	0.4	6.1	1.4	9.3	2.9	5.6	1.7	6	5
	1967	5.4		4.8		7.5		12.2		7.3			
shortleaf pine	1936	11.2	1.9	8.3	-1.3	0.0	2.7	1.6	-1.0	5.6	1.0	7	6
	1967	13.1		7.0		2.7		0.6		6.6			
black oak	1936	7.7	6.1	7.7	6.8	3.0	13.4	1.5	5.8	5.3	8.0	8	3
	1967	13.8		14.5		16.4		7.3		13.3			
Virginia pine	1936	7.3	7.0	5.0	1.2	2.4	1.5	2.2	-0.7	4.5	3.0	9	4
	1967	14.3		6.2		3.9		1.5		7.5			
yellow-poplar	1936	0.8	0.9	1.2	1.4	1.7	1.0	12.9	-2.9	3.7	0.1	10	10
	1967	1.7		2.6		2.7		10.0		3.8			

TABLE 5 (continued)

		Basal Area (square feet per acre)											
		Souty				North						Ranking	
Species	Study	Ridge	Change	Hollow	Change	Ridge	Change	Hollow	Change	Mean	Change	1936	1967
red maple	1936	3.1	3.3	3.2	1.7	4.7	0.8	0.9	2.3	3.5	1.8	11	9
	1967	6.4		4.9		5.5		3.4		5.3			
sourwood	1936	3.7	-1.3	3.4	-0.8	3.0	-1.3	1.8	-0.9	2.9	-1.0	12	14
	1967	2.4		2.6		1.7		0.9		1.9			
dogwood	1936	2.5	-0.2	2.7	0.5	3.5	-1.1	3.3	-1.1	3.0	-0.6	13	13
	1967	2.3		3.2		2.4		2.2		2.4			
blackgum	1936	2.7	1.3	2.1	0.2	2.1	0.8	1.3	0.0	2.1	0.8	14	12
	1967	4.0		2.3		2.9		1.3		2.9			
northern red oak	1936	0.2	0.4	1.4	-1.2	3.3	-2.7	3.8	-2.1	2.0	-1.2	15	17
	1967	0.6		0.2		0.6		1.7		0.8			
sugar maple	1936	1.0	0.2	1.6	-0.1	1.5	2.0	3.1	3.4	1.7	1.3	16	11
	1967	1.2		1.5		3.5		6.5		3.0			
ash	1936	0.2	0.0	0.4	0.8	1.7	-0.4	1.9	0.3	1.0	0.1	17	16
	1967	0.2		1.2		1.3		2.2		1.1			
sassafras	1936	1.0	-0.1	0.7	0.4	1.0	0.5	1.2	-0.2	1.0	0.1	18	15
	1967	0.9		1.1		1.5		1.0		1.1			
totals	1936	95.9	7.9	88.2	-6.7	80.0	19.3	82.7	1.7	86.5	6.1		
	1967	103.9		81.5		100.7		84.4		92.6			

[a]Mean is weighted to show average of 120 plots, irregardless of site averages.

oak increase "more than would be expected," with a decrease in northern red oak. Black oak basal area increased from 9.6 to 17.9 square feet per acre and was second only to the hickories in 1953.

Chestnut oak probably provides a more "normal" record of oak response on the site over time; this species increased in basal area in every site group, but especially in south hollows and north ridges. These sites are intermediate in moisture and temperature and generally considered good sites for chestnut oak development (Martin, 1966). Black oak, scarlet oak, and northern red oak combined showed a total mean basal area per acre of 13.9 square feet in 1936 and 24.4 square feet in 1967.

A breakdown of the oaks by sites shows that average total basal area for <u>all</u> the oaks was very similar in the original study, about 30 square feet per acre, except for the north hollows, which only had about 20 square feet per acre. In 1967 the southern sites had increased to about 40 square feet per acre each, and the northern ridges to about 55 square feet per acre.

Hickory, usually in mixture with oak, increased in basal area from south ridge (dry) to north hollow (moist) sites in both studies. In the current study as compared to 1967, hickory had greater basal area, although number of stems decreased. Hickory responds well to release and with oak was able to maintain dominance on all sites. Nelson (1955) at Coweeta Watershed in North Carolina also found hickory maintaining its basal area from 1936 to 1953.

Beech and sugar maple, in general, increased in basal area from south ridge to north hollow, as sites increased in moisture. More intolerant species eventually die and are replaced by the very tolerant sugar maple and beech from the understory or lower portion of the canopy.

The increase of basal area in shortleaf pine and Virginia pine is the result of trees growing into larger diameter sizes, because the number of smaller stems is decreasing (Tables 2 and 3, pages 65 and 67, respectively). Some shortleaf trees on the drier ridges are already dying at about 70 years of age, although one shortleaf pine on a more moist site was found to be over 225 years old.

In the past 31 years blackgum has gained only one stem per acre (from four to five) over four inches in diameter. Therefore, much of the basal area increase shown in Table 4, page 72, is from the large number of small diameter stems, especially on the south ridges in the more open canopies where blackgum could reproduce and survive.

Total basal area of yellow-poplar shows little change. Yellow-poplar, however, has suffered a considerable drop in basal area in north hollows. Competition with the more tolerant sugar maple and beech have probably contributed to this decline. On all other sites, yellow-poplar basal area is increasing slightly, despite a loss in reproduction. This increase in basal area is a result of an increase in size of established trees. On the more mesic Coweeta Watershed in North Carolina, Nelson (1955) reported large increases in yellow-poplar basal area, mainly due to openings in the stand left by the loss of chestnut. Drier sites, combined with a limited yellow-poplar seed source, precluded this increase on Big Ridge.

Types

Except for the demise of chestnut, and a large increase in black oak, frequency of type names show little change, although there may be considerable movement among plots (Table 6).

Hickory occurred in the type name on 52 plots in 1936 and 54 plots in 1967, a total change of only two plots. However, on south ridges seven plots typed as hickory in 1936 did not have hickory in the type name in 1967; four plots not typed as hickory in 1936 were typed as hickory in 1967. North ridges had seven more plots with hickory in the type name in 1967 than in 1936.

The oaks also showed such changes within species. White oak had a net loss of one plot in the type name from 1936 to 1967 (17 to 16), but this species was a part of the type on five plots in 1967 not named for it in 1936, while six plots named white oak in 1936 were not in 1967.

Chestnut oak had a net gain of four type names in the period between the two studies. The hollows lost three chestnut oak plots, but gained six. The ridges lost seven plots between the two studies, but gained eight. South ridges had 12 chestnut oak plots in 1936 and 11 in 1967, and north ridges had 17 chestnut oak plots in 1936 and 19 in 1967.

Black oak, scarlet oak, and northern red oak types combined occurred on 49 plots in 1936, as compared to 57 in 1967. As mentioned previously, the problem of identification makes the separation of these

TABLE 6. Forest types (by basal area) of plots by site groups for 1936 and 1967 studies[a,b]

Plot	Type	Plot	Type	Plot	Type
		SOUTH RIDGE			
105	Chest-ScO ScO-BO	407	Chest-ShP ShP-ScO	609	Chest BO-BJO
121	H-VaP-ChO[c] ChO-H	408	ShP-ChO ShP-ScO-RM	610	BO-Chest BO-Bg
122	VaP-H-B VaP	410	Chest-ShP VaP-ShP	611	ScO-BO ScO-BO
123	VaP-H-ChO VaP-ChO	411	VaP-Chest-ScO VaP-ChO-ScO	612	ScO-H-ShP ScO-H-ShP
221	WO-ChO-H WO	412	ShP-ScO ShP-ScO	614	WO-Chest WO-H
222	ScO-BO-Chest ScO-B-H	413	Chest-H-BO H-ChO-BO	702	VaP-H-ChO WO-VaP-BO
223	H-BO ScO-H	502	VaP-ScO-ChO VaP-ScO-ChO	703	H-ScO-Chest VaP-BO-H
225	ChO-Chest ChO	503	VaP-ChO VaP-ChO	704	ChO-ShP ChO-ShP
226	H-ScO-Ash VaP-BO	507	Chest-H BO	707	ShP-Chest VaP-ShP
301	B B	510	WO WO-H	709	ChO-Chest SRO-VaP
302	B B-WO	511	H-Dog H-YP	710	Chest-VaP VaP-ShP
308	BO-ShP ShP-BO	606	ShP ShP	713	Chest-VaP-ChO BO-ShP-ScO
309	BO-Chest-ScO ShP-BO-H	607	Chest-BO BO-ChO	714	Chest-VaP VaP
403	ScO-VaP VaP-ChO	608	WO-Chest BO	803	H-ScO-ChO ChO-VaP-H
404	ScO-VaP-H VaP-ScO				
		SOUTH HOLLOW			
120	B-WO-ChO B-H-ChO	203	B-SM B	207	WO-H BO

TABLE 6 (continued)

Plot	Type	Plot	Type	Plot	Type
224	WO-H B-H	504	ChO-WO-H ChO-H	708	Chest-ChO ChO-ShP
303	WO-B WO-B	505	H-WO-ChO H-WO-ChO	711	ShP-Chest ChO
310	ScO-BO-ShP ShP-BO	509	H-BO H-BO	715	VaP-SRO-ShP VaP
311	BO-ChO-ShP[c] BO-ShP-H	613	H-BO-SRO ScO-ChO-H	716	Chest-ShP VaP-ShP
409	ChO-Chest ChO	705	ScO-Chest BO-ScO-RM		
		NORTH RIDGE			
102	B-ChO B	220	Ash-H-ChO ChO-H-WO	701	Chest-RM RM-BO-ChO
103	ChO-Chest WO-ChO	306	BO-Chest-ShP BO-ChO	706	Chest-ScO-ChO[c] ChO-VaP-BO
104	ChO-Chest ScO	307	Chest-Dog-RM[c] BO-SM-Dog	801	ChO-NRO-WO ChO-BO
111	Chest-ScO BO-ScO	401	H-SM-YP B-NRO-WO	802	ChO-Chest-BO[c] BO-ChO-H
112	ScO-Chest ShP-ScO-BO	402	ScO-B-Dog BO-H-ChO	804	H-ChO ChO-H
117	VaP VaP-H	405 406	ScO-VaP ScO-VaP	805	ChO-H-Chest ChO-BO
201	RM-Sass-YP[c] Mag-VaP-H	501	H-ScO-Dog[c] H-ChO-BO	806	H-ChO-NRO ChO
202	B-RM B-YP	506	WO-Chest WO	807	ChO-B-Sour ChO
206	H-ChO H-ChO	512	H-ChO-B ChO-H	809	NRO-ChO-H ChO-BO
212	WO-H H-WO	603	ChO-NRO ChO-H	812	Chest-BO-ScO BO-H
213	WO-H H-WO	604	ChO-H ChO-H	814	Chest-BO BO
215	B B	605	Chest-ChO ChO		

TABLE 6 (continued)

Plot	Type	Plot	Type	Plot	Type
101	B-ChO ChO-B	216	B-WO-YP B-WO	514	RM-ChO-H YP-RM-H
110	Chest-H BO-H	217	H-ChO H-B	601	B-Mag-Chest[c] Mag-BO-B
204	YP-SM SM-YP	218	YP-H B	602	B-NRO H-B-ChO
205	YP-SM-B SM-B-ChO	219	B-H B-SM	712	VaP-ScO VaP-ScO
208	Chest-NRO BO-RM	304	H SM-YP-H	808	H-B-SM B-YP-ChO
209	H H-Dog	305	ChO ChO	810	H-NRO H-ChO
210	H H	508	H-WO WO-H	811	Chest-ChO-B ChO-H
211	H-YP H-YP	513	YP-WO YP-WO	813	ScO-H-YP ScO-BO-YP
214	B-H B-H				

[a]At each plot, the 1936 type is the top name.

[b]Abbreviations are as follows:

Ash	Ash	Dog	Dogwood	ShP	Shortleaf pine
B	Beech	H	Hickory	Sour	Sourwood
Bg	Blackgum	Mag	Magnolias	SRO	Southern red oak
BJO	Blackjack oak	NRO	Northern red oak	SM	Sugar maple
BO	Black oak	RM	Red maple	VaP	Virginia pine
Chest	Chestnut	Sass	Sassafras	WO	White oak
ChO	Chestnut oak	ScO	Scarlet oak	YP	Yellow-poplar

[c]Indicates that three names did not provide 50 percent of the basal area on the plot.

species questionable. Large gains of black oak on the ridges (19 additional plots) make suspect the loss of nine scarlet oak plots on the ridges.

The occurrence of Virginia pine in the type name increased from 23 to 41 plots. Biggest increase, from six to 18 plots, was in old fields. Virginia pine types on south ridges showed fluctuations, losing three plots, but gaining six. Beech, shortleaf pine, and yellow-poplar showed little change in frequency of type.

The chestnut type was completely eliminated by chestnut blight. Table 7 lists the species associated with chestnut in type names in 1936, and those which occurred on the same plots in 1967. Black oak, especially on the ridges, showed large gains in plots originally typed as chestnut. Black oak type showed a total increase of 17 plots, of these 15 plots were found on old chestnut type plots. Some of this increase may be due to the misidentification of scarlet oak and northern red oak, which both lost plots.

Chestnut oak type gained only four plots over the 31 years between studies. On the north ridges, where chestnut oak was typed on one-half of the plots, it gained only two plots on which chestnut was lost. On the contrary, chestnut oak was found to be the most abundant tree species replacing chestnut in the Great Smoky Mountains National Park (Woods and Shanks, 1959). Seventeen percent of the trees filling openings left by dying chestnut were chestnut oak, which occurred in 24 percent of the openings.

TABLE 7. Frequency of species typed with American chestnut, listed in order of replacement

Species	Study	South		North		Total	Ranking	
		Ridge	Hollow	Ridge	Hollow		1936	1967
chestnut	1936	20	5	14	4	43	1	
	1967	0	0	0	0	0		
	Dif.	-20	-5	-14	-4	-43		
black oak	1936	5	0	4	0	9	4	1
	1967	10	1	10	3	24		
	Dif.	5	1	6	3	15		
chestnut oak	1936	3	2	6	1	12	2	2
	1967	4	3	7	1	15		
	Dif.	1	1	1	0	3		
scarlet oak	1936	5	1	4	0	10	3	3
	1967	5	1	3	0	9		
	Dif.	0	0	-1	0	-1		
Virginia pine	1936	4	0	0	0	4	7	3
	1967	7	1	1	0	9		
	Dif.	3	1	1	0	5		
shortleaf pine	1936	3	2	1	0	6	5	3
	1967	6	2	1	0	9		
	Dif.	3	0	0	0	3		
hickory	1936	3	0	1	1	5	6	3
	1967	5	0	2	2	9		
	Dif.	2	0	1	1	4		
white oak	1936	2	0	1	0	3	8	4
	1967	1	0	2	0	3		
	Dif.	-1	0	1	0	0		
red maple	1936	0	0	2	0	2	9	4
	1967	0	1	1	1	3		
	Dif.	0	1	-1	1	1		
beech	1936	0	0	0	2	2	10	5
	1967	1	0	0	1	2		
	Dif.	1	0	0	-1	0		

Virginia pine, hickory, and shortleaf pine types gained in five, four, and three plots, respectively, mostly on south ridges, where chestnut had been most abundant. The pines, capable of development on a wide variety of sites, filled some of the vacancies left in the canopy by the dying chestnut, primarily on the driest sites of the southern ridges. The hickory type gained four plots, but lost seven on south ridges. Hickory gained only one plot on which chestnut was killed on north ridges, but gained six other plots on north ridges not involving the loss of a chestnut type.

Very little difference in the replacement of chestnut was found between types in which chestnut was listed first compared to those in which chestnut was a secondary part of the type. In both cases, about half of the dominant species (other than chestnut) were still dominant, while in eight plots it was a codominant. On only nine plots (five when chestnut was listed first, four when chestnut was secondary) did a new dominant appear.

Importance Value

To further determine the relation of stems and basal area to the different sites, an "importance value"[6] was computed on six species considered to be most important and representative, black oak, chestnut oak, beech, hickory, Virginia Pine, and yellow poplar. These values were designed to magnify the relationship of basal area, density, and

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[6]Basal area was multiplied by density for each plot, by topographic position. These products were summed, and divided by the number of plots in that topographic position.

frequency. These importance values are shown in Table 8. In general, less distinct patterns are seen in the original study than the current study, probably due to logging and dying chestnut prior to 1936. Lower slopes and bottoms are combined because the bottoms had too few plots to be significant.

Black oak was most important on the ridges, where increases between studies were considerable. No strong relationship with position on slope is evident in the original study, but the latter data shows a general trend for greater black oak importance the higher the position on the ridge. From midslope upward black oak appears to obtain a rather uniform importance factor. A sharp drop in importance was evident in black oak below midslope.

Chestnut oak assumed greatest importance on upper north ridges; where large increases in importance values were found. Most other topographic positions, with the possible exception of middle slope hollows, do not appear favorable for chestnut oak.

Beech increased from the top of the ridges to the lower slopes. The mean importance value for north ridges was several times as great as for south ridges, and the increase in importance value was outstanding on the middle north ridges. North hollows, the most mesic sites on the study area, did not exhibit as high an importance for beech as did north ridges, although beech is usually abundant in sheltered coves such as the north hollows.

In the original study, hickory had high mean importance values in north hollows (133.1 compared to 31.6 for beech). Apparently hickory so

TABLE 8. Importance values[a] for black oak, chestnut oak, beech, hickory, Virginia pine, and yellow-poplar by topographic sites

			South		North	
Species	Slope Position	Study	Ridge	Hollow	Ridge	Hollow
black oak	Top	1936	1.8		10.1	
		1967	36.3		40.1	
		Dif.	34.5		30.0	
	Upper	1936	23.5		2.9	
		1967	56.7		33.5	
		Dif.	33.2		30.6	
	Middle	1936	16.1	16.6	2.5	0.4
		1967	12.9	31.7	33.5	5.7
		Dif.	-3.2	15.0	30.6	5.3
	Lower, and Bottoms	1936	0.9	6.0	0.8	0.8
		1967	7.9	10.1	15.8	5.7
		Dif.	7.0	4.1	15.0	4.9
	Means	1936	10.6	13.0	20.8	0.5
		1967	28.5	24.5	30.6	5.7
		Dif.	17.9	11.4	9.8	5.1
chestnut oak	Top	1936	15.9		59.2	
		1967	29.0		83.6	
		Dif.	12.1		24.4	
	Upper	1936	4.6		100.8	
		1967	6.3		155.3	
		Dif.	1.7		54.5	
	Middle	1936	11.4	0.0	34.1	16.2
		1967	18.3	7.0	38.1	41.6
		Dif.	6.9	7.0	4.1	25.4
	Lower, and Bottoms	1936	60.9	17.8	9.6	16.0
		1967	39.7	29.0	15.3	28.3
		Dif.	-21.2	11.2	5.7	12.3
	Means	1936	23.2	17.8	50.9	16.1
		1967	22.8	18.0	73.1	34.9
		Dif.	-0.4	0.2	22.2	18.8

TABLE 9. Original and current volumes (cubic feet per acre) and "merchantable"[a] trees per acre of 11 species[b]

		South Ridge		South Hollow		North Ridge		North Hollow		Mean		Ranking	
Species	Study	Volume[c]	Number of Trees[c]	Volume	Number of Trees	Volume	Number of Trees	Volume	Number of Trees	Volume	Number of Trees	1936	1967
white oak	1936	58.7	1.6	138.3	2.3	90.0	1.7	96.3	1.8	95.8	1.9	1	4
	1967	96.1	1.5	160.7	2.1	181.9	2.4	103.8	1.2	135.6	1.8		
	Dif.	37.4	-0.1	22.4	-0.2	91.9	0.7	17.5	-0.6	39.8	-0.1		
hickory	1936	59.7	3.1	83.8	4.7	60.2	3.9	150.4	8.0	88.5	4.9	2	3
	1967	84.4	3.1	186.4	4.7	114.9	4.7	249.8	7.8	158.9	5.1		
	Dif.	24.7	0.0	102.6	0.0	53.7	0.8	98.4	-0.2	70.4	0.2		
chestnut oak	1936	95.0	3.3	75.8	2.1	102.0	5.5	77.1	3.4	87.5	3.6	3	1
	1967	214.1	4.4	206.9	6.3	261.2	8.9	146.9	3.8	207.3	5.9		
	Dif.	119.1	1.1	129.1	4.2	159.2	3.4	69.8	0.4	119.8	2.3		
shortleaf pine	1936	133.8	5.8	77.6	2.6	12.6	0.6	3.4	0.2	56.9	2.3	4	7
	1967	259.5	7.8	46.8	2.1	42.8	1.3	7.5	0.2	89.2	2.9		
	Dif.	126.7	2.0	-30.8	-0.5	30.2	0.7	4.1	0.0	32.3	0.6		
black oak	1936	91.8	4.1	83.8	2.9	22.6	1.4	27.0	0.8	56.3	2.3	5	2
	1967	182.6	6.6	265.9	7.4	155.5	6.0	97.5	3.2	175.4	5.8		
	Dif.	90.8	2.5	182.1	4.5	132.9	4.6	70.5	2.4	118.9	3.5		
beech	1936	28.5	1.4	27.7	1.0	50.4	2.3	98.9	5.4	51.4	2.5	6	5
	1967	86.1	2.8	90.8	2.9	117.3	3.6	199.8	5.8	123.5	3.8		
	Dif.	56.6	1.4	63.1	1.9	66.9	1.3	100.9	0.4	72.1	1.3		
scarlet oak	1936	101.3	5.5	29.4	1.5	18.9	1.1	2.0	0.2	38.9	2.1	7	8
	1967	150.4	4.7	61.4	2.6	12.1	1.2	64.7	1.2	72.2	2.4		
	Dif.	48.7	-0.8	32.0	1.1	-6.8	0.1	62.7	1.0	23.3	0.3		

TABLE 9 (continued)

Species	Study	South Ridge Volume[c]	South Ridge Number of Trees[c]	South Hollow Volume	South Hollow Number of Trees	North Ridge Volume	North Ridge Number of Trees	North Hollow Volume	North Hollow Number of Trees	Mean Volume	Mean Number of Trees	Ranking 1936	Ranking 1967
yellow-poplar	1936	10.7	0.6	8.2	0.6	8.5	0.6	121.6	4.2	37.3	1.5	8	6
	1967	52.6	0.8	40.4	0.9	48.3	1.4	246.1	4.2	96.8	1.8		
	Dif.	41.9	0.2	32.2	0.3	39.8	0.8	124.5	0.0	60.5	0.3		
Virginia pine	1936	27.4	1.7	74.6	3.8	16.4	0.7	0.0	0.0	29.6	1.6	9	9
	1967	121.1	5.5	68.1	2.6	18.6	1.0	5.9	0.4	53.4	2.4		
	Dif.	93.7	3.8	-6.5	-1.2	2.2	0.3	5.9	0.4	23.8	0.8		
northern red oak	1936	6.9	0.1	22.6	0.6	30.2	1.9	32.4	1.6	23.0	1.1	10	11
	1967	18.1	0.2	0.0	0.0	7.0	0.1	10.9	0.6	9.0	0.2		
	Dif.	12.3	0.1	-22.6	-0.6	-23.2	-1.8	-21.5	-1.0	-14.0	-0.9		
sugar maple	1936	9.4	0.2	31.9	0.9	12.3	0.6	24.9	1.0	19.6	0.7	11	10
	1967	6.6	0.2	20.1	0.3	30.9	0.6	61.8	1.4	29.9	0.6		
	Dif.	-2.8	0.0	-11.8	-0.6	18.6	0.0	37.1	0.4	10.3	-0.1		
totals	1936	623.2	27.5	653.4	23.1	424.6	19.8	633.6	26.4	585.2	24.2		
	1967	1271.6	37.4	1147.3	31.9	990.0	30.8	1194.6	29.7	1151.7	31.9		
	Dif.	647.9	9.9	439.9	8.8	565.4	11.0	561.0	3.3	566.5	7.7		

[a]All trees over 12 inches diameter breast height containing at least an eight foot log, to a small end diameter of eight inches.

[b]Chestnut not included because it was recognized that no chestnut volume would be present in later studies.

[c]Per acre.

black oak. North hollows contained more hickory volume than any other species in both studies although yellow-poplar and beech displayed greater increases here.

Chestnut oak possessed the largest volume in 1967, the greatest number of merchantable trees, and the greatest increase in volume between the two studies. This species had large volume increases on all sites, but showed the greatest increase (159.2 cubic feet per acre) and greatest volumes in both studies on north ridges. Chestnut oak also had a high increase in volume (129.1 cubic feet per acre) and ingrowth (4.2 trees per acre) in south hollows.

Black oak had the second highest increase in volume, the greatest ingrowth (3.5 trees per acre), and second highest volume in 1967. Increases were very similar to those of chestnut oak on all sites, although number of ingrowth trees was higher in black oak. In south hollows black oak had the largest volume increase of any species.

Yellow-poplar and beech showed the highest volume increases in north hollows. They maintained second and third rankings in these coves, considered to be optimum sites for their growth. It is noteworthy that yellow-poplar growth exceeded beech and hickory in the north hollows, although the number of trees per acre was less than that of the other two species. Number of merchantable trees of the three species hardly changed on these sites in the 31-year period between the cruises. Although yellow-poplar increased in number of merchantable trees on all sites, except north hollows, the latter site had more trees in both studies, more original yellow-poplar volume, more final yellow-poplar volume, and more yellow-poplar volume increase than all other sites combined. Beech exhibited increases in current volume and volume growth from south ridge (dry) to north hollows (wet), although south hollows had much fewer stems.

Scarlet oak gained in number of trees on all but south ridges, where it showed a 50 percent increase in volume. On north ridges, volume decreased slightly. The large increase of scarlet oak volume in north hollows is due to an increase in number of trees.

Shortleaf pine and Virginia pine exhibited large volume increases on south ridges, volume and tree losses in south hollows, and smaller gains on the other sites. Virginia pine increased from 1.7 to 5.5 merchantable trees per acre on the south ridges, while the increase in number of shortleaf pine on south ridges was much smaller.

<u>Relationships of Soil-Site to Stand Composition</u>

Some strong relationships occur between soil and site factors and plot species composition. These relationships are strongest between soil-site factors indicating mesic conditions and species restricted to mesic sites, or xeric conditions and those species restricted to zeric sites. The data were divided into three diameter class groups, size one (one-to-three inches), size two (four-to-eight inches), size three (over eight inches). Canonical analysis was completed for each size group on both 1936 and 1967 data.

In the original study (Table 10) for size one, soil and site factors indicative of moist sites, such as finer-textured A horizon, dense shrub cover, and more complete canopy closure showed a high

TABLE 10. Canonical analyses of 1936 and 1967 data for 14 soil-site factors and density of the 21 most abundant species, size one (one-to-three inches diameter breast height)[a,b]

Study	Weight	Soil-Site Factors	Weight	Species
1936	.5370	texture of A horizon	-.4435	sourwood
	-.3626	herbaceous ground cover	.4154	beech
	.3178	shrub cover	.2830	ash
	.3078	canopy closure	.2629	hickory
	-.2750	texture of B horizon	.2054	black oak
	-.1440	slope direction	-.1761	red maple
	.1432	erosion	-.1732	Virginia pine
	.1411	thickness of A horizon	.1495	magnolias
	.1036	fire damage	-.1265	sassafras
			.1134	blackgum
Canonical Correlation = 0.8162			-.1108	scarlet oak
1967	-.6393	herbaceous ground cover	-.5596	shortleaf pine
	.4512	shrub cover	-.2825	white oak
	.3062	canopy closure	.2517	sugar maple
	-.1864	slope direction	-.2379	red maple
	.1767	stone percent	.2075	beech
	.1723	erosion	-.2017	sassafras
	.1474	fire damage	-.1851	dogwood
	.1425	thickness of A horizon	.1771	black oak
	.1425	texture of A horizon	.1471	magnolias
	-.1176	texture of B horizon	-.1142	ash
	.1125	steepness of slope	.1123	hickory
Canonical Correlation = 0.8743				

[a]Weight less than plus or minus .1000 are omitted.

[b]Code used in ranking soil-site factors is in Appendix A. Soil-site factors and species used in the analyses are in Appendix B.

positive relationship to the mesic beech, and a lesser relationship to ash, hickory, and black oak. Conversely, the denser the herbaceous ground cover, characteristic of more open stands, and the coarser the A texture, the greater is the occurrence of the intolerant sourwood. Herbaceous ground cover was primarily poison ivy which was denser under open stands where more light reached the forest floor.

However, after 31 years, no soil factor was important to establish tree reproduction (Table 10). Vegetation has become the important or "limiting" factor in establishment of regeneration. Herbaceous ground cover, shrub cover, and canopy closure retained their positions and relationship to species requirements. Herbaceous ground cover is highly related to shortleaf pine, and to a lesser degree to white, oak, red maple, and sassafras, which often exhibit greatest abundance of reproduction on drier sites in oak-hickory forests where stands are more open. Denser shrub cover and canopy closure are still related to sugar maple and beech, climax species in coves and on protected sites.

Shortleaf pine reproduction has moved from an extremely low weight in 1936, to the most important weight (-.5596) in 1967. Furthermore, sugar maple has increased from lowest to third (.2517) in weight from the original to the current study. These changes suggest that effects of logging and dying chestnut are no longer a force in the reproduction of the stands. The intolerant shortleaf pine reproduction increased on the drier, more open sites. It was restricted from the mesic sites by the development of the more tolerant species, especially beech and sugar maple, seedlings of which could develop in the low light intensities under closed canopies.

For pole-sized trees (size two) in 1936, the most important soil-site factor in the canonical analysis was slope direction. The more southwestern the slope direction and denser the herbaceous ground cover, the greater was the abundance of shortleaf pine, scarlet oak, and sourwood (Table 11). Conversely, the more moist conditions associated with greater stone percent, greater "erosion," and increased canopy closure related to ash, hickory, beech, northern red oak, and yellow-poplar. Yellow-poplar, exhibiting almost no relation to any soil-site factor in size one, showed a strong relation to mesic conditions in size two, which indicates that site factors have less influence in the survival and growth of yellow-poplar seedlings than in later development.

In 1936 black oak decreased from a weight of .2054 in the size one group to a very small weight in size two, and red maple reacted similarly. Cutting and dying chestnut probably opened up the stand so that black oak and red maple were able to reach this size group on a wide variety of sites, including sites on which they would have been excluded without disturbance. In 1936 the relationship between size two species and shrub cover decreased from the size one species relationship to shrub cover. The importance of stone percent increased considerably from the small size group. Stone percent was probably a measure of downward movement on the very steep slopes. The erosion factor was a measure of sheet erosion most prevalent on the steepest slopes. Steepness of slope

TABLE 11. Canonical analyses of 1936 and 1967 data for 14 soil-site factors and density of the 21 most abundant species, size two (four-to-eight inches diameter breast height)[a,b]

Study	Weight	Soil-Site Factors	Weight	Species
1936	.4858	slope direction	-.3812	ash
	-.4164	stone percent	-.3694	hickory
	-.3440	erosion	-.3250	beech
	.3087	herbaceous ground cover	.3142	shortleaf pine
	-.2488	canopy closure	-.2825	northern red oak
	.1887	texture of B horizon	.2304	scarlet oak
	-.1853	texture of A horizon	-.2228	yellow-poplar
	-.1401	shrub cover	.2131	sourwood
	.1056	fire damage	.1772	Virginia pine
			-.1606	chestnut oak
			.1426	hophornbeam
			.1268	sugar maple
Canonical Correlation = 0.7755			.1195	white oak
1967	-.4365	stone percent	.3863	Virginia pine
	.3884	herbaceous ground cover	.3313	sassafras
	-.3871	shrub cover	-.2927	hickory
	-.3747	canopy closure	.2580	scarlet oak
	.2822	texture of B horizon	.2384	sourwood
	-.2126	texture of A horizon	.2314	blackgum
	.1557	slope direction	-.1987	beech
	-.1481	fire damage	-.1574	basswood-buckeye
			-.1490	magnolias
			.1395	black oak
			.1322	shortleaf pine
			-.1284	northern red oak
			.1231	chestnut oak
Canonical Correlation = 0.8181			.1086	white oak

[a]Weights less than plus or minus .1000 are omitted.

[b]Code used in ranking soil-site factors is in Appendix A. Soil-site factors and species used in the analyses are in Appendix B.

increased with the lower positions on the slopes, adjacent to the most mesic sites and related to mesic conditions.

The 1967 canonical analysis for size two exhibits the same moisture relationships as found in 1936 (Table 11). Stone percent, shrub cover, canopy closure, and texture of the A horizon relate highly to hickory, and less to beech, northern red oak, ash, and yellow-poplar. The texture of the A horizon increased but little in weight from 1936 to 1967. Finer A horizons are associated on the study area with lower slopes and bottoms, which are more moist by position and by water-holding capacity. In 1967 herbaceous ground cover still shows the highest relationship to drier sites, although texture of the B horizon is also related to them. Finer texture of the B horizon was found on the upper ridges where soils were shallowest. Fine-textured B horizons inhibit deep penetration of moisture into the soil and promote rapid internal drainage on the steep slopes. Dry site species in the size two group in 1967 are Virginia pine, sassafras, scarlet oak, sourwood, and blackgum.

In timber size, trees (size three), only slope direction was positively related to dry site species in 1936 (Table 12). The more southwestern the slope direction, the more shortleaf pine and black oak occurred. The more mesic conditions were indicated by stone percent, shrub cover, erosion, and form of slope. These mesic factors were related most highly to chestnut oak, sugar maple, and ash, and in a lesser degree to hickory, northern red oak, basswood-buckeye, and yellow-poplar. The abundance of these species was probably influenced

TABLE 12. Canonical analyses of 1936 and 1967 data for 14 soil-site factors and density of the 17 most abundant species, size three (over eight inches diameter breast height)[a,b]

Study	Weight	Soil-Site Factors	Weight	Species
1936	.3975	slope direction	.4533	shortleaf pine
	-.3571	stone percent	-.2210	chestnut oak
	-.3088	shrub cover	-.2375	sugar maple
	-.2362	erosion	-.2344	ash
	-.2096	form of slope	.2157	black oak
	.1897	canopy closure	-.1830	hickory
	-.1786	fire damage	-.1671	northern red oak
	-.1672	thickness of A horizon	-.1638	basswood-buckeye
	.1632	position on slope	.1495	Virginia pine
	.1197	most important element in	-.1405	yellow-poplar
		ground and shrub cover	.1121	white oak
	.1132	steepness of slope	.1070	sassafras
	-.1035	texture of A horizon		
Canonical Correlation = 0.8286				
1967	.4096	texture of A horizon	-.4152	shortleaf pine
	.3943	shrub cover	-.3671	Virginia pine
	-.3509	slope direction	-.2662	black oak
	-.2770	position on slope	.2651	yellow-poplar
	.2328	steepness of slope	.2607	ash
	.1559	stone percent	-.2577	basswood-buckeye
	.1334	canopy closure	-.2131	blackgum
	-.1230	texture of B horizon	.2030	sugar maple
	-.1021	herbaceous ground cover	.1414	beech
			-.1069	chestnut oak
Canonical Correlation = 0.8057				

[a]Weights less than plus or minus .1000 are omitted.

[b]Code used in ranking soil-site factors is in Appendix A. Soil-site factors and species used in the analyses are in Appendix B.

by logging. Large yellow-poplars very likely would have had a higher relation to mesic sites if the yellow-poplar had not been logged more heavily on these sites where it was most abundant. Logging is likely responsible for the negative relationship of canopy closure to mesic sites and species in 1936 as opposed to the positive relationship found in 1967.

In the 1967 study, size three shows some interesting comparisons and contrasts to the other size groups, and to the 1936 study (Table 12). The more southwestern the direction, the more of the drier site species are found. Position on slope is another major factor influencing species density; higher up the slope more drier site species occur. Shortleaf pine, Virginia pine, black oak, and blackgum, are dominant. The more mesic site factors related to size three trees are texture of the A horizon, shrub cover, and steepness of slope. Dense shrub cover is indicative of moist sites, and the steepest slopes are usually near the bases of the slopes, next to the most mesic sites. Mesic site species in 1967 are yellow-poplar, ash, and sugar maple, with beech less related. Yellow-poplar and ash, although intolerant and intermediate in shade tolerance, were able to reach the upper canopy after logging, as indicated by the abundance of these stems in the size two class in 1936, and the corresponding abundance of them in size three in 1967. Herbaceous ground cover and canopy closure have relatively little weight in the largest size class. While these factors were important in establishment and early growth of reproduction, both studies show their weight decreasing from small to large stems.

Some indication of the sensitivity of species distribution to changes in soil-site factors may be gained by taking note of the species which have high weights in the six different canonical analyses. Using plus or minus .3 as a "significance" level shortleaf pine is mentioned four times, Virginia pine and beech two times each, and ash, hickory, sassafras and sourwood once.

CHAPTER IV

CONCLUSIONS

Hickory, dogwood, red maple, chestnut oak and blackgum maintained a frequency of almost 100 percent on the study area in the 31 years between 1936 and 1967. Black oak showed a large increase in frequency on north sites, while scarlet oak and northern red oak decreased sharply on all sites. Since the 1936 inventory was conducted in March and April, the writer believes misidentification accounts for some of the changes in frequency of these three species. Beech and sugar maple, climax components of the mixed mesophytic forest, showed increases in frequency. Beech showed a significant increase in frequency on south ridges, but usually remained a subordinate tree on these sites. Beech and sugar maple increased in frequency from dry to moist sites, especially on north ridges.

Logging prior to the original inventory and loss of chestnut to chestnut blight had significant effects on the density of the vegetation. Although the extent of the openings by these factors is unknown, they are believed to account for the very high number of small trees present in 1936, particularly those with greater light requirements. Sourwood, hickory, scarlet oak, northern red oak, sassafras, and shortleaf pine generally showed sharp declines in number of smaller stems between 1936 and 1967. These species are intermediate or intolerant to shade. Increasing in density were red maple, sugar maple, blackgum, and beech, all components of climax forests. Although the number of trees of these species over eight inches in diameter did not increase, reproduction has survived despite closed canopies. Percentages of stems in the different diameter groups show little change for these species between 1936 and 1967.

Sourwood, red maple, blackgum, Virginia pine, shortleaf pine, white oak, and scarlet oak showed definite decreases in density as sites progressed from dry to moist. Sugar maple, beech, ash, and yellow-poplar showed increases in density from dry to moist sites. In 1936, the understory sassafras and dogwood showed increases in density as moisture increased, but just the opposite in 1967 after canopies closed.

Logging and the openings in the stand from dying chestnut prior to the 1936 study would indicate that basal area should increase considerably in the 31 years between studies. The total of the 18 most abundant species shows a gain of only 6.1 square feet per acre, but when chestnut is omitted from both studies, a gain of 18.3 square feet per acre is recorded. Black oak showed the largest increase (from 5.3 to 13.3 square feet) in the 31-year period, while scarlet oak and northern red oak showed small decreases. The problem of misidentification very possibly influenced these results. Combining the three species, a considerable increase in basal area is still evident.

Chestnut oak exhibited a considerable increase in basal area between 1936 and 1967, especially in south hollows and north ridges, the sites medium in moisture content. Chestnut oak also showed a considerable increase in number of trees over eight inches in diameter between studies.

The openings of the stands prior to the 1936 inventory would have provided opportunities for chestnut oak saplings to reach the overstory.

Hickory increased in basal area from dry south ridges to moist north hollows, but the largest increase was on north ridges, where chestnut loss was greatest. Virginia pine doubled its basal area on south ridges.

With the exception of scarlet oak and northern red oak, only the understory species, sourwood and dogwood lost basal area. Although densities remained high, closing of the stands curtailed reproduction and growth of these species.

No clear picture of the forest types was indicated from the data. Although only small differences occurred for most species in frequency, several species exhibited considerable movement. Chestnut oak and white oak were typed on several additional plots in the current study, but were eliminated from the type name on about an equal number of plots. Chestnut was completely eliminated from the types as a result of chestnut blight. Black oak appeared to be the primary species replacing chestnut. Black oak occurred on nine plots with chestnut in the type name in the original study, but occurred on 24 plots formerly typed chestnut in 1967. Chestnut oak increased from 12 plots typed with chestnut in 1936 to 15 in 1967.

Important values were determined for black oak, chestnut oak, beech, hickory, Virginia pine, and yellow-poplar by topographic position. Black oak showed its highest value on the ridges, with a considerable increase in the 1967 study. Black oak values increased in upper positions, and showed a marked decrease below middle slopes. Chestnut oak was also more important on upper and middle ridges. On the other hand, beech importance increased from top to bottom of slopes as moisture increased. The shade tolerant beech was capable of competing under the dense canopies of the mesic species.

Hickory exhibited greatest importance on the middle slopes of north ridges, but in the period between studies had declined on all lower sites as a more climax forest was established. Hickory importance on northern sites was almost double that of southern sites.

Virginia pine showed a large increase in importance in south hollows between studies, and consistent increases on south ridges. Importance on northern sites declined.

Merchantable volumes showed a large increase from 1936 to 1967. Total of mean volumes increased from 585.2 cubic feet per acre with 24.2 trees to 1151.7 cubic feet per acre with 31.9 trees. Growth increases were greatest on south ridges, but the greatest increase in number of merchantable trees occurred on north ridges.

Chestnut oak increase in volume (119.1 cubic feet per acre) was greatest on north ridges with intermediate moisture conditions and competition. However, large chestnut oak increases were found on all sites. Scarlet oak increased from 46.4 cubic feet per acre in 1936 to 85.9 cubic feet per acre in 1967, while northern red oak decreased from 21.5 cubic feet per acre to 10.7 cubic feet per acre. Black oak volume, however, increased from 56.3 to 175.4 cubic feet per acre in the same period with increases on all sites, but especially in south hollows.

Hickory dropped from second to third ranking in volume over the 31-year period between studies. Most volume and largest gains of hickory were shown in the hollows

Both basal area and volume did not increase between studies as greatly as on the other sites. These unusual findings cannot be explained from the data.

Canonical analyses showed definite relationships between dry site conditions and dry site species, and between mesic soil-site factors and mesic species. The relationships were generally consistent through the three size groups and in both studies.

Factors indicative of dry sites in general were heavy herbaceous ground cover, fine texture of B horizon, and slope directions approaching southwest. Herbaceous ground cover increase was related to the amount of light reaching the forest floor, a function of canopy closure and slope direction. Slopes approaching southwest receive more sunlight and were usually drier than slopes of equal steepness and canopy closure on other exposures. Finer B horizon was found on the shallower soils which had less available moisture on the relatively steep slopes of the study area. The drier sites were unable to produce dense canopy closures characterized by the more mesic sites. These sites were generally restricted to species with ability to thrive in droughty soils. The species best related to dry sites were shortleaf pine, Virginia pine, white oak, sassafras, sourwood, black oak, and scarlet oak. Only red maple reproduction was related to dry sites. Although black oak reproduction (one-to-three inches in diameter) was related to mesic sites and species, it could not compete on these sites, and the larger trees were highly related to dry site factors.

Soil-site factors highly related to mesic sites were dense shrub cover, more complete canopy closure, and high stone percentage. To a lesser degree, a fine-textured and thick A horizon and increased sheet erosion were also related to mesic sites. Shrub cover was densest on the most mesic sites and very steep slopes. On the study area these slopes were usually located at the bottom of the ridges adjacent to the most mesic sites. This steepness of the lower slopes also accounted for the relationship of erosion to mesic conditions and species; sheet erosion was more prevalent on steepest slopes, adjacent to the bottoms.

Species highly related to mesic sites were beech, ash, and hickory. Reproduction of black oak and magnolias, was also related to moist sites while larger trees of sugar maple, northern red oak, and yellow-poplar were also common in these locations. Beech, sugar maple, and magnolias are tolerant or very tolerant components of the climax mixed mesophytic forest, found on the more mesic sites of East Tennessee. A climax component of the oak-hickory forest associated with uplands, hickory occupied the lower northern slopes and south hollows on the study area.

Very few "old growth" forests remain in the Ridge and Valley Province of East Tennessee. This area will become even more valuable in the future for studies in forest ecology. Therefore, it is recommended that the natural area be preserved to allow future studies of a forest which is developing into a climax, following disturbances more than three decades ago. It is also recommended that the rotten posts marking the plot boundaries be replaced before the plot boundaries become obscure.

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APPENDIXES

APPENDIX A

PLOT DATA CODING

Item		Code
Date		Year, month,day
Plot number	Same as on stakes in the field	
Soil series	See Soil Survey, code as in texture of A horizon below	
Slope direction		
Flat 0-1 percent		1
NE		2
N		3
E		4
NW		5
SE		6
W		7
S		8
SW		9
Steepness, percent		
0-1 Flat		1
1-5		2
5-12		4
12-20		4
20-30		5
30-45		6
45-65		7
65-75		8
75 and over		9
Position on slope		
Bottom		1
Lower		2
Middle		3
Upper		4
Crest		5
Form of slope		
Concave		1
Straight		2
Convex		3

Item	Code
Erosion factor	
No apparent erosion	1
Some sheet erosion, as evidenced by bare spots in humus layer	2
Abundant sheet erosion, humus layer sparse, some rills may be present	3
Abundant rills, some gullies may be present	4
Thickness of A-horizon (inches)	
16 plus	9
14-16	8
12-14	7
10-12	6
8-10	5
6-8	4
4-6	3
2-4	2
0-2	1
Texture of A-horizon	
Sand	1
Loamy sand	2
Sandy loam	3
Loam	4
Silt loam	5
Silt	6
Sandy clay loam	7
Clay loam	8
Silty clay loam	9
Sandy clay	10
Silty clay	11
Clay	12
Texture of B-horizon	Same as A-horizon above
Stone in percent of total soil volume	
0-20	1
20-40	2
40-60	3
60-80	4
80-100	5

Item	Code
Canopy closure by trees, in percent (overstory)	
0-15	1
15-25	2
25-35	3
35-45	4
45-55	5
55-65	6
65-75	7
75-85	8
85-100	9
Shrub cover (all woody plants excluding overstory)	
Coded same as canopy closure above	
Herbaceous ground cover (percent)	
Coded same as canopy closure above	
Most important elements in ground and shrub cover. Consider contribution to total cover, excluding overstory.	
Forest tree reproduction	1
Rhododendron and Mt. Laurel (Kalmia)	2
Blueberries (Vaccinium) and other deciduous shrubs	3
Deciduous shrubs (non-tree) other than heath	4
Grasses and grasslike plants	5
Broadleaved herbs	6
Woody vines	7
Ferns (all)	8
Mosses and lichens	9
Fire damage	
Trees show definite fire damage	1
Trees show signs of past fires by blackened bark or butt damage	2
No apparent fire damage	3

APPENDIX B

SOIL–SITE FACTORS AND SPECIES USED IN CANONICAL ANALYSES

Soil–Site Factors	Species
canopy closure	ash (primarily *Fraxinus americana*)
erosion	basswood–buckeye
fire damage	beech
form of slope	black oak
herbaceous ground cover	blackgum
most important element in ground and shrub cover	chestnut*
position on slope	chestnut oak
shrub cover	dogwood*
slope direction	hickories (*Carya glabra* and *C. tomentosa*)
steepness of slope	magnolias (*Magnolia Acuminata* and *M. macrophylla*)
stone percent	northern red oak
texture of A horizon	persimmon*
texture of B horizon	red maple
thickness of A horizon	sassafras
	scarlet oak
	shortleaf pine
	sourwood*
	sugar maple
	Virginia pine
	white oak
	yellow–poplar

*Eliminated from size three analyses for lack of data.

VITA

Daniel Donovan Summers was born in Lodi, Ohio, on May 19, 1941. He attended elementary school in Edinburg, Texas, and graduated from Edinburg High School in 1959. He attended Pan American College from September, 1959, to May, 1961; Texas A & M University from September, 1961, to January, 1962; and Louisiana State University from February, 1962, until his graduation in August, 1963.

He was employed by the Tennessee Division of Forestry in Middle Tennessee until October, 1965, and taught high school until May, 1966. In June, 1966, he entered the Graduate School of The University of Tennessee, holding a teaching assistantship. In December, 1968, he received his Master of Science degree.

He is married to the former Barbara Kay Gorenflo of Baton Rouge, Louisiana, and has one son.