RELATION OF SOIL PROPERTIES TO SITE INDEX OF SHORTLEAF PINE AND DISTRIBUTION OF TREE SPECIES IN THE COASTAL PLAIN SOILS OF SOUTHEAST OKLAHOMA

By

SATYANARAYANA PAKA

Bachelor of Science
Osmania University
Hyderabad, India
1955

Master of Science
Osmania University
Hyderabad, India
1961

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
August, 1969

RELATION OF SOIL PROPERTIES TO SITE INDEX OF
SHORTLEAF PINE AND DISTRIBUTION OF TREE
SPECIES IN THE COASTAL PLAIN SOILS OF
SOUTHEAST OKLAHOMA

Thesis Approved:

Lester W. Reed
Thesis Adviser

Billy B. Tucker

Wayne W. Huffine

Robert D. Morrison

James M. Davidson

D. D. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

The author wishes to thank the Agronomy and Forestry Departments for the facilities and assistance provided to investigate the present study.

I am deeply indebted to each and every one who have helped in the completion of this study. In particular I am indebted and grateful to my major adviser, Dr. Lester W. Reed, who is sound and profound in knowledge and fair in actions, for his counsel, inspiration, advice, and help throughout this study.

Appreciation and thanks is also extended to other members of my advisory committee, Drs. R. D. Morrison, W. W. Huffine, B. B. Tucker, and J. M. Davidson for their valuable suggestions and timely guidance.

A special note of appreciation and thanks is extended to Mr. Ted H. Silker for his encouragement and constructive critism at all stages of this work.

Sincere appreciation is also extended to my former adviser, Dr. J. Q. Lynd for his guidance.

An expression of gratitude is also extended to Mr. Robert Reasoner and Mr. Joe Nichols, Soil Scientists of the Soil Conservation Service for their immense help, in locating profiles, collection of soil samples and classifying soils present in study area.

Appreciation is also extended to Mr. W. Dale Wilson of the Forestry Department for his help in identifying forest tree species and in collecting field data. Credit is due to Mr. Henry Magalit of the

Mathematics and Statistics Department for his valuable guidance and help in running the computer programme.

Appreciation is also extended to my friends Dr. Sheshadri, and Mr. C. Srinivas Rao for their help in completion of this study.

The author is grateful to his parents, kith and kin for their encouragement without which his stay in the United States would not have been possible.

Sincere appreciation and special thanks are extended to my wife, Lakshmi Bai, and daughter Keerthi, for their tolerance of all the hardships they have undergone during the entire study.

Finally the author also wishes to thank Mrs. Theodore Davis and Mrs. Clifton Hicks for their prompt and expert typing of this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

Figure | Page

CHAPTER I

INTRODUCTION

Three great patterns dominate the earth and are of tremendous importance to man, the pattern of climate, the pattern of vegetation, and the pattern of soils. When the three patterns are laid one upon another, their boundaries coincide to a remarkable degree because climate is the fundamental dynamic force shaping the other two.

The most obvious difference in appearance between one region and another is found in surface configuration, with such contrasts as those between flat, open plains and rugged mountains or low marsh land and high rocky plateaus. Vegetation also varies; forests for example, contrast sharply with open grass land or desert. Forest areas in turn can be distinguished from one another by the kind of trees that compose the stands. The influence of climate on the growth of plants is a predominant factor affecting their distribution; and the relationship between soil formation on the one hand and vegetation and climate on the other is so close that the pattern displayed by soils maps likewise reflects climatic conditions.[1]

---

[1]Blumen Stock, D.I., C. W. Thornthwaite, Climate and the World Pattern, Climate and Man, U.S.D.A. Year Book of Agriculture 98-127, 1071-1075, 1941.

Both vegetation and soils are considered to be functions (88) of gradients in the environmental factors, climate, parent material, relief, organisms and time.

Soils affect the trees principally through soil air, soil moisture, and plant nutrients. The relationship between the same set of general soil properties and tree growth in widely separated and different regions suggests that the soil-tree relationships are basic and applicable to forest regions.

Foresters as well as Agronomists and those engaged in soil research are interested in appraising the productivity of different classes of soil, since this is important in terms of land use planning, land purchase prices, and management plans. The forester deals with a long-range crop measured in terms of cords, cubic feet, or board feet. He relates yields to slope, exposure, altitude, soil type, soil profile characteristics, soil texture, permeability or friability of soil, general soil moisture relations, or comparative abundance of organic matter. Often as many as four to six site factors may be meaningful in terms of wood production of a given species of tree, and two or three are likely to be of paramount importance.

Scientific forestry, no less than scientific farming (92), must be based on a knowledge of the productive potential of the land. Efficient forest management in many parts of the country today requires site classification of timber land and large expenditures for forest development are fully warranted on good sites. With intensification of forest management has come the need for acre by acre classification of site quality (108).

Forest land in eastern Oklahoma was estimated to 5.5 million acres in 1966. Approximately 4.8 million acres of the total was classified as commercial forest land. Much of this commercial acreage is thought to have considerable potential for the production of shortleaf pine (<u>Pinus echinata</u> Mill) but ther is increasing need to delineate land management classes. Much of eastern and southeastern Oklahoma's pine land is subject to environmental terrain because it is on the fringe of the southern pine range. The area has been subject to frequent drought periods. Careful consideration of site-quality must be made before expensive types of conversion operations can be undertaken on some sites (106).

Estimating land value from soil properties is not new, farmers have been buying land on the basis of taste, feel, and color for many years. As forest land cost has increased, however, the need for better methods of estimating its productive capacity has also increased. As a result much progress has been made in the past 20 years in classifying the productive potential of forest land on the basis of measurable soil properties (72).

The present investigation has been designed to study the utilization of soil properties for site evaluation, while pursuing the following specific objectives:

1) To determine the relationship between soil properties and site index of shorleaf pine (<u>Pinus echinata</u>) in order to estimate the growing capacity of the coastal plain soils of southeastern Oklahoma.

2) To investigate the causes for the distribution of forest tree species in the area studied.

The study area is located in the vicinity of Broken Bow, Oklahoma in McCurtain County, as shown in Figures 1 and 2.

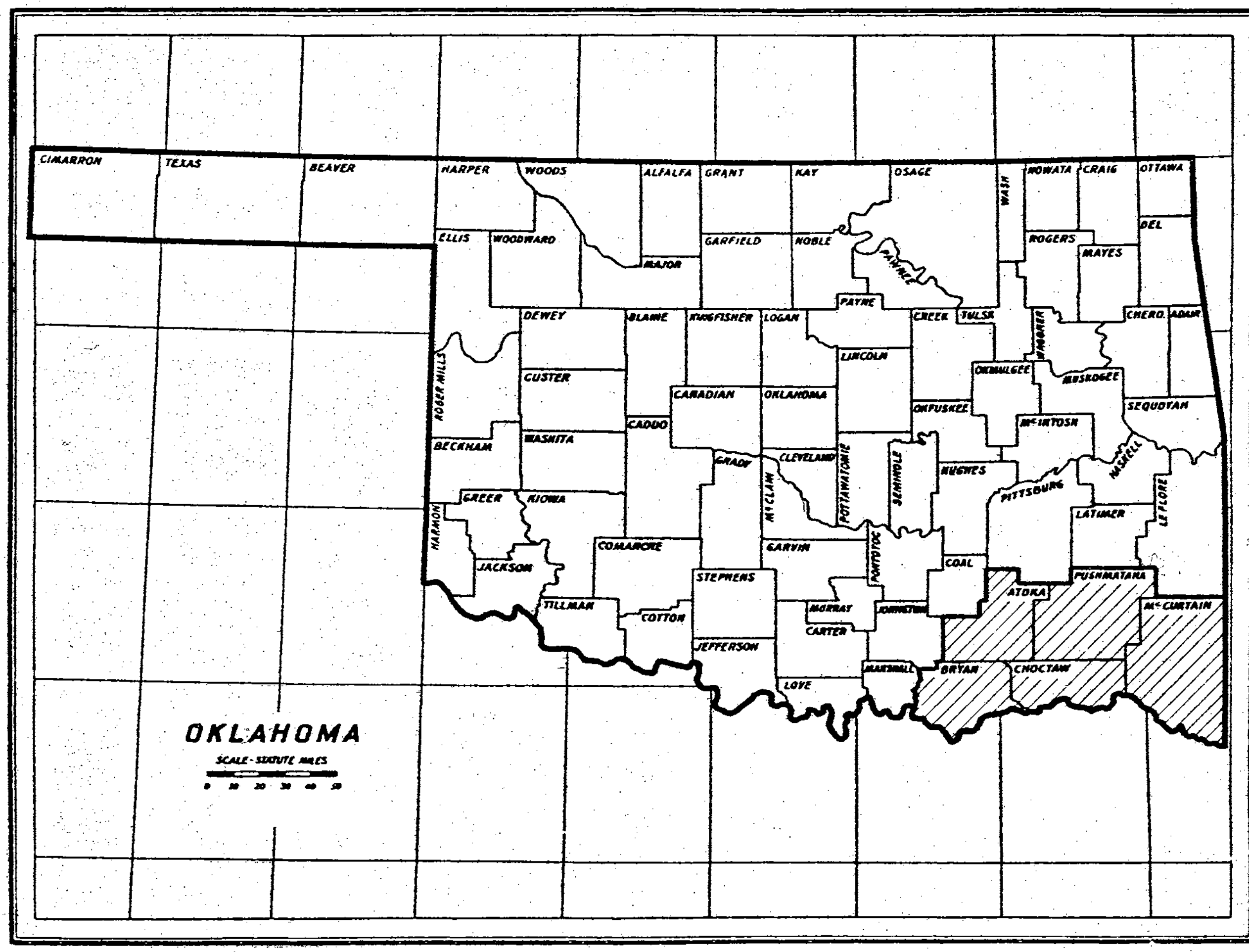


Figure 1. McCurtain and Other Neighbouring Counties.

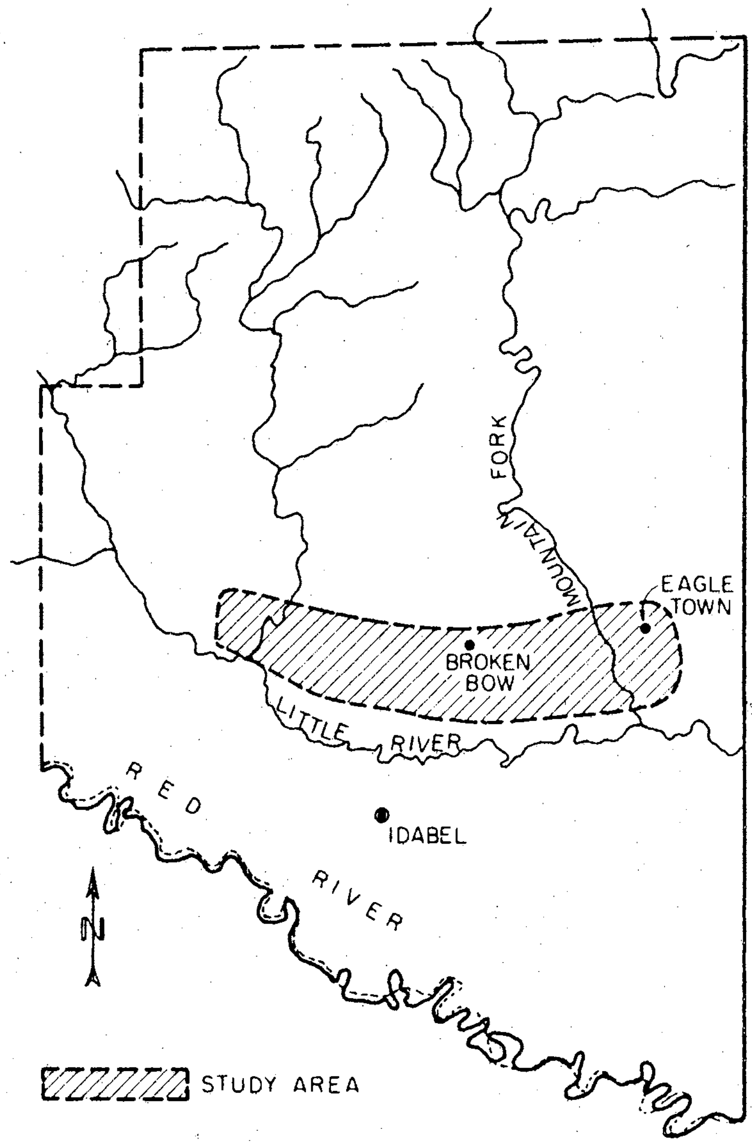


Figure 2. McCurtain County Showing the Study Area.

CHAPTER II

LITERATURE REVIEW

Measure of Forest Growth

Measures of forest growth include annual and periodic volume increase in cords, cubic feet and board feet units per acre. Yield at a given age is also expressed in these units. However, in even aged stands, the total height of trees in the dominant crown canopy is the best measure of soil productivity because it is least affected by stand density of the number of trees per acre at any given age. Stand density is usually expressed as basal area (the sum of the cross sectional areas of the tree stems 4.5 ft. from the ground expressed in square feet/acre), or stocking in milacres (16).

In forestry a site may be defined as an area of land with a characteristic combination of edaphic, topographic, climatic, and biotic factors. Site quality refers to the productive capacity of an area of land for a tree species or a mixture of species. It may be expressed in terms of total height of trees in the dominant crown canopy at an index age (50 years of many species). When site quality is expressed in terms of height of trees at a given age, it is called site index (20).

There are different methods of classifying forest sites.

1) Ground vegetation (plant indicators)
2) Direct method

3) Indirect i.e., soil-site index method

4) Short cut methods.

Ground Vegetation and Plant Indicators

The plant cover (95) if properly interpreted, can be used as an indicator of the climatic conditions under which it is produced, of the soils on which it is grown, and of the practices of grazing or other uses to which it has been subjected.

The plant indicator concept is based on a cause and effect relationship where the effect is taken as a sign of the cause (83). All plants are admittedly a measure of their environment, because plant production and to some extend form of growth is determined by habitat. Any plant species may indicate the nature of its surroundings, yet only a few key species of a given locality are, as a rule, sufficiently restricted by growth conditions to be helpful. According to Sampson (83) Clements stated that the problem of using plant indicator groups is chiefly one of analyzing the factor complex, the habitat and relating the functional and structural response of both plant and community to it. According to him indicators are the dominant species which consitute a climax since they bear the unmistakable impress of the climate and other site factors in the corresponding life form. According to Sampson (83) Braun-Blanquet held that characteristic species are those which are logically specialized and dependent for their existence on specific organism and factors and have high value as indicators. In the species are embodied certain definite adjustments and demands upon the environment with the result the species must be regarded as conspicous indicators of certain conditions of life.

Plant indicators have directly or indirectly received the attention of many capable workers in various parts of the world. As early as 300 B.C. Theophrastus recognized that trees on southern or "sun facing slopes" were different in growth form and in character of their wood from those which occupied the cooler northward slope. According to Kelly (59) the beginning of the Christian era, Columella adds "rushes, reeds, grass, clover, and other plants are known to search for water and sweetness." These plants demonstrate the case for correlation between soil and flora. Similar ideas were held throughout the Middle Ages and were transferred to the new world by those early settlers who were classicists as well as farmers. The scientific aspect, however, developed after plant physiology had its beginning, and noted early workers were King, 1685, Degner, 1729; Buffon, 1742; and Biberg, 1749. The importance of plant indicators was suggested by Linne, 1751; emphasized by Heldenberg, 1754; while Schuow, 1832, classified them by habitats (59). In Medieval times the indicator idea (83) was enlarged and somewhat refined. According to Sampson (83) Hales and others noted that various plant species exhibited different rates of growth on divergent soil types. During the nineteenth century strongly divergent schools of thought relating to soil and plant inter-relations arose. Decandollé, for example refused to admit that the chemical composition of the soil materially influenced plant growth or delimited the plant community, yet he recognized the influence of outside factors on plant distribution. Unger placed great emphasis on the dependence of plants on the chemical nature of the soil. Thurmann supported primarily the theory of the influence of physical properties of the soil and Humboldt contended that growth was primarily related to soil, climate and to latitude. Edmund Ruffin, according to Kelly (59) contrasted the pines and Andropogon of shelly lands with black locust, hackberry, and pawpaw on Rich River margins, and he noted that trees which thrive on one class of soil were seldom found on the other, and even if they were found they were stunted. Hilgard (51) in his work on plant indicators stressed size, form and relative development of a plant association. Shantz (84) used certain plant types as indicators of soil condition for a classification of government lands. Soil acidity influences flora to such an extent that certain plants may be assigned as indicators, a number being listed for each type. Soil acidity perhaps induces variations in plant species (59).

One of the most fascinating facts about tree growth is the manner in which the efficiency of physiological processes within a species varies with changes in environment. For example, white pine is much more efficient than loblolly pine in absorbing water at low soil temperatures. These species differences may play a significant part in restricting species ranges (62).

According to Coile (18) the problem of forest classification immediately brings forward the question of the use of a given classification scheme. Considerable attention has been given to classification of forest land on the basis of ground vegetation since the theory of forest types (site-types) was expounded by Cajander in Finland. The fundamental hypotheses behind the use of forest (site) types are that: 1) The ground vegetation reflects the inherent-quality of site better and with less variation than do forest stands. 2) Forest (site) types are to a high degree independent of the comparison, age, and density of the forest stands that may occupy an area at any given time. These hypotheses are valid except under exceptional conditions of climate, topography and forests.

Early advocates of classigying forest land according to ground vegetation types gave the following points in arguments against using forest stands as a measure of site quality; 1) Differences in results obtained from using different kinds of stand growth measurements, such as height growth, diameter growth and volume growth. 2) Difference in measurements due to difference in initial and subsequent stand density. 3) Differences in past history of stands that influence development (18).

Heimberger (49) made a study of forest (site) types in the Adirondack Mountains of New York. The first breakdown in 22 types recognized was on the basis of geology and climate of the region; and the second breakdown was on the basis of broad forest cover types into softwood, mixed wood types and hardwood types. When one compares the description of Heimberger's forest cover types with associated ground vegetation types it is readily apparent that stand composition is almost perfectly confounded with ground vegetation type. As an example, when the number of species whose litter is high in base (sugar maple, bass wood, and white ash) increased in the stand, richness of the herbaceous cover also increased.

Hesselman according to Coile (18) expressed the point of view that from the stand point of conditions in Sweden, forest (site) types might better be called treatment types rather than quality types. Spurr (91) according to Hodgkins (54), and Toumey and Korstian emphasized the damaging effects of past forest disturbances on the utility of indicator typing after the method of Cajander. In the south, particularly in the southeastern states, past disturbances such as cultivation and persistant fire have been widespread.

Hodgkins (54) pointed out that as one moved southward the proportion of all forest species having narrow ecological tolerance or amplitudes decreased markedly. This was considered to militate effectively against any precise definition of site class by means of one or two indicator species even where forests had not been subjected to intensive disturbances in the past. Nevertheless, it is widely recognized that the plant community, as a whole, will reflect the total effect of the habitat. That it will also reflect past treatments and disturbances is aside from the point. After any disturbance, the process of invasion, competition and reaction is normally produced within a surprisingly short time, and a plant community that is in strict balance with its enviornmental communities can be grouped into societies and associations that in turn reflect the site.

According to Linteau (64) it is the failure of many to recognize the ability of vegetation to grow in orderly societies and associations that causes them to reject the vegetative classification of site. Concentrating on individual species instead of on the plant community, they see only a loose connnection between vegetation and the site.

According to Hodgkins (54) Becking, the Russian and the Zürich-Montpellier Schools of phytosociology recognize the inseparability of the habitat and of the community. Any change in the habitat will be reflected floristically in due time by the community. When a regional vegetation is well known all of the species can be grouped into diagnostic (indicator) groups. In that case it is to find groups of species that will reflect plant communities or associations which in turn will reflect site classes. A given site class will be identified by the presence and abundance of any of the members of its specific group of indicators, and a given indicator may appear in more than one group. The density and composition of the overstory and the stage in plant succession of the entire plant community will make no difference to the outcome if the indicator group is large enough and diverse enough to include all the possible combinations of these factors which might occur on a given site class.

Spurr (91), approached the problem for northeastern spruce and fir stands by setting up an indicator plant spectrum. Groups of indicators were given for each of four site classes. Site classes were arranged, in order, from the driest and most infertile site at the top of the list to the moistest and most fertile site at the bottom. Indicators were checked as present, common or abundant, and the weight of the checks opposite the various indicator groups determined the site classification.

Hodgkins (54) developed a plant indicator site index system for longleaf pine in Alabama, using ground flora, forest floor brush, and some overstory hardwoods, and he assigned a number rating system to reflect their frequency. After making the species inventory, a mean tree site index was calculated for each indicator species by finding the average longleaf site index for all the plots containing the species. In doing this, the site index on any one plot on which the indicator occurred was weighed according to the dominance rating of the species on that plot. For any one indicator species, then the mean longleaf site index for the plots containing that species was as follows:

$$S.I. = \frac{\sum(\text{Tree site index X dominance of the species})}{\sum(\text{All of the dominance values for the species})}$$

The indicator species were then ranked from the lowest to the highest on the basis of their mean longleaf site index values. The examination of individual plot data indicated that this approach would not be productive, however, species ranking was rearranged to represent progression in the moisture regime, from the driest to the wettest sites.

Dryness and Youngberg (38) appraised five brush associations that can be used for site quality estimation of ponderosa pine (Pinus Ponderosa) in the pumice region of central Oregon. They found that each plant association was indicative of a completely different effective environment and was accompanied by changes in the amounts of advanced timber regeneration, timber stand density, supplies of forage available to livestock, and other factors important in forest and range management, even though all five plant groups occurred on the same soil mapping unit. They reported that differences in the forest environment were not often reflected in readily discernible soil characteristics, and the under story vegetation serves as a much more sensitive indicator of changes in the many variables regulating tree growth.

The rate of height-growth of ponderosa pine (Pinus ponderosa) was studied in eastern Washington and northern Idaho by Daubenmire (28). When the data was grouped according to habitats based on plant associations that were climax for the sites, good correlations were obtained. Thus, vegetation whether climax or not, serves as a rapid and useful means of predicting in advance the probably growth rate of the pine. Susceptibility of the tree to infection by (Arcenthobium) was also correlated with these vegetative indicators. A key was provided for the identification of the seven habitat types supporting natural stands of ponderosa pine in the region studied. Habitat types were divided into four unequal groups on the basis of rate of height-growth of ponderosa pine:

I. Best potentiality

1) Abies grandis/Pachistima myrsinites h.t.

II. Good Potentiality

1) Pseudotsuga menziesii/Physocarpus malvaceus h.t.

2) Pinus ponderosa/Physocarpus malvaceus h.t.

3) Pinus ponderosa/Symphoricarpos albus h.t.

III. Fair potentiality

1) Pseudotsuga menziesii/calamagrostis rubescens h.t.

IV. Low potentiality

1) Pinus ponderosa/Purshia tridentata h.t.

2) Pinus ponderosa/Agropyron spicatum h.t.

In New Zeland according to Pegg (76) Ure successfully used the height and composition of the ground vegetation to predict the site index of exotic species (P. radiata D. Don and Pseudotsuga taxifolia Britt.)

Silker (86) developed an ecological ladder using under story and overstory hardwoods for pine site evaluation for East Texas and Southeastern Oklahoma. He proposed the use of hardwoods as a primary indicator rather than ground flora for the following reasons:

1) Soil moisture is usually the most important factor controlling plant adaption to a site, when other minimums are met.

2) The most critical period for soil moisture demand appears to be in the early seedling stage.

3) Groups of hardwoods are practical, natural, statistical

expressions of total site factors affecting physiological minimums or maximums; or, species frequency and commercial bole length and form are mirror images of what the total environment may express.

4) Hardwoods used to assay a site should be common species that will occur throughout broad geologic, physiographic, and climatic provinces.

5) Hardwoods should be reliable indicators because; (a) most are climax plants, (b) they are less subject to rapid change than ground flora that are readily affected by fire, cutting and grazing, (c) they usually reflect an age or minimum expression of 50 to 150+ years; and they are usually conspicuous and readily identified by foresters and others.

He also developed a "wedge-chart" for Coastal Plain soils to illustrate the order of plant group changes with increasing or decreasing water reservoir capacity. This was developed to suggest the correlation between soil profile conditions, soil moisture availability, and plant frequency expressions. He also related the above potential silvicultural tool investments and the implied cost return ratios for given land classes.

The use of ground vegetation indicators did not show any promise, in East Queensland (82) partly because of the difficulty in determining the original composition with any accuracy. The degree of persistence under varying canopy densities was not constant for all species. The use of ground vegetation in classification was restricted to <u>Banksia robur</u> Cav. and <u>Hakea gibbosa</u> Cav., which were indicators of wet sites. Similarly heavy heath undergrowth or <u>Banksia serratifolia</u> knight indicates a ground water padzol.

The regression approach has been used much more than that involving ground vegetation probably because the soil variables measured are reasonably constant whereas the ground vegetation is likely to be disturbed by management practices (76).

Use of indicator types in the classification of plantable open-land, as an aid in selection of proper species of trees for planting, requires a fundamentally different method of approach than the one ordinarily used in the application of forest (site) type classification. Within a given climatic region dry sites will have a characteristically different ground vegetation than wet sites. However, such large differences in site can as readily be identified with topography or with easily identified soil characteristics as with ground vegetation type in most cases. Certain ground vegetation types are associated with relatively fertile forest soil conditions, whereas other types of ground vegetation are associated with relatively unfertile conditions. As such, the ground vegetation types are treatment types and are not directly related to the inherent quality of a site or presence or absence of certain species of plants. The ground vegetation under stands of timber may afford an indication of the intensity of composition between members of the forest community for soil moisture, nutrients, and light; in such instances, ground vegetation types are indicators of treatemnt or conditions in the upper part of the soil mass and not indicators of the basic and inherent growth capacity of land (18).

In general, if a classification of forest sites is desired, it should be based upon fundamental and permanent features of site, namely soil and relative topographic position of the soil mass.

Characteristic of the soil mass, the sub-stratum, and topography, which are related to the availability and total volume of water present for use by forests, should be the primary criteria in any classification of site. Markedly different chemical characteristics of soil may be a secondary criteria of classification (18).

Site Index

Site index (S.I.) is the measure of all effective factors of site, climatic, biotic, physiographic, as well as edaphic. By definition, it is the average height of dominant and codominant trees at 50 years of age from established curves. Site index may be estimated for trees of any age.

Because any one of the above mentioned factors of site may be limiting, soil-site index relationships are difficult to ascertain. Other factors contributing to soil index errors include growth-mathematical relationships which result in errors of unknown magnitude regarding the form of the curve and distrance between curves. With younger stands on better sites than those supporting old growth, average site index curves will be warped upwards at younger ages and downward at older ages. Conversely, on poorer sites, the opposite may occur. Genetically-inherited characteristics of trees may also influence the apparent site index and appear to confound the factors of site.

Site index alone is, at best, a measure of site-potential for a specific geographic or genetic strain of a species. Actual productivity of land should couple site index with measurements of volume, basal area or cubic feet of growth. Use of basal area and growth, likewise, is fallible since very little forest land has optimum stocking. It is for all of the reasons outlined that we turn to the soil for helpful information in indicating site potential (100).

Direct Measurement

Tree site index method is probably the most common tool used to evaluate site quality. It may be expressed in terms of total height of trees of the dominant crown canopy at an index age (50 years for many species). When site quality is expressed in terms of height of trees at a given age, it is called site index. Some workers have criticized the use of site index as a measure of productivity for a number of reasons such as errors made in extra polation, and in the site index curve themselves, effect of weather during the early years after planting or natural regeneration, variation in growth patterns between races and also between genotypes within races. In spite of these objections site index remains in constant use as a measure of site productivity because of its general independence of stocking (76).

For this method plots containing 100 to 300 trees have to be established. Diameter breast height of the average dominant tree is determined using the basal area method. Furthermore, a curve of total height over diameter breast height must be constructed. Six or more dominant trees must be bored to obtain an estimate of stand age. Data in conjunction with standard site index curves are then used to arrive at the site index value (58).

Indirect or Soil-Site Method and Short Cut Methods

The soil-site method of evaluating the growth potential of forest land has gained in use the past decade and replaces to a rather large extent, the older tree-site index method. This shift in use of procedure is to be expected when one considers the difference in the time and effort needed to make the two kinds of evaluations.

The principal use for the indirect or soil method was originally proposed for land not supporting stands of suitable age, stocking or species for direct site determination; examples of this are cut-over or abandoned fields, very young stands, uneven-aged or partially-stocked stands, or even land which presently supports other tree species.

In the case of soil-site evaluation all that is usually needed is several soil borings around the sampling site and some evaluations of soil texture, consistency, depths of horizons and subsoil properties that are employed in the original work. However, field tests with the soil method of estimating site potential show that it is just as precise as the direct method and requires only about 1/3rd of the time needed to measure total height and ages accurately and then obtain site index for curves or tables.

Many who use the direct method of site determination do not fully recognize the sources and magnitude of errors or inaccuracies involved therein. Common inaccuracies in measurement of total heights of trees with any Abney level are due to : (21)

1) Base line not properly measured or not as long or longer than the height of the tree.
2) Abney is not in adjustment.
3) Tip of tree and its base are difficult to see because of under story or density of the stand.
4) Total age of a tree cannot be obtained accurately because

a) Tree centre is not encountered

b) Ring counts may be confused by false rings when a core is taken with an increment borer or

c) when age is taken at 4.5 ft the time required for the tree to reach that height may be estimated.

Tests of the relation between site index as estimated for the soil and tree site index for stands 10-30 years of age have indicated that site curves for loblolly and shortleaf pines give over estimates for young stand (21).

All that soil-site measurements provide are estimates of what the equivalent tree-site index should be. These estimates certainly are subject to sampling errors, errors arising from the lack of perfect correlation between soil and tree site indices, and to human errors. The first two of these sources introduce at least some error into any estimate but are not as critical as the third. Before an effective job of soil-site evaluation can be done the evaluator must be well trained and experienced.

Short cut method procedures are quite simple. One of these requires the establishment of a 1/5th acre plot at the sampling point. Within this plot three to six of the largest trees in terms of d.b.h. located and ranked by size from largest to samllest. The evidence obtained in the course of the statistical analysis of data shows that a strict ranking is not necessary (19).

One method of providing information more quickly and conveniently is to relate the site index of several species to one another (species comparison). If the site index can be determined for one species, either from tree or by soil-site methods, the site indices of the other species can also be estimated (37).

According to Doolittle (37) one of the preliminary results of soil-site research in the western white pine type is reported by Copeland (26) where the relationship of the site index (S.I.) of western white pine (Pinus monticola Dougl) is compared with the side indices of western larch (Larix occidentalis Nutt.), Douglas fir (Pseudotsuga menziesii (Mirb) Franco) and grand fir (Abies grandis (Dougl.) Lindl.).

The Southeastern Forest experiment stations, annual report for 1954 included a chart relating to the site indices of several species in the southern Appalachians. Site indices of 10 species common in the southern Appalachian Region were correlated by Doolittle (38). The relationships were shown in the following regression equations:

1) Scarlet, black, northern red, and chestnut oak = 6.251 + 11.001 (shortleaf and pitch pine)
2) Scarlet, black, northern red, and chestnut oak = 27.642 + 0.586 (yellow poplar)
3) White oak = 0.929 (Scarlet, black, northern red, and chestnut oak) - 1.088
4) White pine = 34.968 + 0.630 (yellow poplar)
5) Yellow poplar = 1.540 (shortleaf and pitch pine) - 24.629
6) White pine = 13,900 + 1.029 (shortleaf and pitch pine).
7) Virginia pine = 12.746 + 0.932 (shortleaf and pitch pine).

It was suggested that those who wish to use the soil-site method for estimating land quality would benefit by testing both methods of tree vs soil measurements (22, 23).

Principal Soil Properties Related to Forest Growth

The productivity of soil for forest growth is conditioned by the quantity and quality of growing space for tree roots. Soil properties that may be classed under these two categories may have direct effects on growth, both direct and indirect effects (interaction), or only indirect effects.

The soil factors are (20):

(a) Depth of surface soil (A horizon), depth to least permeable layer, or depth to mottling. These measures of quantity of growing space imply effective root depth for trees (small roots). The relationship of growth to these measurements is generally curvilinear. The net effects of increments of depth are great when depth is low. The effects of increasing depth on growth decrease beyond a certain point.

(b) Total depth of soil, and soil material functions as a measure of quantity of growing space in the case of immature or poorly differentiated soil profiles.

(c) Physical nature of the sub soil, least permeable layer or substratum as it influences water movement, water availability to root aeration and mechanical hindrance to root. This factor may be exhibited with either "a" or "b" above with significant effects or interactions with tree growth. Physical properties of the sub soil that may be directly correlated with forest growth include texture, pore space distribution, imbibitional water values, water holding capacity, and changes of volume with moisture content (shrinkage and swelling).

(d) Physical properties of the surface soil, notably pore space distribution and texture may under certain conditions influence water infiltration and storage which is especially important to tree growth in semi-arid regions or when precipitation is erratic.

(e) Organic matter in the form of either incorporated or unincorporated humus influences the moisture regime of soils as well as their structure and porosity to air. It serves as a direct source of energy for soil organisms and as a reservoir of nitrogen and other essential plant nutrients. In excessive amounts of organic matter may reflect poor drainage and be associated with low productivity.

(f) Chemical characteristics involving nutrient supply may be a limiting factor in forest growth on deep, excessively drained silicious sands in humid climates. In such cases, the fertility factor is usually confounded with adverse physical soil properties and low water table.

Factors other than soil may also affect tree growth, such as: (20)

(a) Climate and length of day: These two factors are confounded for tree species that have a wide latitudinal range. The relatively rapid growth of certain species of trees in northern latitudes can be attributed in part to long days during the frostfree period which offsets the short growing season. Climate, expressed as inches of rainfall, number of frost free days per year, or defined indriectly by latitude and longitude, has been found to be correlated with growth of forests independent of soil factors.

(b) Aspect and Exposure: In regions or areas of marked relief, aspect of land (compass direction that a slope faces), and exposure (susceptibility of land surface to be drying winds) greatly affect the local climate, as it is characterized by precipitation and temperature, wind movement (direction and rate), and evaporation. Northerly facing slopes (NW, N, and NE) are cooler and more moist than southerly facing slopes.

(c) Topography and water table. The relating of topographic position of land to forest productivity is primarily indirect. Relative topographic position and distance from the soil surface to the water table both influence water supply to the soil and tree roots. This moisture supply, modified by climate and soil properties may range from excessive to insufficient.

(d) Surface Geology: The permeability to water of rocks, rock formation, or unconsolidated geologic material may influence land productivity independent of the soil if the latter is shallow (20).

In forestry, broadly speaking, soil moisture occupies a position of prime importance as a controllable factor in growth. Soil moisture is often one of the most critical factors of the edaphic complex.

Water is important as a constituent of living protoplasm, a reagent in chemical reactions, a medium in which reaction occurs, and a solvent. It is also very important in the maintenance of leaf turgidity. Wilted or partially wilted leaves are ineffective photosynthetic mechanisms. Claims have been made for many years that all the soil moisture in the range from field capacity to wilting percentage was equally available to trees. There are many observations, however which indicate that physiological processes are profoundly influenced by drying of the soil and that very real effects on metabolism and growth of plants are manifested some time before the soil reaches the wilting percentage (62).

In coarse textured soils the moisture tension changes are relatively small from field capacity almost down to the wilting percentage. At the latter point the tension changes rather precipitously to permanent wilting percentage. Moisture tension, moisture content curves for finer-textural grades of soils do not exhibit such a sharp break and indicate that water is withheld from plants with appreciably greater energy over the lower part of the available range than the upper part. In terms of energy relationships the water in such soils becomes gradually less available as the moisture content decreases from field capacity to wilting percentage (62).

When the effects of light intensity on photosynthetic efficiency of pine and hardwood seedlings were studied it was found that photosynthesis of pine increased progressively with light intensity up to the highest light intensities. Hardwoods however, reached a maximum at one-third or less of full sunlight. In addition, it was shown that the hardwood had an inherent capacity for greater quantititive production of photosynthate. Furthermore, with decreasing soil moisture content the photosynthetic rate of pine decreased at a higher moisture content than did the rate of the hardwoods (62).

Wilting coefficient can be obtained by dividing the "moisture equivalent" (M.E.) by the factor 1.84. This common factor may not be applicable to all soils. The moisture equivalent is the best single value determination for interpreting the moisture properties of soils (99).

The results reported by Peele and Beale (75) showed that the field capacities of South Carolina soils can be predicted from the moisture equivalent by the equation:

$$Y = 2.62 + 0.865\ X$$

in which

Y = the field capacity

X = the moisture equivalent.

The regression of wilting percentages by the plant method on percent of moisture, when soil is subjected to 15 atmosphere pressure over a cellophane membrane was expressed by the equation:

$$Y = 0.99 + 0.97\ X$$

Y = wilting percentage

X = % of moisture at 15 atmosphere.

Retention storage of water is affected by texture. Lassen et al (63) pointed out that fine sand has a retention storage capacity of 0.5" in depth of water per foot of soil. For clay this capacity was 4.5". Organic matter increased the storage by adding to the surface area in the soil.

On the coastal plain soils it is often either a question of having not enough water or too much. Lack of water may be due to light impervious clay or hardpan near the surface or excessive by drained sands (19).

Forest growth is better on grayling fine sand than on grayling medium sand. Moisture release curves constructed for samples from these two types of soils and for pure sand fractions separated from samples showed that fine sand retained 10% water and the medium sand soil retained 7% water by weight at field capacity; while both soils retained equal amounts, 2.5% of water, at 15 atm tension. Of the pure sand fractions, very fine sand retained substantially more water at low tensions than did the larger fractions amounting to more than five times the amount of readily available water. The fine sand soil type contained six times the amount of very fine sand fraction than did the medium sand soil type, 12% vs. 2% by weight. Thus, much of the difference in water retention between the two examples is attributed to the very fine sand fraction, probably also accounting for much of the difference in tree growth (109).

Soil moisture may also significantly affect the rate and suite of cations exchanged from the soil to the plant roots, since plant growth is affected by the availability of cations as well as by internal water requirements, the amount of cations exchanged increased sharply as the soil moisture increased. The increase in cation exchange at saturation, when based upon that exchanged at the moisture equivalent, was seven fold for Lakeland, five for Rustan, two for Richland, three for Crowley, but only a 0.2 fold increase for Sharkey, Houston, and Gila series. The percentage decrease in cation exchange at the wilting percentage, when based upon the exchange at the moisture equivalent was 50, 65, 85 and 72 for Lakeland, Rustan, Richland, and Crowley, respectively, but only 14, 19 and 25% for Sharkey, Houston, and Gila respectively. The percentage of calcium and magnesium increased in the suite of cations, while that of potassium and sodium decreased correspondingly as the soil moisture increased. The Ca:K ratio increased from 60 to 266 over the moisture range, wilting percentage to saturation for the Houston series, 10 to 60 for the Richland series, but only 7 to 10 for the Lakeland series. The cation exchange moisture relationships were explained on the basis of the relative abundance and continuity of the water films within the pore system of the soil that may effectively serve as a medium for the diffusion of cations through the soil (11).

Total site evaluation is an attempt to classify all the variables that affect site and plant species requirements. Hodgkins (55) adds "when one understands that a given site index for a given species may occur on more than one site, he has taken a long step towards understanding the concept of total site classification. In total site classification, site index is relegated to the status of one of many attributes of the site, and is no longer the basis for classification. This does not constitute a de-emphasis of the site index, but rather a recognition that other attributes of the site are also important. The use of total site classification implies that research on forestland and management of forestland, will be done with due regard for all of the significant attributes of the various site classes. Thus total site classification becomes most fundamental to an advanced and intensive brand of forestry."

Studies of the characteristics of native vegetation and of soils in relation to their environment have developed more or less concurrently in this country. The study of vegetation has been dominated to a considerable degree by the philosophy of Clements (88) on the existance of discrete plant communities and the convergence of plant succession to a well defined climax type in response to climate. Others modified this concept somewhat by distinguishing among climate, edaphic, topographic, biotic and other factors resulting in the so called "polyclimax concept as opposed to the monoclimax of Clements." The difference between the two concepts is perhaps mostly a difference in semantics, since Clements essentially accounted for these deviations from climatic climax with his elaborate system of preclimax, post climax, disclimax types, etc. (103).

The study of soil genesis and morphology developed in a manner similar to that of the study of structure, succession and classification in plant ecology. Study of soil classification initially began in Russia in the late 19th century with the work of Dokuchoev (93). He emphasized climate as perhaps the major factor influencing soil development although he recognized the effects of other factors such as parent material, topography and vegetation. The concept of zonal, azonal and intrazonal soil had reference to variation in soil development with respect to general climate much as Clements climax, preclimax and post climax for vegatation (31). It is perhaps significant that the work of both clements and Dokuchoev started in the chernozem prairie regions of the U.S.A. and Russia.

The basic idea and approach to the study of soil genesis and classification were considerably clarified by the work of Jenny (1941). He theorized that soil is functionally related to five independent soil forming factors by the following equation:

$$s = f\ (cl,\ r,\ pr,\ o,\ t)$$

where

s = soil properties

cl = the overall climate

p = initial state of soil system i.e. parent material at time zero

o = organic matter or the biotic factor

t = time

y = topographic effects

The five factors may interact with each other but are independent in the sense that one could be varied without changing the others. While the concept was not entirely a new one (27), it did provide a concise basis for quantitive study of soil development by Jenny's own admission the equation will probably never be completely solved.

Jenny's equation implies the continuum concept with respect to soils, although he does not use the term continuum explicitly (58). He and others have noted that vegetation could be expressed in a similar way i.e. $V = f\ (cl,\ r,\ p,\ o,\ t)$ and here used the concept in studying the relationship of vegetation and soils in space and time. The arbitrary nature of soil classification seems to be accepted (90).

The correlation procedure is also represented by the functional approach to the study of both soils and vegetation using the equation S or $V = f\ (cl,\ r,\ p,\ o,\ t)$ already defined, Jenny (57) Crocker (27), Major (70). These authors advocated the studying of the effect of one independent variable on the dependent (S or V) or holding all other independent variables constant and allowing the one of interest to vary, thus defining a functional relationship or simple regression between the dependent and independent variables. Klemedsen (61) carried out a study of this sort by holding all factors constant except slope and aspect and thereby defining a topographic. The major difficulty in this approach is the limited occurence of situations which allow several factors to be held constant or nearly so (57).

Major (70) states that since soils and vegetation develop in response to the same independent variables it may be concluded that there are no universal correlations between their properties, that one is not determined by the other, but that they develop consistently. In response to this statement Crocker (27) maintains, quite logically it seems that if they both develop in response to the same factors these obviously must be correlated correlations between them, but no universal correlation would be expected due to great possibilities for variation in factors and time.

Regression methods are those used to determine the best functional relation among the variables while correlation methods are used to measure the degree to which the different variables are associated. The resulting measure of correlation is usually called correlation coefficient.

The conditions for validity of regression analysis are best expressed in terms of the model:

$$Y = \alpha + Bx + \epsilon$$

where

Y = dependent variable

X = deviation X-x

α, B = are parameters

ϵ = the variable part of Y

In soil-site index regression studies linearity, if not already present, is achieved by means of mathematically transforming the curvilinear regression to a linear form. The condition of random and independent discrepancies is not met, since this can be achieved completely only through the replication and randomization procedures of the careful experimental design (55). The soil-site index regressions studies have not employed experimental design of course, but have depended upon simple field surveys for their data. Published soil-site index regressions studies revealed that the investigators involved have apparently been learning by experience of these hazards in the regression techniques. Earlier studies did cover large and ecologically complex areas, but later studies have been based upon samller and more nearly uniform areas.

The use of simple, partial or multiple correlations coefficients to express the relationship between soils and vegetation has been advocated or used by many researchers as for example, Cook (1960), Steward and Keller (1936), Greig Smith (1964), Median (1960), Geist (1966) and Box (1961) (36).

The necessity of holding all independent variables constant except one can be avoided to some extent by the use of multiple regression. In this method the effects of several variables and the covariance between them can be taken into account simultaneously (36). This technique has been used to predict the growth of plants from measurement of site characteristics (Coile, 1938, Median, 1960, Clalry, 1966, and Geist, 1966).

Stepwise multiple regression analysis is useful in determining the amount of variation that can be accounted for a set of independent variables and the relative importance of these variables. However, caution must be exercised in interpreting the equation. Major (1966) pointed out that equations are only of predictive value. They cannot be used with safety on data of a different nature than the original data from which they are derived; nor can biological conclusions be derived from either magnitude or signs of individual coefficients in the equation.

Foresters can profitably study experiences in crop responses in agriculture to obtain leads on factors that might be meaningful in terms of tree growth and their statistical and graphical means of handling the data.

Bray (8) in discussing correlation of crop responses to fertilizer additions, proposes a theoretical concept for a situation where two different nutrient elements are inadequate. He suggests that yield, expressed percentage-wise, will be the product of the sufficiency of A times the sufficiency of B. He suggests the concept may work for available potassium, phosphorus, and magnesium. As regards nitrogen, he suggests plant-tissue tests are probably the solution. He believes the "yield concept would not apply to nitrate nitrogen and water;" and he doubts whether general correlations can be found between exchangeable calcium and yield in a "normal, carbonate-free soil. Bray's yield concept, as a product of sufficiency of several specific nutrients, might apply to growth or yield in certain forest species, as long as the unit of yield was in terms of cords, board feet, or cubic feet, but it is almost a foregone conclusion that it would not apply to site index. The first three are volumetric expressions based on three dimensions. The last (site index) is a one-dimensional expression based on height of the average dominant and codominant trees in feet, and a product of sufficiency approach to the nutrient problem would no doubt produce excessive penalities against even moderate deficiencies of phosphorus, potassium, magnesium and calcium.

Smith and Cook (92) have obtained high correlation of percentage of full yield of wheat and available phosphorus as determined by the Bray absorbed phosphorus method, using a 1:50 extractive ratio. Correlation coefficients "r" ranged from 0.454 for Spurway reserve phosphorus test, to 0.534 for Spurway's test for active phosphorus, to 0.660 for Bray absorbed phosphorus test. Ulrich (98) has elaborated Bray's concept. He refers to a critical zone as a separating line between zones of luxury consumption and poverty adjustment. Foliar analysis is cited as a means of detecting the relative nutritional status of certain plants, especially in orange, cherry, and apple.

Close correlations of specific soil tests with each other are apparently much easier to establish than is the case of crop yield and soil tests. At least the former appears to yield considerably higher correlation coefficients. Chandler (14) shows a very close correlation between exchange capacity plotted over loss on ignition the former being about twice the latter when both are expressed as percents. Lunt (67) showed good correlation of volume weight and percent of organic matter.

Coile (21) demonstrated the well-known correlation of percent of silt and clay and moisture equivalent. According to Stoeckeler (92), Kellogg found there is a close correlation of base exchange capacity of specific horizons (A_2 and B_2) with the percent of clay in a soil in the Miami series.

Southern Pines

The rapid development of forest management in the southern United States during the past three decades has marked an important milestone

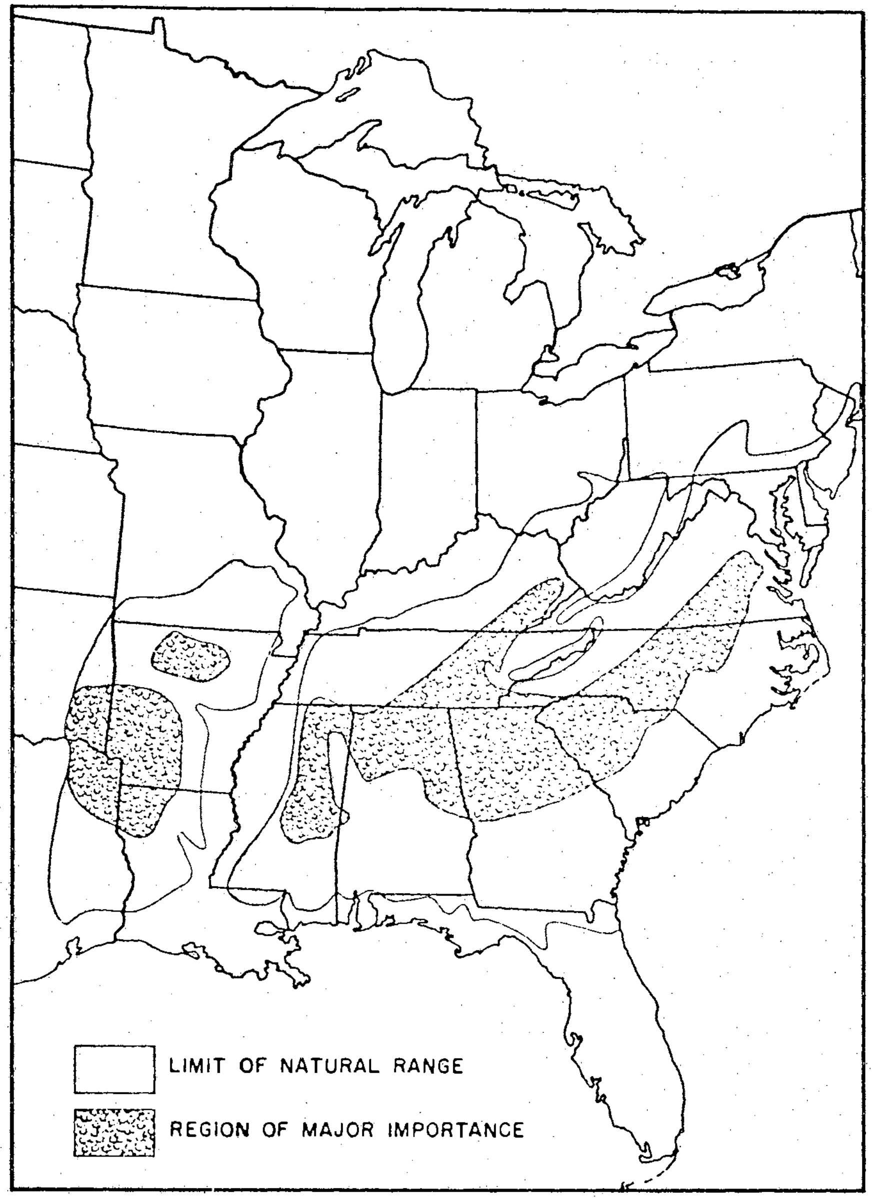


Figure 3. Range of Shortleaf Pine, Showing the Limit of its Natural Range and its Region of Major Importance.

Source (46)

in American forestry. Much of this progress has been directed towards the southern pines. A series of regression studies have been made throughout the southeast for the purpose of relating height growth and site indices to environmental factors for the four major species of southern pines:

1. Long leaf — *Pinus palustris* Mill
2. Slash — *Pinus elliottii* Engelm
3. Loblolly — *Pinus taeda* L.
4. Shortleaf — *Pinus echinata* Mill

Shortleaf pine, is one of the four pine species commonly referred to as southern yellow pine. It comprises about 1/4 of the total volume of pine timber in the south, which is shown in Figure 3. Its botanical range extends from New Jersey to Texas and Oklahoma, in some 22 states. Shortleaf pine is commercially important in the Piedmont region of Virginia, North Carolina, South Carolina, and Georgia; in the northern portions of Alabama and Mississippi; along the western foothills of the Appalachian Mountains in Tennessee, Kentucky and West Virginia; and in eastern Texas; southeastern Oklahoma, and northwestern Louisiana. In recent years, shortleaf pine has become an important planting species in southern Indiana, Illinois and Missouri (46).

In the United States where most of the site index correlation studies have been made, the emphasis has been on the physical properties of the soil profile, rather than the chemical (76). Soil properties which may be significantly correlated with forest growth in one region may not be significant in another region because of differences, in tree species, climate, length of growing season, length of day or action of other limiting factors (17).

In a study of soils with highly differentiated profiles, derived from sedimentary rocks of triassic age, in the lower Piedmont plateau of North Carolina, Coile (20) found that the site-index of shortleaf pine was related to the texture and depth of the soil profile. Higher site indices were found where the texture vs. depth index of the soil was on the average between 4 and 6. On the average, this would represent a soil with 13" of A horizon and a B horizon containing 60% silt and clay. Site index of shortleaf pine on these soils was 80 feet.

Turner (96) studies the growth of loblolly and shortleaf pines as influenced by soil properties on 222 plots in 22 soil types of the coastal plain region of Southern Arkansas. However, soil measurements were confined to thickness of soil horizons in the profile, mechanical composition and acidity. The various site classes were classified qualitatively as follows:

i. Superior Sites: S. I. 96 to 115 located in flood plains of small streams. Fine sandy loam or silt loam soils without marked profile development and with good internal drainage.

ii. Intermediate Sites. S. I. 76 to 95. Distinct profile development surfaces soil shallower than for superior sites. Some series are imperfectly drained.

iii. Inferior sites. S. I. 56 to 75. Shallow surface soil associated with previous accelerated erosion on slopes from 5 to 20% and shallow surface soils on flat topography. Both of the above conditions of shallow surface soil were ordinarily associated with sub-soil having a relatively high clay content. Some soil profile with excessive internal drainage belong to this group.

Frequent fires in loblolly and shortleaf pine stands of the Piedmont plateau reduce height growth of the trees (92). On the basis of soil and true measurements an unburned versus frequently burned stands of loblolly and shortleaf pines in the Carolinas and Georgia, it was found that burning lowered the apparent site index. Statistical results showed that the effects of depth of the surface soil (x_1) and physical properties of the sub-soil (x_9) were not influenced by geographic location or burning, but the equation constant or level of the regression was significantly reduced by recurrent fires:

$$S.I._L \text{ (burned)} = 74.50 \pm 3.1 - \frac{75}{x_1} - 1.39x_9$$

$$S.I._S \text{ (burned)} = (57.12 \pm 3.1) - 45 - 1.00x_9$$

where

L = Loblolly pine

S = Shortleaf pine

x_1 = depth of surface soil

x_9 = physical properties of sub soil

An intensive study was made by Coile (20) with regard to the relation between soil features and the site index of loblolly and shortleaf pines in the lower Piedmont plateau of North Carolina. The study consisted of 53 plots in loblolly pine, 75 plots in shortleaf pine and 23 plots in mixed stands of the two species. Nine soil variables were tested and the data was first classified and analyzed by three topographic position classes (1) ridges, (2) middle slopes and (3) lower slopes and bottoms. Four soil variables, all significant at the 1% level were found to be correlated with the site index and the following regression equations were developed:

$$S. I._L = 38.71 - \frac{71}{x_1} + 40.27\, x_2 - 6.58x_4 - 1.17x_9$$

$$S. I._S = 80.67 - \frac{44}{x_1} - 2.50x_2 - 1.08 \quad - 1.19x_9$$

Although soil variables x_2 and x_4 were statistically significant estimates of site index using the above equations did not differ appreciably from the following equations:

$$S.I._L = 100.04 - \frac{75}{x_1} - 1.39\, x_9$$

$$S.I._S = 77.32 - \frac{45}{x_1} - 1.00\, x_9$$

where

$S.I._L$ = site index of loblolly pine

$S.I._S$ = site index of shortleaf pine

x_1 = Thickness of the A horizon

x_2 = Ratio of silt + clay to the M.E. of the B horizon.

x_4 = Second power of x_2 $(x_2)^2$

x_9 = I.W. value of the B horizon.

On the basis of stand and soil observations in 217 areas of even aged loblolly pine over 20 years of age in the Coastal Plain regions of South Carolina, Georgia, Florida and Alabama, Metz (20) found the following soil and topographic features to be significantly correlated with height growth of the loblolly pine:

1. Product of depth of A horizon and I. W. value of the B horizon.

2. Product of depth of A horizon and the silt content of the B horizon.

3. Product of depth of A horizon and the clay content of the B horizon.

4. Degree of surface drainage that is well, imperfectly, or poorly drained.

The net effect of increasing the imbititional water value, silt content and depth to B horizon was positive with respect to height growth, Height growth was increased with decreasing surface drainage.

$$\log(\text{total height}) = c - 6.97/\text{age} + (0.000420\ (\text{I.W. of B}) + 0.000021\ (\text{silt of B}) - 0.000077\ (\text{clay of B})\ (\text{depth of A})$$

where c = 2.0605 for well drained soil

c = 2.0729 for imperfectly drained soil

c = 2.0887 for poorly drained soil

According to Coile (20) Gaiser reported the relationship between site index of loblolly pine and soil characteristics and drainage of the Coastal Plain region of Virginia, North Carolina and the N. E. part of South Carolina. The following variables were all significant at the 1% level and were found to affect the site index:

1. Depth in inches of soil from the surface to the least permeable sub layers.

2. I. W. water value of the sub soil.

The equations were:

$$\log(\text{S.I.}) - 1.692 + 0.110\ (\log \text{depth} + \log \text{I.W.})$$ for good drained soil

$$\log(\text{S.I.}) = 1.715 + 0.110\ (\log \text{depth} + \log \text{I.W.})$$ for poorly drained soil with plastic sub soils.

$$\log(\text{S.I.}) = 1.983 - \frac{0.772}{\text{depth}}$$ poorly drained soil with friable sub soil.

According to Coile (20) the effect of soil properties and other factors on the growth of natural slash pine stands over 20 years of age was studied by Knudsen. Soil and stand measurements were made on 231 plots in South Carolina, Georgia, Florida and Alabama. Twenty independent variables were tested as to their effects on height growth. The soil variables were imbibition water values of the B horizon, moisture equivalent of the B horizon, depth of A horizon, mechanical composition of the A and B horizon, acidity (pH of the A_2

and B horizons) and depth to mottlings. The only soil property found to be correlated with site index of slash pine was the nature property of the sub soil as reflected in its imbibition water value as follows:

$$\log (S.I.) = 1.89153 + 0.0024423 \; (I.W. + 0.0071144 \; (T) \;)$$

where I.W. = imbibitional water value of the B horizon

T. = +1 for round trees -1 for turpentined trees.

The height growth of long leaf pine (P. <u>palustri</u> Mill) as influenced by soil properties and other factors was studied by Ralston (77). Soil and mensurational data were analyzed from 303 plots in well-stocked even aged stands of this type in the Carolinas, Georgia and Florida. The equation for estimating height growth of 115 plots on imperfectly and poorly drained soil was:

$$\log (\text{total height}) = 1.886 - 11.20 \; x_1 + 136.0 \; x_1^2 + 0.00244 \; x_2 + 0.00191 \; x_3 + 0.000384 \; x_4 - 0.00072 \; x_5$$

where $x_1 = \frac{1}{\text{age}}$

x_2 = moisture equivalent of the sub soil in percent

x_3 = depth in mottling in inches

x_4 = stand density in number of stocked milacres

x_5 = +1 for plots in the Carolina and -1 for Georgia and Florida

Analysis of data from 188 plots on well-drained soils using the same independent variables that were tested for the imperfectly and poorly drained soils with the exception of depth to mottling resulted in the following growth equation:

$$\log\text{ (total height)} = 1.915 - 11.11\ x_1 + 136.0\ x_1^2 + 0.00118\ x_2$$

$$+ 0.000374\ x_3 - 0.014\ x_4 - 0.022\ x_5 + 0.008 x_6$$

where x_1, x_2 and x_5 were the same as mentioned previously

x_3 = number of stocked milacres

x_4 = +1 for turpentine trees and -1 for "round trees

x_6 = +1 for stand turpentined in the north or round in and -1 for stand that is round in the north or turpentined in the south.

Well-drained soils supporting longleaf pine tend to have rather uniformly deep surface soils. Here the only soil factor related to growth was the physical nature of the sub soil, measured as the moisture equivalent. Sub soils for 147 plots showed that their values were so highly concentrated that either could be used for estimating, Y (silt + clay of B horizon) = 2.34 (M.E. of B horizon).

A revision of the earlier work of Coile (20) on the growth of pines in the Piedmont plateau region was made by Coile and Schumacher (22). One-hundred and sixty additional plots were measured in this physiographic region from North Carolina to Alabama.

The final regression equation for estimating site index of even-aged loblolly and shortleaf pines in the Piedmont region:

$$\log\ (S.I.)_L = 2.0188 - \frac{0.399}{x_1} - 0.00843\ x_9 - \frac{0.0198}{x_9}$$

$$\log\ (S.I.)_S = 1.8878 - \frac{0.1580}{x_1} - 0.00859\ x_9 - \frac{0.0408}{x_9} + 0.0053\ (L)$$

where

x_1 = depth of surface soil

L = +1 if the North and L is -1 if the South

x_9 = imbititional water value of the B horizon

The field tests of tree-site index compared with soil-site index methods indicated there was no difference between these two methods.

An interesting application of the relation between soil profile features and site index of loblolly and shortleaf pines was made for correcting existing site curves. In the lower age classes, that is, stands under fifty years of age, using total height and ages of trees in the dominant canopy in conjunction with conventional site class curves for the species. The site index estimates for young stands (10 to 30 years old) were found to be much higher than site estimates for older stands on the same type of soil. This led to a conclusion that existing site curves for southern pines over estimate site index quality in young age classes. A correlation factor for existing site curves of the two species was developed having the equation:

$$\log \frac{\gamma}{y} = b_1 \left(\frac{1}{A} - \frac{1}{50}\right)$$

where $\frac{\gamma}{y}$ = correction factor to be applied to existing curves

γ = S. I. estimated from curves

y = S.I. estimated from soil

$\frac{1}{A}$ = reciprocal of age

An intensive study of the growth of shortleaf pine plantations in relation to difference in soil properties was made in a small area of Missouri by Dingle and Burns (35). They found that site quality for shortleaf pine was strongly related to the thickness of the surface horizon, and the percentage of clay of this layer. Site quality as measured by height growth was much better on soils with deep A horizon rich in clay than on those with shallow A horizon containing little clay or organic matter. The pH of the A horizon was inversely related to site quality. Sites with high organic matter and high pH were poorest. Available moisture in the upper 3" was not correlated significantly with site quality. No constant relationship of soil colour to site quality could be established.

Methods were developed for estimating site quality of land for loblolly and shortleaf pines in the Piedmont region based on soil characteristics alone by Coile and Schumacher (21). Soil properties that were significantly correlated with height growth were:

x_1 = depth of the surface soil in inches

x_9 = imbibitional water value of the sub soil

$$\text{for loblolly pine} = (S.I.)_L = 100.04 - \frac{75}{x_1} - 1.39\, x_9$$

$$\text{for shortleaf pine} = (S.I.)_S = 77.32 - \frac{45}{x_1} - 1.00\, x_9$$

L = loblolly pine

S = shortleaf pine

Coile and Schumacher (21) obtained data on stands of both species, i.e. loblolly and shortleaf pine, and the soils that produced them in other parts of the Piedmont region of North Carolina, South Carolina, Georgia and Alabama. Soil factors tested were:

$\frac{1}{x_1}$ where x_1 = depth of A horizon in inches.

x_9 = imbibitional water value of the B horizon

Main factors tested were burning (B) and geographic location (L). Analysis showed for loblolly pine, depth of surface soil (x_1) and imbibitional water value of the sub soil (x_9) both to be highly significant but neither geographic location (L) nor the effects of burning (B) were of any significance.

Final regression equation for estimating site index

$$\log (S.I.)_L = 2.0188 - \frac{0.399}{x_1} - 0.00843 (x_9) - \frac{0.0198}{x_9}$$

For shortleaf pine the depth of surface soil (x_1) and physical properties of the subsoil, expressed as imbibitional water value (x_9), were high but significant.

$$\log (S.I.)_S = 1.8878 - \frac{0.1580}{x_1} - 0.00859 (x_9) + 0.0053 (L)$$

The correlation between the growth of planted slashpine and soil productivity throughout Florida was studied by Barnes and Ralston (6).

Depth to a fine-textured horizon and depth to a mottled horizon were highly significant. Additional relationships were developed which showed how estimates of site quality can be used to predict future yields of cordwood for various ages and spacings.

Hodgkins (53) studied and tested the application of soil-site index tables of longleaf, slash and loblolly pine stands in Baldwin, Escambia and Monroe counties in southwestern Alabama. The soil-site index tables of long leaf, slash and loblolly pine stands of highest utility were designed for relatively small geographic areas with uniform climates and distinctive soil conditions. Such tables can be of considerable value on many areas where it is not possible to obtain reliable site indices.

Zahner (108) attempted to obtain basic data from which a method for evaluating site quality for loblolly and shortleaf pine could be estimated on upland and terrace soils in Southern Arkansas and northern Louisiana. Through regression analysis site index was related to soil and topographic variables. Soil factors that help to regulate soil moisture and soil aeration were highly correlated with site index. On mature upland soil with well-differentiated horizons, both loblolly and shortleaf pines were influenced similarly. As the thickness of the surface soil was increased up to a depth of 18" site quality also increased. Site quality decreased somewhat for deeper surface soil. Another soil variable significantly correlated was clay content of the subsoil. On immature soil with poor horizon development loblolly pine site index was associated with three factors: 1. silt content of the surface soil, 2. silt + clay content of the sub soil, and 3. surface drainage.

Row (82) predicted the height growth of slash pine planations on old field sites in the sand hills of North and South Carolina. Statistical analysis demonstrated that height of slash pine can be estimated for their age and two soil variables: (1) depth to a fine textured horizon, (2) thickness of the A horizon.

$$\text{log height} = 1.987 - 5.941 \frac{1}{\text{age}} + 0.008963 \text{ (thickness of } A_1) - 0.000004245 \text{ (depth to fine texture).}$$

McGee (72) studied the relationship between soil properties and site index of slash pine in the middle Coastal Plain of Georgia. The soil properties found to be highly correlated with height growth were (1) the thickness of the A_1 horizon and (2) depth to a fine textured horizon. Site quality was increased as the thickness of the A_1 horizon increased. Optimum growth was found on sites having a 28-30" depth to a fine textured horizon.

$$\text{Log height} = 2.0058 - 5.5907 \left(\frac{1}{\text{age}}\right) + 0.005968 \text{ (thickness of the } A_1 \text{ horizon)}$$

$$- 0.1445 \left(\frac{1}{A_1}\right) + 0.001837 \text{ (depth to fine texture horizon)}$$

$$- 0.000032 \text{ (depth to fine texture)}^2$$

Pegg (76) studied the relationship between site index of slash pine and soil variables in East Queenland. The soil groups studied were:

I. Well drained areas.

a. red earth residuals

b. lateritic podzolics

c. regosols

d. miscellaneous soil series

II. Poorly drained areas.

a. ground water podzols

b. podzolic gleys

c. gleys

d. humic and humic gleys

Variables which were tested included the following:

x_1 = height in feet of the original tree vegetation
x_2 = depth in inches to the horizon of finest texture
x_3 = depth in inches to the horizon of finest to hard pan
x_4 = topographic position
x_5 = thickness in inches of the A_1 horizon
x_6 = clay colors
x_7 = average annual rainfall.

Other independent variables which were tried without success were depth to a layer of dense concretions, percentage concretion in the layer, species composition of the tree vegetation, colors of horizon other than clay and total P_2O_5. He developed a regression equation for each one of the soil groups mentioned above.

Similar types of work have been done with other forest tree species by many research workers. In brief this work is as follows:

1. Red pine (Pinus resinosa Ait). Haig, (1929: Hicock et al, (1931): Heiberg, (1941), White and Wood, (1958); Mader and Owen.

2. Jack Pine (Pinus banksiana), Arneman, H. F.

3. Quacking Aspen (Pinus tremuloides), Stoeckeler (1948), Kittredge (1938).

4. Black locust (Robinia pseudoacacia)
Black walnut (Juglans nigra L) Roberts, (1939) & Auten (1945).

5. Oak (Quercus spp) Lunt, (1939), Einspahrand McComb (1951) Youngberg and Scholz (1949) Locke (1941) Cryseland Arend (1953); Doolittle (1957) Trimble and Weitzman (1958): Carmean (1961) Della - Bianca & Olson (1961).

6. Yellow poplar (Liriodendron tulipifera L) Auten (1937 & 1945) Della-Bianca & Olson (1961) Tryon, Beers & Meritt (1960)

7. Douglas Fir (Pseudotsuga texifolia) Gessel (1949) Hill et al, (1948): Tarrant (1949); Schlots, Lyod and Deardorff (1956): Carmean (1954).

8. Ponderosa Pine (Pinus ponderosa) Holtby (1960); Zinke, Cox McConnel & Matthew (1960) Livingston (1949).

9. White Pine (Pinus strobus)Harold Young, (1954); Copeland (1958).

10. Redcedar (Juniperus virginiana) Ledford (1951).

11. Pond Pine (Pinus scrotina) Hofmann (1949), Zahner (1951).

12. Sand pine (Pinus clausa chapm) Barnes (1951).

CHAPTER III

MATERIALS AND METHODS

Oklahoma is specially favorable for the study of vegetation since it is a border state between the temperate north and the warm temperature south and between the arid west and the humid east (28). It comprises an area of approximately 70,000 square miles. The highest point in the state, about 4,500 feet above sea level, is in the Black Mesa area, in the northwestern corner of Cimarron County. From this point the altitude decreases eastward and southward to a minimum level of somewhat less than 350 feet in the extreme southeastern corner of the state (7). The climate of Oklahoma is of the continental type, with pronounced seasonal and geographic ranges in both temperature and percipitation. Western sections of the state are cooler and drier; in the east showers are more frequent because of the higher frequency of moisture in the atmosphere. The annual precipitation varies from more than 50" in the northeastern part of McCurtain County, in the extreme southeastern part of the state to only slightly more than 17" in Texas and Cimarron counties, both in the Panhandle. Snowfall also varies greatly, with averages ranging from less than 3" in the extreme southeastern section to more than 20" in the extreme western part of Cimarron County. The mean annual temperature ranges from 63.9°F at Idabel, in the extreme southeastern corner of the state, to 53°F at Boise City, in the western part of the Panhandle.

Temperature of 100^{o}F or higher may be expected in Oklahoma from June to September, while maxima of 90^{o}F or higher are of record in January, February and November. While killing frosts or freezing temperatures have occurred as late as May 1st in all parts of the state, they are not to be expected in the southern section later than the first week in April, and not later than April 15-20 in the north. The average length of the growing season varies from 180 days in the western part of Cimarron County to 240 days in the extreme southeast. Oklahoma has wide variation in precipitation and heavy to almost torrential rains occasionally occur. Falls of more than 10" over 24 hours are recorded at a number of stations in scattered localities. On an average 75% of the annual parcipitation occurs during the growing season, March to October, inclusive. Rains are most general and abundant during the spring and early summer. In late summer and early fall there are more local and often uncertain rains in the western part of the state. However, general rains frequently began again during September and October, thus conditioning the soil for the seedling and germination of winter grains (7). Climatic conditions in Oklahoma in brief is presented in Table I.

The three sections of the state listed have unique topographic features which influence the development of natural vegetation:

1. Panhandle.

2. Western Oklahoma.

3. Eastern Oklahoma. (Part of S.E. Oklahoma contains the Gulf Coastal Plain).

Residual native vegetation is grasslands in the western part and forest in the eastern portion (28), Figure 4.

TABLE I

CLIMATIC CONDITIONS IN OKLAHOMA

I. Oklahoma: average precipitation at selected stations

	Least rainfall		Most rainfall		Total annual
Station	Month	Inches	Month	Inches	rainfall
Altus	Jan.	0.7	May	3.5	25.4
Boise City	Jan.	0.3	June	2.6	16.8
Idabel	Sept.	2.5	May	5.4	44.2
Miami	Feb.	1.5	June	5.7	43.2
Okla. City	Feb.	1.1	May	4.8	31.1
Woodward	Jan.	0.7	May 3.5		25.0

From Morris (1953)

II. Oklahoma: average temperatures at selected stations

	Average Low		Average High		Average
Station	Month	Temp.	Month	Temp.	Annual
Altus	Jan.	40.7	July	84.1	62.8
Boise City	Jan.	33.5	July	77.2	54.4
Idabel	Jan.	44.0	July	82.4	63.7
Miami	Jan.	36.0	July	81.4	59.6
Okla. City	Jan.	37.6	July	80.6	59.4
Woodward	Jan.	36.1	July	82.4	59.4

From Morris (1953)

III. Precipitation (Inches)

	At O.C.		O.Cm%	P-E ratios
A. Eastern, 41	Spring,	10.31	13	90
B. Central, 35	Summer,	9.20	33	80
C. Western, 26	Autumn,	8.06	29	60
D. Panhandle, 19	Winter,	4.10	25	40

IV. Tempreature (Frost-free season)

A. Southeast, 250 days
B. Central, 223 days
C. Northwest, 180 days

V. Killing Frost, O. C.

A. Last in spring, March 30 (as of 1956)
B. First in fall, November 6 (as of 1956)

VI. Wind

A. January, February - North
B. Other months - South

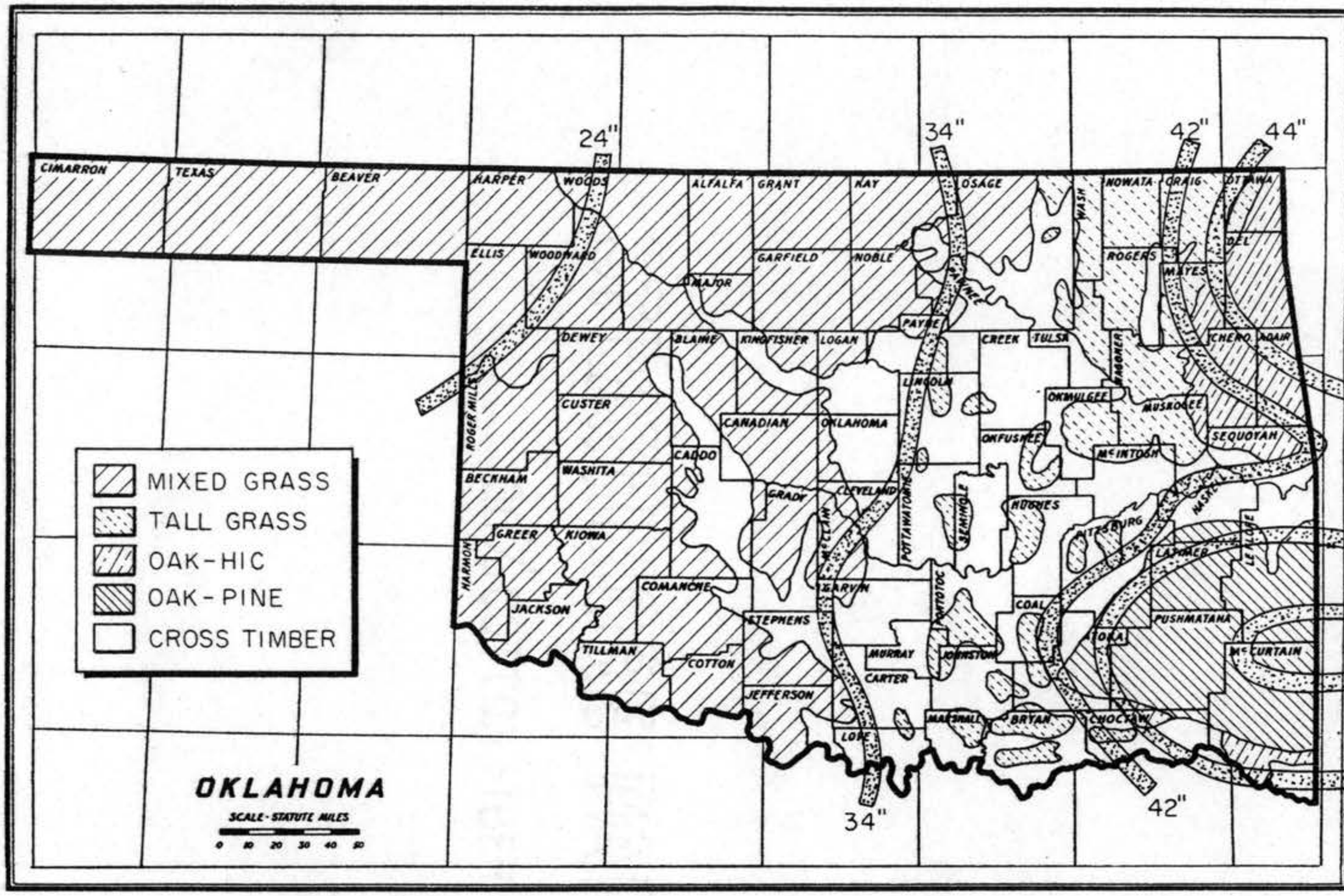


Figure 4. Natural Vegetation and Annual Precipitation of Oklahoma

The area studied is located in the extreme southeastern corner of Oklahoma in the civinity of Broken Bow in McCurtain County, shown in Figure 2. It is bordered on the east by Arkansas, on the south by Texas, on the west by Choctaw and Pushmataha Counties, and on the north by Pushmataha Leflore Counties.

McCurtain County has a warm humid climate. In winter the temperatures are generally mild, there being only occasional short periods of severe cold and almost no snow. In summer some days are uncomfortably hot and there are many warm nights. Precipitation generally exceeds the losses by evaporation and plant use, resulting in a moist subsoil and additions to the ground water. Several years of average or above average rainfall may be followed by several dry years during which soil moisture is deficient. The annual precipitation has ranged from 28.72 to 73.37". Average annual precipitation is 46" and about 60% of the total annual precipitation occurs in the months of December through May. January has the lowest average temperature and July and August have the highest. The average annual temperature at Idabel is about 64.4^{o}F, which is about 3.8^{o}F above the average for the state. The average number of days between the last killing frost in the spring and the first killing frost in the fall, for the period of record is about 229 days. The last killing frost generally occurs late in March, but has ranged from March 7 to April 19. The first frost in the fall usually occurs in the latter part of November, but has ranged from October 8 to November 23. This data is shown in Tables III and IV.

The Red River is a perennial stream with a wide, relatively shallow channel having a low gradient and a large sediment load. The low gradient and a large sediment load have resulted in intricate

TABLE II

GENERALIZED SECTION OF ROCKS EXPOSED IN SOUTHERN MC CURTAIN COUNTY, OKLAHOMA

System	Series	Group	Formation	Thickness (feet)	Lithology and water-bearing properties
QUATERNARY	Pleistocene and Recent		Alluvium	0 - 80	Gravel, sand, silt, and clay on the present and old flood plains of the Red and Little Rivers and their tributaries. Yields hard water to domestic and stock wells; probably capable of yielding several hundred gallons of water per minute in some localities.
			Terrace deposits	0 - 40	Unconsolidated gravel, sand, silt, and clay occurring in large and small deposits over southern McCurtain County; probably remnants of formerly more extensive deposits; found mostly on higher ground. Generally too highly dissected and drained of ground water to yield more than enough for domestic or stock use.
		UNCONFORMITY			
CRETACEOUS	Gulf		Ozan and Brownstown formations, undifferen- iated	- - -	Soft chalky marls and limestones with interbedded calcareous clays. Yield only enough ground water for domestic use.
		UNCONFORMITY			
	Gulf		Tokio formation	0 - 595	Gray cross-bedded sand, interbedded with gray and dark-gray shale. Transmissibility generally low, owing to clay and silt in formation. Probably yields less than 20 gpm.

TABLE II — Continued

System	Series	Group	Formation	Thickness (feet)	Lithology and waterbearing properties
CRETACEOUS	Gulf		Woodbine formation	0 - 355	Upper member mostly gray to brown cross-bedded quartz sand and sandy gravel. Lower member principally cross-bedded dark tuffaceous sand, red clay, and gravel lentils. The formation is not a productive aquifer; most wells yield only sufficient water for domestic or stock use. Quality is poor.
			UNCONFORMITY		
CRETACEOUS	Comanche	Washita	(Includes Kiamichi formation of Fredericksburg group)	0 - 235	Gray fossiliferous limestones and caleareous dark-blue shale: thins eastward. Contains relatively small amounts of water of poor quality in solution openings and cracks in the limestones.
		Fredericksburg	Goodland limestone	25 - 130	Thin-bedded dense limestone at the top; soft chalky and massive limestone in lower part. Entire formation fossiliferous. Does not yield much water to wells. Water is of poor quality
			UNCONFORMITY		
CRETACEOUS	Comanche	Trinity	Paluxy sand	0 - 900	Mostly quartz sand with some interbedded clay and a few shaly limestone lentils. Contains large amounts of ground water. Maximum reported yield about 260 gpm from a municipal well at Valliant. Probably could supply sufficient water for irrigation in some areas.

TABLE II — Continued

System	Series	Group	Formation	Thickness (feet)	Lithology and water-bearing properties
CRETACEOUS	Comanche	Trinity			Water is saline southwest of Idabel and east of Idabel south of Little River.
			De Queen limestone	0 - 190	Glayey limestone, blue-gray;gray,thins westward. Contains a small amount of water along bedding planes; wells in it have small yields, which are quickly exhausted.
			Holly Creek formation	0 - 1,070	Gravel, mostly interbedded with silt and clay; thins westward. Yields little ground water to wells, generally only enough for home and stock use.
UNCONFORMITY					

(Source 29)

TABLE III

AVERAGE MONTHLY TOTAL PRECIPITATION AND DEPARTURE FROM LONG TERM MEANS AT IDABEL,MCCURTAIN COUNTY, OKLAHOMA

YEAR	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE	
	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE
1956	1.63	-2.66	6.71	2.95	2.08	-2.06	3.55	-1.71	2.62	-3.79	1.37	-2.05
1957	4.91	0.62	4.68	0.92	8.32	4.18	14.34	9.28	12.41	6.00	4.77	1.35
1958	2.93	-1.36	1.04	-2.72	6.26	2.12	7.03	1.97	6.80	0.39	2.63	-0.79
1959	0.63	-3.66	4.67	0.91	2.99	-1.15	2.79	-2.27	4.78	-1.63	5.43	2.01
1960	4.13	- .16	2.96	-0.80	2.49	-1.65	2.82	-2.24	3.75	-2.66	5.30	1.88
1961	0.86	-3.43	3.44	-3.2	7.17	3.03	2.60	-2.46	3.11	-3.30	3.81	0.39
1962	3.56	- .49	5.32	1.52	3.85	- .34	5.13	- .10	1.63	-4.72	7.17	3.67
1963	1.47	-2.58	.43	-3.37	6.03	1.84	3.88	-1.35	1.60	-4.75	4.11	0.61
1964	1.05	-3.00	3.97	.17	8.30	4.11	10.68	5.45	3.36	-2.99	1.63	-1.87
1965	6.01	1.96	4.7	0.9	2.86	-1.33	2.03	-3.2	5.11	-1.2	1.3	-2.2
1966	2.44	-1.61	4.7	0.9	0.65	-3.54	10.30	5.07	3.21	-3.14	.59	-2.91
1967	.39	-3.66	2.73	-1.07	2.30	-1.89	8.12	2.89	11.49	5.14	4.85	1.35

TABLE III — Continued

YEAR	JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		ANNUAL	
	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE	PRECIPITATION	DEPARTURE
1956	1.36	-2.03	2.22	-0.11	0.29	-2.92	1.67	-1.37	4.56	0.83	2.67	-1.08	30.53	-16.0
1957	0.66	-2.73	1.82	- .51	7.11	3.90	3.93	0.89	7.99	4.26	2.65	-1.30	73.79	26.86
1958	6.62	3.23	5.41	3.08	4.87	1.66	3.21	.17	7.28	3.55	0.92	-2.83	55.0	8.47
1959	13.14	9.75	1.55	- .78	2.16	-1.07	5.82	2.78	2.98	-0.75	5.42	1.67	52.34	5.81
1960	7.17	3.78	3.52	1.19	3.00	- .21	4.52	1.48	2.84	-0.89	8.33	4.58	50.83	4.33
1961	7.33	3.94	2.92	0.59	3.72	0.51	2.82	- .22	7.02	3.29	2.94	- .81	47.74	1.21
1962	0.97	-2.82	2.98	0.56	7.82	4.57	4.64	1.47	3.13	- .83	1.27	-2.51	47.47	- 0.2
1963	5.73	1.94	3.32	0.90	.11	-3.14	1.94	-1.23	2.41	-1.55	2.33	-1.45	33.36	-14.13
1964	.67	-3.12	5.55	3.13	7.21	3.96	.19	-2.98	2.63	-1.33	1.11	-2.67	46.35	- 1.14
1965	1.63	-2.16	2.18	- .24	6.5	3.25	1.76	-1.41	.74	-3.22	1.17	-2.61	35.99	-11.50
1966	2.81	-0.98	5.17	2.75	3.31	.06	2.72	- .45	.61	-3.35	3.80	.02	40.31	- 7.18
1967	3.84	.05	.57	-1.85	4.42	1.17	6.0	2.83	1.46	-2.50	5.31	1.53	51.48	3.99

TABLE IV

AVERAGE MONTHLY TEMPERATURES IN DEGREES F AND DEPARTURE FROM LONG TERM MEANS AT IDABEL, MC CURTAIN COUNTY, OKLAHOMA

YEAR	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE	
	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE
1956	41.5	-2.9	49.2	1.6	54.9	0.3	62.5	-0.8	74.1	4.0	79.3	0.7
1957	42.5	-1.9	53.3	5.7	51.3	-3.3	62.0	-1.3	71.0	0.9	77.6	-1.0
1958	41.9	-2.5	41.4	-6.2	49.2	-5.4	61.1	-2.2	70.8	0.7	78.5	-0.1
1959	42.5	-1.9	46.9	-0.7	53.7	-0.9	61.9	-1.4	73.5	3.4	77.2	-1.4
1960	43.1	-1.3	41.6	-6.0	44.9	-9.7	64.8	1.5	68.6	-1.5	77.2	-1.4
1961	40.5	-3.9	46.8	-0.8	58.0	3.4	60.1	-3.2	69.2	-0.9	74.5	-4.1
1962	-	-	52.0	4.6	51.4	-2.6	60.9	-2.3	73.3	3.0	76.1	-2.4
1963	36.0	-8.1	43.3	-4.1	59.2	5.2	66.5	3.3	72.2	1.9	79.6	1.1
1964	44.7	0.6	43.9	-3.5	54.6	0.6	65.9	2.7	72.5	2.2	78.1	-0.4
1965	46.2	2.1	47.0	-0.4	45.9	-8.1	68.3	5.1	71.9	1.6	77.3	-1.2
1966	39.2	-4.9	44.2	-3.2	55.4	1.4	63.1	- .1	69.0	-1.3	75.2	-3.3
1967	45.9	1.8	45.5	-1.9	62.3	8.3	66.5	3.3	69.3	-1.0	79.1	.6

TABLE IV — Continued

YEAR	JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		ANNUAL	
	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE	TEMPERATURE	DEPARTURE
1956	85.5	3.2	84.5	2.1	76.6	0.9	68.2	2.8	50.5	-2.2	49.8	4.5	64.7	1.2
1957	84.1	1.8	81.4	-1.0	72.8	-2.9	60.2	-5.2	51.3	-1.4	49.9	4.6	63.1	-0.4
1958	82.0	-0.3	81.8	-0.6	76.6	0.9	64.2	-1.2	55.1	2.4	42.3	-3.0	62.1	-1.4
1959	79.5	-2.8	80.8	-1.6	75.6	-0.1	64.8	-0.6	47.8	-4.9	48.1	2.8	62.7	-0.8
1960	80.3	-2.0	80.3	-2.1	76.5	0.8	66.3	0.9	55.6	2.9	41.1	-4.2	61.7	-1.8
1961	78.7	-3.6	78.5	-3.9	74.7	-1.0	64.7	-0.7	-	-	-	-	-	-
1962	81.3	-1.0	82.1	-0.2	75.1	-0.6	67.3	2.0	52.4	-0.2	45.4	-0.1	-	-
1963	80.8	-1.5	82.1	-0.2	75.8	0.1	70.9	5.6	57.8	5.2	38.3	-7.1	63.6	0.2
1964	84.3	2.0	83.1	0.8	74.3	-1.4	62.9	-2.4	57.6	5.0	46.0	0.5	64.0	0.6
1965	82.8	0.5	80.7	-1.6	75.7	-	63.3	-2.0	59.9	7.3	48.7	3.2	64.0	0.6
1966	82.7	0.4	77.9	-4.4	-	-	61.4	-3.9	58.3	5.7	43.5	-2.0	-	-
1967	78.3	-4.0	78.9	-3.4	71.5	-4.2	64.5	- .8	52.6	-	45.7	0.2	63.3	- .1

stream meanders over a wide alluvial plain. Ox-bow lakes and marshy areas are numerous and the river may annually flood thousands of acres. Little River is a perennial stream with steep mud banks, a sand and gravel stream bed, and heavy timber on the bottomlands. Other perennial streams are the Mountain Fork River, Glover, Yashau and Lukfata Creeks, which flow into the Little River from the north, and Norwood, McKinney, Waterhole, and Clear Creeks, which flow into the Red River.

Southern McCurtain County is in the dissected Gulf Coastal Plain. The north boundary of the Province is the north edge of the outcrop of the Trinity group of rocks. The northern part of southern McCurtain County is characterized by a rolling topography developed by differential erosion of the sands and clays of the Trinity group and overlying terrace gravels. In the Southern part of the area, from about the latitude of the Little River, south to the alluvium and terrace deposits of the Red River, the general dip of the rocks is southward, locally interrupted by gentle folding. The alternation of resistant and weak strata produces a "stairstep" topography. The limestone and other resistant beds form northward-facing escarpments and gentle slopes to the south. Local relief in most places does not exceed 100 feet and generally is much less. Little River crosses about midway of southern McCurtain County flowing eastward, and Glover Creek and Mountain Fork River flow into it from the north.

Red River, flowing southeast froms the south boundary of the county. Alluvial plains on these streams range in width from less than a quarter of a mile to about five miles. A high terrace deposit, ranging in width from half a mile to about four miles, and about 20 miles long, borders the north edge of the Red River alluvium in the southeastern part of the area.

The bedrock exposed in southern McCurtain County consists of sedimentary rocks of the Comanche age and the Gulf series of the Cretaceous system. The oldest formation is the Holly Creek, which is overlain by the De Queen limestone and Paluxy sand, all of the Trinity group. These outcrop in the northern part of southern McCurtain County. Above them, from oldest to youngest, are the Fredericksburg and Washita groups, which outcrop as east-west bands south of the latitude of the Little River. The Trinity, Fredericksburg and Washita groups constitute the Comanche series of rocks in this county. The Gulf series, overlying the Comanche, consists of the Woodbine formation at the base followed by the Tokio formation. The ozan and Brownstone formation, undifferentiated, outcrop in a small area in the southeastern part of the county.

The regional structure of the Cretaceous rocks in McCurtain County is a southward dipping homocline, the maximum dip of which is about 100 feet per mile. The comanche series is separated from the underlying rocks by a profound unconfirmity. They are separated from the adjacent upper cretaceous (Gulf) rocks by an angular unconformity whose plain truncates all the several formations of lower Cretaceous (Comanche) age, the youngest in Oklahoma and the oldest in Arkansas. Generalized section of rocks exposed in Southern McCurtain County is furnished in Table II.

In McCurtain County the upper part of the Comanche series is represented by the Washita group. The erosion that caused the eastward thinning of the Washita marks the end of the Comanche epoch. The contact between the Washita and the overlying Woodbine formation marks a plane of unconformity. The local differences in thickness of the Washita group doubtless are partly due to unevenness of the eroded surface, even though that surface may have approximated a peneplain. The differences may be due partly to the influence of minor folding during the period of erosion. The quartz veins in their rocks apparantly were covered as late as Woodbine time. Some sites in northern McCurtain County have a covering of vein-quartz of pebbles possibly derived from the Ouachita Mountains. Erosion has worn down and removed the sediments to create the present topography. During this period of erosion the quartz veins were uncovered, and they supplied much quartz to make up the matrix of the terrace gravels which are widespread throughout southern McCurtain County (29).

Oklahoma's forested Coastal Plain is a part of the broad Gulf Coastal Plain of the U.S.A. The Coastal Plain is the major physiographic problem of the south half of McCurtain County. The Ouachita Highlands tower over it to the north. The plain rises from 350 feet in the southeast corner of McCurtain to over 700 feet in its western extremity. Local relief is seldom greater than 50 feet, but the sandy areas are much dissected and short, steep slopes are common. Surface drainage is toward the Red River to the south. Major streams have rather low gradients and consequently occupy fairly wide bottoms. Small stream courses are short and narrow.

The weakly consolidated sediments of the forested Coastal Plain are generally considered to have been deposited as a series of marine terraces with a gentle inclination to the south. Sands and sandy clays

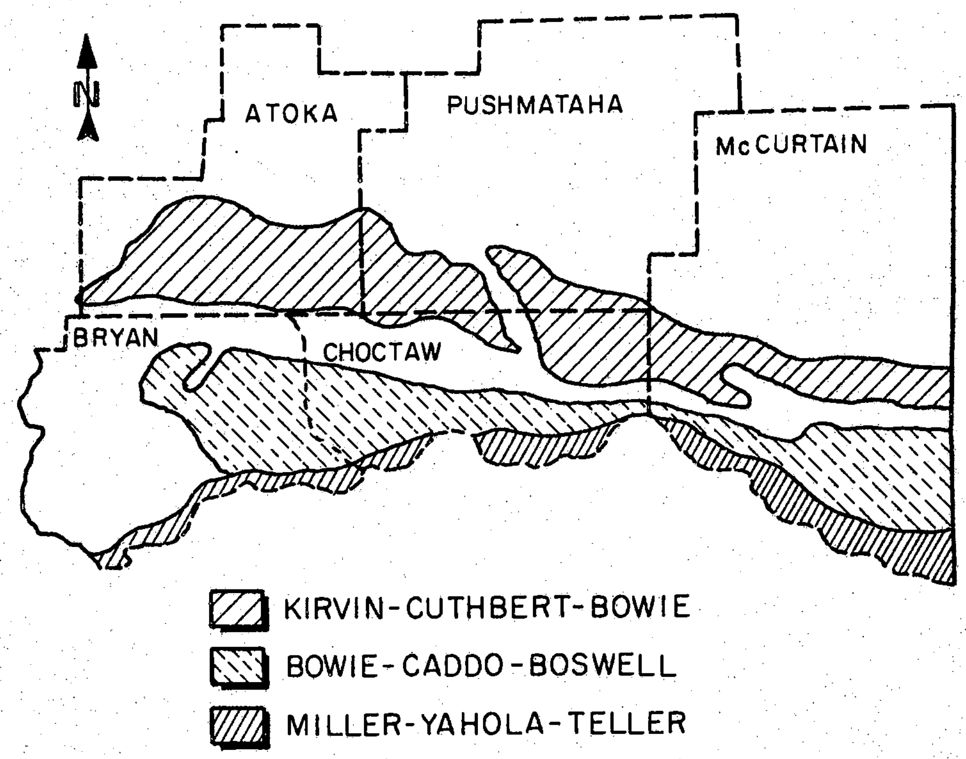


Figure 5. Forested Coastal Plain Soils of McCurtain and Other Neighbouring Counties.

are dominant in the forested part; however, there are beds of limestone, marls, and clays in the central part that support only tall grasses. Successive layers were deposited in a receding sea, leaving exposures as narrow east-west belts. These belts parallel former beach lines that developed as the sea regressed and moved outward towards the present Gulf.

The Gulf Coastal Plain land surface was formed during several periods of submergence since Cretaceous time. Material was carried down by regional drainage from the older mainland on the north and was deposited as horizontal beds of clays and sands in the former shallow coastal waters. Successive uplifts exposed these marine beds and erosion has long since dissected and transfigured the terrain. From this land form has developed the gently rolling hills of the uplands and the flat terraces along major streams. The forested Coastal Plain soils are red-yellow-podzolics. They are strongly leached and strongly acid. Intensity of leaching lessens from east to west, and the sandy soils of the western part have much in common with the cross timbers (43) soils to the west.

In the U.S.A., the red-yellow-podzolic soils have been formed from granites, gneisis, schists, sand stones, shales, limestones and various unconsolidated sediments. All of these parent materials contain appreciable quantities of quartz or its equivalent in the sand and silt fractions and most of them are relatively low in calcium (87).

Analysis of the clay of fine red and yellow podzolic soils indicated 60-90% Kaolinite, 10-20% hydrous mica, 8-15% free iron oxides (1).

Analysis of the Coastal Plain and adjacent soils region of southeastern United States indicated that the clay fraction of their soils of this region. Kaolinite, while dominant in a few more highly weathered soils, is present in lesser amounts than had been generally thought in soils of rather wide occurrence in the region (23).

For eastern Oklahoma Duck and Fletcher described the following vegetation types (28).

1. Tall grass praire

Dominants:	Little bluestem	(*Andropogan scoparius*),
	Big bluestem	(*Andropogan gerardi*),
	Indiangrass	(*Sorghastrum nutans*),
	Switchgrass	(*Panicum virgatum*).

2. Post oak-black jack

Dominants:	Post oak	(*Quercus stellata*)
	Blackjack	(*Quercus marilandica*)
	Black hickory	(*Carya texana*).

3. Oak hickory

Dominants:	Black oak	(*Quercus velutina*)
	Spanish oak	(*Quercus falcata*)
	Mockernut hickory	(*Carya tomentosa*).

4. Oak pine

Dominants:	Shortleaf pine	(*Pinus echinata*)

5. Loblolly pine hardwood

Loblolly pine	(*Pinus taeda*)
Water oak	(*Quercus nigra*)
Spanish oak	(*Quercus falcata*)
Mockernut hickory	(*Carya tomentosa*)

6. There are several forest communities in the bottomland including oak-maple, redgum-oak, elm-ash-hackberry,

cottonwood, willow-salt cedar and bald cypress.

Field Procedure

Site Selection

The plots were located irrespective of soil series or phase, slope position or aspect in a zone of similar topography and climatic condition. One-tenth acre plots were selected because of the extreme variability in site quality and rapid change in soil characteristics over a small area.

A portion of the plots studied by Wilson (113) on upland topography were used in this study. Also included were a few plots at toe-slope or intermittent stream terrace-border positions. Plots were chosen as long as they had a black gum-white oak or higher order plant association.

Vegetation Tally

All plants on the plot over 4.5 feet in height were tallied. Those plants over 3.6" in diameter at breast height (d.b.h.) were tallied by species, vigor class and crown class. Regeneration of 0.5 to 4.5 feet in height was tallied by species on eight 0.001 acre sub plots located 20 feet from the plot centre, at 45 degree intervals clockwise from north.

Plant frequency was rated for each species as predominant if several plants occured in each of the four quadrants of a plot. A common frequency rating required a tally of at least one plant in each of three quadrants of a plot. When stems occured in only one or two quadrants the species was given a scattered, frequency rating.

The actual site index of each plot was determined by extrapolation after plotting mean values of height over age for three sampled pine trees per plot on adjusted shortleaf pine site index curved by Coile and Schumacher (47). Age was estimated from increment borings made at six inches above ground level. Annual rings were counted and one year was added for total age.

Morphological Studies

One representative soil profile in each plot was studied. Soil samples were collected by horizons. Prior to sampling, each soil profile was described using standard classification nomenclature.

Laboratory Procedures

The soil samples which were collected in the field were brought to the laboratory, air dried, ground to pass a 2 mm sieve, and stored for analyses. Physical analysis consisted of determination of the particle size distribution and moisture release characteristics. The chemical analysis consisted of the determination of cation exchange capacity and exchangeable bases, soil pH, nitrogen, and available nutrients.

Praticle size distribution was determined by using a Bouyoucos hydrometer (30).

Moisture contents on a dry weight basis were determined at tensions of 1/3, 1, and 15 atmosphere. The difference between the two values of one-third atm and 15 atm, was used as readily available moisture holding capacity (78).

The pH of soil samples was determined on a soil-distilled water paste and on a 1:1 mixture of soil and 1 normal KCl. The readings were taken on a Beckman pH meter.

The cation exchange capacity was determined by the standard methods (15, 79). The NH_4OAC leachate was used for the determination of exchangeable cations. Exchangeable hydrogen was determined by barium chloride triethanolamine of Mehlich according to Chapman and Parker (15). Exchangeable calcium, magnesium, potassium and sodium were determined with a Beckman Model DU flame spectrophotometer.

Nitrogen in soil samples was determined following the method of modified micro Kjeldahl procedure (15, 79).

Available phosphorus was determined by a method of Bray and Kurtz (9).

Available potassium was determined by analysis of the ammonium acetate extract with Du flame spectrophotometer with an oxy-hydrogen and photomultiplier (73).

Statistical Analysis

Regression studies were undertaken to study the relationship of site index of shortleaf pine to soil properties by following the stepwise multiple regression procedure.

Simple linear correlation studies were also undertaken to measure the degree of association amongst soil properties, and forest tree species, and between soil properties and forest tree species.

The statistical analysis i.e. regression and correlation data was run through 7040 FORTRAN Computer with BMDO2R, and BMDO3D program respectively.

CHAPTER IV

RESULTS AND DISCUSSION

A number of climatic elements in addition to precipitation are important in determining the distribution of vegetation, soil surface features, and land utilization. They include temperature, evaporation, insolation (sunshine), cloudiness and fog. Those of greatest significance are precipitation evaporation and temperature.

Climate plays a great part in soil genesis. The major differences between soils are due to the effect of climate operating through soil forming processes. This is partly due to the fact that direct influence of climate on soil formation and partly to the fact that soils are strongly influenced by vegetation which in turn is related to climate (7).

Morphology

Twelve plots were selected for specific plant groups for this investigation. The ratios of plots by different soil series is shown in Figure 6. Location of soil profiles is summarized in Table V. The soils included in this study represent four soil types, namely Bowie fine sandy loam, Goldsboro loam, Herndon loam and Myatt silt loam. The profile in each plot is studied and described as follows:

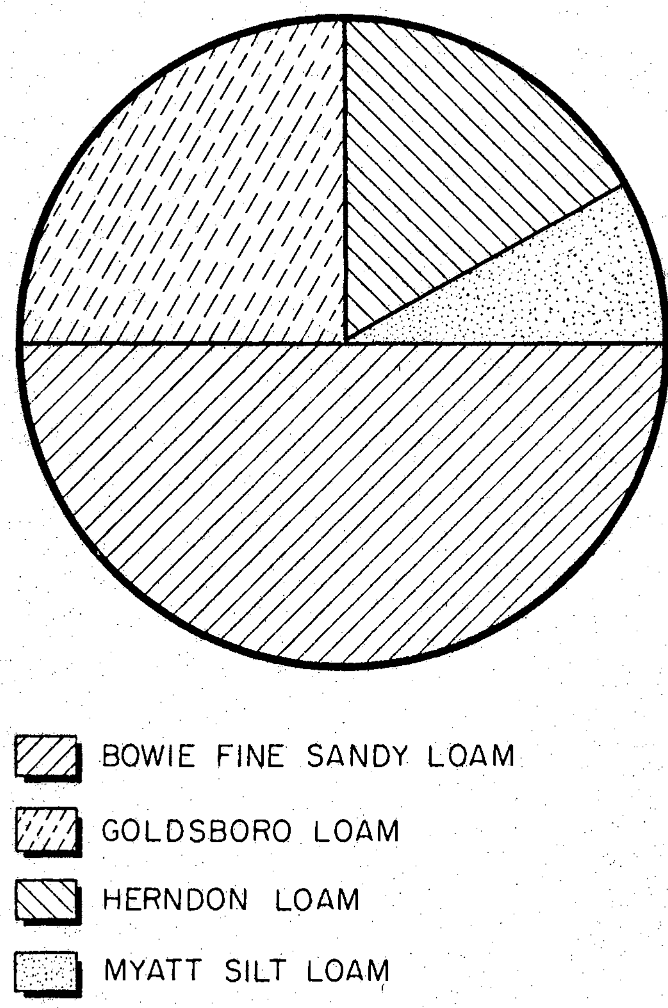


Figure 6. Different Soil Types in Study Area.

TABLE V

SHOWING LOCATION, CLASSIFICATION AND SOIL TYPE OF SOIL PROFILES

S. No.	Plot Number	Location	Classification	Soil Type
1	66-S-367	S. E. Corner Sec. 6, T6S, R27E (S.E. CFI 156)	Ultic paleudalf, coarse-loamy, mixed, thermic.	Bowie fine sandy loam.
2	66-S-371	110 yds. N.W. of S.E. corner Section 31, T5S, R27E.	Typic paleudalf, fine-loamy, mixed, thermic.	Bowie fine sandy loam.
3	66-S-375	600 ft. South of N.W. corner Section 14, T6S, R25E along Highway 70.	Typic paleudalf, fine-loamy, mixed, thermic.	Bowie fine sandy loam.
4	66-S-387	N.E. corner SE ¼ Section 24 T6S, R26E.	Ultic paleudalf, fine-loamy, mixed, thermic.	Bowie fine sandy loam.
5	66-S-392	N.E. corner Sec 23, T6S, R26E.	Typic paleudalf, coarse-loamy, mixed, thermic.	Bowie fine sandy loam.
6	67-S-805	200 ft. East, 300 ft. South N.W. corner NE ¼ Sec. 30, T6S, R27E.	Ultic paleudalf, fine-loamy, mixed, thermic.	Bowie fine sandy loam.
7	66-S-358	C.F.I. 157 110 yds. N.W. of Sec. 1, T6S, R26E.	Aquultic paleudalf, coarse-loamy, mixed, thermic.	Goldsboro loam.
8	66-S-379	S.W. corner, SW ¼ Sec. 8, T6S, R27E.	Aquultic paleudalf, coarse-loamy, mixed, thermic.	Goldsboro loam.
9	67-S-808	S.W. Corner SE ¼ SE ¼ Sec. 13, T6S, R25E.	Ultic paleudalf, fine-loamy, mixed, thermic.	Goldsboro loam.
10	66-S-350	N.W. corner Section 33, T4S, R27E.	Ultic Hapludalf, fine-loamy, mixed, thermic.	Herndon loam.

TABLE V — Continued

S. No.	Plot Number	Location	Classification	Soil Type
11	66-S-354	S.E. corner Section 32, T4S, R27E.	Ultic Hapludalf, fine-loamy, mixed, thermic.	Herndon loam.
12	66-S-383	110 yds. N. W. of S.E. corner Sec. 29, T6S, R27E.	Typic Ochraquults, fine-silty, Mixed, thermic.	Myatt silt loam.

Plot No. 6 66-S-367

Classification: Ultic Paleudalf, coarse-loamy, mixed thermic

Soil type: Bowie fine sandy loam

Location: SE corner Section 6, T6S, R27E (SE CFI 156)

Vegetation: Shortleaf pine, white oak, Red and black gum

Slope: Footslope of SE facing 3% gradient

Parent Material: Regolith of thick beds of unconsolidated sandy clay loam, sandy loam and sandy clay.

Typifying Pedon:

(Colors are for moist conditions)

01	1/2 -0"	Decayed forest liter
A1	0-4"	Very dark grayish brown (10YR 4/2) loam weak fine granular structure; soft, very friable; many roots, pH 4.8, clear smooth boundary.
A2	4-12"	Yellowish brown (10YR 5/4) loam; weak fine granular structure; soft, very friable; many roots, pH 4.8; clear wavey boundary.
B21t	12-31"	Strong brown (7.5YR 5/8) loam; weak medium granular structure; slightly hard; friable few clay films, many roots; pH 4.8; gradual smooth boundary.
B22t	31-43"	Brownish yellow (10YR 6/6) loam, with few fine faint brown mottles and few prominent red mottles; weak, medium subangular blocky structure; hard, friable; few roots; common fine pores; thin continuous clay films on ped surfaces and in pores; few fine hard iron oxide concretions and few plinthite nodules; gradual boundary.
B23t	43-70"+	Prominently mottled brownish yellow (10YR 6/6) red (2.5YR 4/8) pale brown (10YR 6/3) and light brownish gray (10YR 6/2) sandy clay loam; weak medium to coarse subangular blocky structure; hard, friable; red mottles are brittle nonindurated plinthite comprising 10 to 15 percent soil volume, thick continuous clay films on ped surfaces; pH 4.5.

Plot No. 7 66-S-371

Classification: Typic Paleudalf, fine-loamy, mixed thermic

Soil type: Bowie fine sandy loam CFI 153

Location: 110 yds NW of SE corner Section 31, T5S, R27E

Vegetation: Shortleaf pine, white oak, Red and black gum and red maple

Slope: Footslope of SE facing 3% gradient

Parent Material: Regolith of thick beds of unconsolidated sandy clay loam, sandy loam and sandy clay.

Typifying Pedon:
(Colors are for moist conditions)

01	1/2 -0"	Decayed forest liter
A1	0-4"	Very dark grayish brown (10YR 4/2) loam weak fine granular structure; soft, very friable; many roots, pH 4.8, clear smooth boundary.
A2	4-14"	Yellowish brown (10YR 5/4) loam; weak fine granular structure; soft, very friable; many roots, pH 4.8; clear wavey boundary.
B21t	14-24"	Brownish yellow (10YR 6/6) sandy clay loam; weak fine subangular blocky structure slightly hard; friable, thin continuous clay films many roots; pH 4.8; gradual smooth boundary.
B22t	24-31"	Brownish yellow (10YR 6/6) sandy clay loam; with many coarse distinct yellowish brown mottles; moderate medium subangular blocky structure; hard; friable; thick continuous clay films; few roots, many fine pores, occasional fine gravel; pH 4.8; gradual smooth boundary.
B23t	31-38"	Brownish yellow (10YR 6/8) sandy clay loam with few fine, faint gray (10YR 6/1) and coarse prominent red (2.5YR 4/8) mottles, moderate medium subangular blocky structure, hard, friable; common fine pores; thick continuous clay films on ped surfaces and in pores; few hard iron oxide concretions and few plinthite nodules; pH 4.4; gradual smooth boundary.
B24t	38-70"+	Prominently mottled brownish yellow (10YR 6/6) red (2.5YR 4/8) pale brown (10YR 6/3) and light brownish gray (10YR 6/2) sandy clay loam; weak medium to coarse subangular blocky structure; hard, friable; red mottles are bright nonindurated plinthite comprising 10 to 15 percent soil volume, thick continuous clay films on ped surfaces; pH 4.5.

Plot No. 8   66-S-375

Classification: Typic Paleudalf, fine-loamy, mixed thermic

Soil type: Bowie fine sandy loam

Location: 600 ft. South of NW corner Section 14, T6S, R25E along Highway 70.

Vegetation and Use: Mixed pine and hardwood forest, principally sweet gum and white oak.

Slope: Gently sloping 1 to 3 percent gradient; 480 ft. elevation.

Parent Material: Thick beds of unconsolidated marine sediments of sandy clay loams, sandy loams and sandy clays.

Typifying Pedon: Bowie fine sandy loam - forested (Colors are for moist soil unless noted otherwise)

O1	1-0"	Decayed forest liter.
A1	0-5"	Dark grayish brown (10YR 4/2) moist fine sandy loam; weak fine granular structure; soft, very friable; many roots; slightly acid; clear wavy boundary. 2 to 7 inches thick.
A2	5-14"	Brown (10YR 5/3) moist fine sandy loam; weak fine granular structure; soft, very friable; many roots; medium acid; clear smooth boundary. 4 to 10 inches thick.
B21t	14-32"	Yellowish brown (10YR 5/6) moist light sandy clay loam; weak medium subangular blocky structure; hard, friable; fine and medium roots; common fine pores; thin continuous clay films on ped surfaces and in pores; very strongly acid; gradual wavy boundary. 8 to 20 inches thick.
B22t	32-54"	Yellowish brown (10YR 5/6) moist; sandy clay loam, common medium prominent red (2.5YR 5/6) and gray (10YR 6/1) mottles; moderate, medium and fine subangular blocky structure; very hard, friable; few roots; common fine pores; thin continuous clay films of ped surfaces; 2 percent by volume plinthite or plinthite like nodules; occasional hard and soft iron oxide concretions; gradual boundary; 12 to 24 inches thick.
B23t	54-70"+	Prominently mottled light gray, red, yellowish brown and strong brown sandy clay loam moderate medium subangular blocky structure; very hard, friable; few red mottles have brittle interiors when dry; 5 to 8 percent plinthite or plinthite like nodules; very strongly acid.

Plot No. 11   66-S-387

Classification: Ultic Paleudalf, fine-loamy, mixed, thermic

Soil type: Bowie fine sandy loam

Location: NE corner SE 1/4   Section 24, T6S, R26E

Vegetation: Shortleaf pine, white oak, red and black gum

Slope: Footslope of SE facing 3% gradient

Parent Material: Regolith of thick beds of unconsolidated sandy clay loam, sandy loam and sandy clay.

Typifying Pedon:

(Colors are for moist conditions)

O1	1/2 -0"	Decayed forest liter
A1	0-4"	Very dark grayish brown (10YR 4/2) loam weak fine granular structure; soft, very friable; many roots, pH 4.8, clear smooth boundary.
A2	4-9"	Yellowish brown (10YR 5/4) loam; weak fine granular structure; soft, very friable; many roots, pH 4.8; clear wavy boundary.
B21t	9-21"	Brownish yellow (10YR 6/6) sandy clay loam; weak fine subangular blocky structure slightly hard; friable; thin continuous clay films many roots; pH 4.8; gradual smooth boundary.
B22t	21-33"	Brownish yellow (10YR 6/6) sandy clay loam; with many coarse distinct yellowish brown mottles; moderate medium subangular blocky structure; hard; friable; thick continuous clay films; few roots; many fine pores, occasional fine gravel; pH 4.8; gradual smooth boundary.
A'2 and B22t	33-38"	Brownish yellow (10YR 6/8) sandy clay loam with many coarse prominent gray (10YR 6/1) and red (2.5YR 4/8) mottles and few short columnar streaks of light gray (10YR 7/1); moderate medium subangular blocky structure; friable; light gray streaks are stripped of clay; clay films are present on many peds; few pitted iron oxide concretions and red interior plinthite nodules; pH 4.8, gradual irregular boundary.
B23t	38-70"+	Prominently mottled brownish yellow (10YR 6/6) red (2.5YR 4/8) pale brown (10YR 6/3) and light brownish gray (10YR 6/2) sandy clay loam; weak medium to coarse subangular blocky structure; hard, friable; red mottles are bright nonindurated plinthite comprising 10 to 15 percent woil volume, thick continuous clay films on ped surfaces; pH 4.5.

Plot No. 12 66-S-392

Classification: Typic Paleudalf, coarse-loamy, mixed, thermic

Soil type: Bowie fine sandy loam

Location: NE corner Section 23, T6S, R26E

Slope: Footslope of SE facing 3% gradient

Vegetation: Shortleaf pine, white oak, red and black gum

Parent Material: Regolith of thick beds of unconsolidated sandy clay loam, sandy loam and sandy clay.

Typifying Pedon:

(Colors are for moist conditions)

01	1/2 -0"	Decayed forest liter
A1	0-5"	Very dark grayish brown (10YR 4/2) loam weak fine granular structure; soft, very friable; many roots, pH 4.8, clear smooth boundary.
A2	5-14"	Yellowish brown (10YR 5/4) loam; weak fine granular structure; soft, very friable; many roots, pH 4.8; clear wavy boundary.
B21t	14-31"	Brownish yellow (10YR 6/6) sandy clay loam; weak fine subangular blocky structure slightly hard; friable; thin continuous clay films many roots; pH 4.8; gradual smooth boundary.
B23t	45-60"	Brownish yellow (10YR 6/8) sandy clay loam with few fine, faint gray (10YR 6/1) and coarse prominent red (2.5YR 4/8) mottles, moderate medium subangular blocky structure, hard, friable; common fine pores; thick continuous clay films on ped surfaces and in pores; few hard iron oxide concretions and few plinthite nodules; pH 4.4; gradual smooth boundary.
B24t	60-70"+	Prominently mottled gray (10YR 6/1) yellowish brown (10YR 5/4) red (2.5YR 4/8) and pale brown (10YR 6/3) sandy clay loam; weak medium to coarse subangular blocky structure; hard; friable; red mottles are brittle nonindurated plinthite comprising 10 to 15 percent soil volume; thick continuous clay films on ped surfaces. pH 4.4.

Plot No. 13   67-S-805

Classification: Ultic Paleudalf, fine-loamy, mixed thermic

Soil type: Bowie fine sandy loam

Location: 200 ft. East, 300 ft. South NW corner NE 1/4 Sec. 30, T6S, R27E

Slope: Footslope of SE facing 3% gradient

Vegetation: Shortleaf pine, white oak, red and black gum

Parent Material: Regolith of thick beds of unconsolidated sandy clay loam, sandy loam and sandy clay.

Typifying Pedon:

(Colors are for moist conditions)

O1	1/2 -0"	Decayed forest liter
A1	0-8"	Very dark grayish brown (10YR 4/2) loam weak fine granular structure; soft, very friable; many roots, pH 4.8, clear smooth boundary.
A2	8-15"	Yellowish brown (10YR 5/4) loam; weak fine granular structure; soft, very friable; many roots, pH 4.8; clear wavy boundary.
B21t	15-36"	Brownish yellow (10YR 6/6) sandy clay loam; weak fine subangular blocky structure slightly hard; friable; thin continuous clay films many roots; pH 4.8; gradual smooth boundary.
B22t	36-52"	Brownish yellow (10YR 6/6) sandy clay loam; with many coarse distinct yellowish brown mottles; moderate medium subangular blocky structure; hard; friable; thick continuous clay films; few roots; many fine pores, occasional fine gravel; pH 4.8; gradual smooth boundary.
B23t	52-78"	Brownish yellow (10YR 6/8) sandy clay loam with few fine, faint gray (10YR 6/1) and coarse prominent red (2.5YR 4/8) mottles, moderate medium subangular blocky structure, hard, friable; common fine pores; thick continuous clay films on ped surfaces and in pores; few hard iron oxide concretions and few plinthite nodules; pH 4.4.

Plot No. 5 66-S-358

Classification: Aqualtic Paleudalf, coarse-loamy, mixed, thermic

Soil type: *Goldsboro loam CFI 157

Location: 110 yds. NW of SE corner Section 1, T6S, R26E

Vegetation: Shortleaf pine, white oak, red and black gum

slope: Nearly level 0-1% slope gradient (Edge of interm stream)

Parent Material: Regolith of thick beds of unconsolidated silty clay loam, loam and sandy clay.

Typifying Pedon:
(Colors are for moist soils)

O1	1-0	Decayed forest liter
A1	0-2"	Very dark grayish brown (10YR 3/2) fine sandy loam; weak fine granular structure slightly hard; very friable; pH 5.8; clear boundary.
A2	2-5"	Brown (10YR 5/3) fine sandy loam with few thin threads of organic strains; weak fine granular structure; slightly hard very friable; many roots; pH 5.8; clear boundary.
B1	5-16"	Yellowish brown (10YR 5/4) loam with few fine faint light brownish gray and dark brown mottles; weak to moderate granular structure; hard, friable; pH 5.7; gradual smooth boundary.
B21t	16-28"	Yellowish brown (10YR 5/6) loam with many medium and coarse distinct light brownish gray (10YR 6/2) mottles; weak medium and fine subangular blocky structure; hard, friable; patchy clay films on ped faces and bridging sand grains; few medium and fine pores; pH 5.1, gradual boundary.
B22t	28-52"	Same as horizon above only texture is clay loam.
B23t	52-70"+	Prominently mottled of gray (10YR 6/1) yellowish brown (10YR 5/4) and pale brown (10YR 6/3) silty clay loam, weak structure: friable; clay films present on broken ped faces. pH 4.5.

* Previously named Caddo silt loam in McCurtain County. Tenetative name given by Classification of Series of Southern States.

Plot No. 9   66-S-379

Classification: Aqualtic Paleudalf, coarse-silty, mixed thermic

Soil type: *Goldsboro loam

Location: SW corner SW 1/4 Section 8, T6S, R27E

Vegetation: Shortleaf pine, white oak, red and black gum

Slope: Nearly level 0-1% slope gradient (Upper slope near ridge top)

Parent Material: Regolith of thick beds of unconsolidated silty clay loam, loam and sandy clay.

Typifying Pedon:
(Colors are for moist soils)

O1	1-0"	Decayed forest liter
A1	0-2"	Very dark grayish brown (10YR 3/2) fine sandy loam; weak fine granular structure slightly hard; very friable; pH 5.8, clear boundary.
A2	2-10"	Pale brown (10YR 6/3) silt loam with few thin threads of organic stains; weak fine granular structure; slightly hard very friable; many roots; pH 5.8; clear boundary.
B1	10-26"	Pale brown (10YR 6/3) silt loam with few fine faint light brownish gray and dark brown mottles; weak to moderate granular structure; hard, friable; pH 5.7; granular structure; hard, friable; pH 5.7; gradual smooth boundary.
B21t	26-35"	Brownish yellow (10YR 6/6) silt loam with many medium and coarse distinct light brownish gray (10YR 6/2) mottles; weak medium and fine subangular blocky structures; hard, friable; patchy clay films on ped faces and bridging sand grains; few medium and fine pores; pH 5.1, gradual boundary.
A2'-B2t	35-41"	Light gray (10YR 7/1) silt loam with many fine and medium prominent mottles of light yellowish brown and yellowish red; weak medium subangular blocky structure; friable; slightly brittle, light gray areas stripped of clay; light yellowish brown areas coated and bridged with clay; few fine reddish concretions; pH 4.6; clear irregular boundary.
B22t	41-70"+	Prominently mottled of gray (10YR 6/1) yellowish brown (10YR 5/4) and pale brown (10YR 6/3) silty clay loam, weak structure; friable; clay films present on broken ped faces. pH 4.5.

Plot No. 14 67-S-808

Classification: Ultic Paleudalf, fine-loamy, mixed, thermic

Soil type: *Goldsboro loam

Location: SW corner SE 1/4 SE 1/4 Sec. 13, T6S, R25E

Vegetation: Shortleaf pine, white oak, red and black gum

Slope: Nearly level 0-1% slope gradient

Parent Material: Regolith of thick beds of unconsolidated silty clay loam, loam and sandy clay.

Typifying Pedon:
(Colors are for moist soils)

O1	1-0"	Decayed forest liter
A1	0-5"	Dark grayish brown (10YR 4/2) fine silt loam; weak fine granular structure slightly hard; very friable; pH 5.5; clear boundary.
A2	5-12"	Brown (10YR 5/3) fine sandy loam with few thin threads of organic strains; weak fine granular structure; slightly hard very friable; many roots; pH 5.8; clear boundary.
B21t	12-34"	Yellowish brown (10YR 5/4) loam with few faint light brownish gray and dark brown mottles; weak to moderate granular structure; hard, friable; pH 4.5; gradual smooth boundary.
B22t	34-65"	Yellowish brown (10YR 5/6) loam with many medium and coarse distinct light brownish gray (10YR 6/2) mottles; weak medium and fine subangular blocky structure; hard, friable; patchy clay films on ped faces and bridging sand grains; few medium and fine pores; pH 4.5, gradual boundary.
B23t	65-70"+	Prominently mottled of gray (10YR 6/1) yellowish brown (10YR 5/4) and pale brown (10YR 6/3) silty clay loam, weak structure; friable; clay films present on broken ped faces, pH 4.5.

Plot No. 2 66-S-350

Soil Series Classification: Ultic Hapludalf, fine-loam, mixed thermic

Soil type: Herndon loam

Location: NW corner Section 33, T4S, R27E

Vegetation: Shortleaf pine - White oak - Red and Black gum

Slope: Middle of North facing 12% gradients

Parent Material: Regolith of weathered acid interbedded shales, shist and fine grained sandstone.

Typifying Pedon:
(Colors are for moist conditions)

O1	1/2 -0"	Decayed forest liter
A1	0-2"	Very dark grayish brown (10YR 3/2) loam; weak medium granular structure, very friable; many roots; few pieces of quartz gravel; pH 5.1; clear boundary.
A2	2-5"	Yellowish brown (10YR 5/4) loam; weak fine granular structure, very friable; many roots; few pieces of quartz gravel; pH 5.0; clear wavey boundary.
B1	5-14"	Strong brown (10YR 5/6) loam; weak fine subangular blocky structure; friable; few roots; few thin patchy clay films on ped faces; pH 5.0; gradual boundary.
B21t	14-30"	Yellowish red (5YR 5/8) clay loam; moderate medium subangular blocky structure; firm; thick clay films on ped surfaces, occasional sandstone fragments; pH 4.6; gradual boundary.
B22t	30-50"	Yellowish red (5YR 5/8) clay; moderate to weak medium subangular blocky structure; firm; thin clay films on ped faces; few to common weathered shale fragments that have a greasey feel; pH 4.4; gradual boundary.
C	50-75"+	Mottled red (2.5YR 5/8) strong brown (7.5YR 5/8) white white (10YR 8/2) weathered shale and materials mixed with clay loam; pH 4.4.

Plot No. 3 66-S-354

Soil Series Classification: Ultic Hapludalf, fine loamy, mixed, thermic

Soil type: Herndon loam

Location: SE corner Section 32, T4S, R27E

Vegetation: Shortleaf pine - White oak - Red and Black gum

Slope: Middle of North facing 12% gradients

Parent Material: Regolith of weathered acid interbedded shales, shist and fine grained sandstone.

Typifying Pedon:
(Colors are for moist conditions)

O1	1/2 -0"	Decayed forest liter
A1	0-4"	Very dark grayish brown (10YR 3/2) sandy loam; weak granular structure, very friable; many roots; few pieces of quartz gravel; pH 5.1; clear boundary.
A2	4-10"	Yellowish brown (10YR 5/4) sandy loam; weak fine granular structure, very friable; many roots, few pieces of quartz gravel; pH 5.0; clear wavey boundary.
B21t	10-18"	Yellowish red (5YR 5/8) clay loam; moderate medium subangular blocky structure; firm; thick clay films on ped surfaces, occasional sandstone fragments; pH 4.6; gradual boundary.
B22t	18-37"	Yellowish red (5YR 5/8) clay; moderate to weak medium subangular blocky structure; firm; thin clay films on ped faces; few to common weathered shale fragments that have a greasey feel; pH 4.4; gradual boundary.
B23t	37-52"	Red (2.5YR 4/8) clay loam with many streaks of strong brown (7.5YR 5/8) weak fine blocky structure; a few clay films, many thick greasey shale flakes and hard sandstone fragments; pH 4.4; gradual boundary.
C	52-60"+	Mottled red (2.5YR 5/8) strong brown (7.5YR 5/8) white (10YR 8/2) weathered shale and materials mixed with clay loam; pH 4.4.

Plot No. 10 66-S-383

Classification: Typic Ochraquults - fine, silty mixed thermic

Soil type: Myatt silt loam

Location: 110 yds. NW of SE corner Section 29, T6S, R27E

Vegetation: Shortleaf pine, white oak, sweet gum and water oak

Slope: Low lying concave slope of 0 to 1 percent.

Parent Material: Regolith of thick beds of unconsolidated silty clay loam and silt loam.

Typifying Pedon:
(Colors are for moist conditions)

O1	1-0"	Partly decomposed forest liter.
A1	0-5"	Dark grayish brown (10YR 4/2) silt loam with thin threads of organic stains; weak fine granular structure; very friable; many fine roots; pH 4.6, abrupt smooth boundary.
A2q	5-16"	Light brownish gray (10YR 6/2) silt loam with many fine distinct yellowish brown (10YR 5/4) mottles; weak fine granular structure; many fine roots; pH 4.6 gradual wavy boundary.
B2tq	16-32"	Gray (10YR 6/1) silt loam with many coarse distinct yellowish brown (10YR 5/6) mottles; weak fine and medium subangular blocky structure; friable; patchy clay films of peds and in pores; pH 4.9; gradual wavy boundary.
B22tq	32-65"+	Distinctly mottled gray (10YR 5/1) and yellowish brown (10YR 5/8) heavy loam; weak medium subangular blocky structure; friable; clay films along vertical cracks; pH 4.9.

Bowie Fine Sandy Loam

Six profiles are studied in this type. It is classified through family level as ultic or typic paleudalf coarse or fine loamy mixed thermic. It was formerly classified in the red-yellow podzolic great soil group. These soils have sandy loam to fine sandy loam "A" horizons and also have yellowish brown fine sandy loam to sandy clay loam upper B horizons. All the layers are acidic in nature. These plots are situated on upland of the Coastal Plain. Slopes are generally 1 to 3% but they range from 0 to 12%. The regolith consists of thick beds of unconsolidated sandy clay loam, sandy loam, sandy clay and in some cases the regolith consists of thick beds of unconsolidated marine sediments of sandy clay loam, sandy loams and sandy clays. Permeability is moderate in the upper part of the B horizon and moderately slow in the lower part that contains plinthite. Runoff is slow to medium and internal drainage is medium. These are moderately well to well drained soils.

Goldsboro Loam

Three profiles are studied. It was named formerly as Caddo silt loam. It is classified through family level as Aqualtic or Ultic paleudalf, coarse loamy, or fine loamy, mixed thermic. This series was formerly classified in the red-yellow podzolic great soil group. These soils have grayish brown sandy loam to loam "A" horizon and thick yellowish sandy clay loam B horizons. Horizons are acidic in nature. These plots are situated on nearly level to gently sloping surfaces. In general slopes range from 0 to 5%. The regolith is a thick bed of unconsolidated silty clay loam and sandy clay. These plots are moderately well-drained and have moderate permeability. Runoff is slow to medium.

Herndon Loam

Two profiles are studied. It is classified through family level as Ultic Hapludalf, fine loamy mixed, thermic. Formerly it was classified in the red-yellow podzolic great soil group. These soils have loamy "A" horizons and yellowish brown clay loam to clay B horizons that contain more than 30% silt. These profiles are acidic in reaction. Slope gradient is generally varied from 6 to 12%. The regolith includes a weathered, acid interbedded shales, schist and fine grained sand stone. Plots are well drained having moderate permeability and medium runoff.

Myatt Silt Loam

Myatt soils are classified through family level as typic Ochraquults fine loamy, mixed thermic. Previously it was classified in the low humic gley great soil group. These soils have grayish brown coarse textured "A" horizons and gray moderately fine textured thick mottled "B" horizons. Horizons are acidic in reaction. Sites are situated on level or nearly level fairly broad stream terraces that are occasionally flooded as an upland flats. The regolith consists of thick beds of unconsolidated silty clay loam and silt loam. These soils are poorly drained having slow permeability and slow to very slow runoff.

Laboratory Analyses

The results of the particle size distribution analysis for all soil horizons are furnished in Tables XIV to XVI. Average of each soil type are furnished in Table VI and comparisons are shown in Figures 7 to 10. Variations in mechanical analysis, reflect different degrees

TABLE VI

PHYSICAL PROPERTIES

SOIL TYPE: BOWIE FINE SANDY LOAM (average of six profiles)

Hori-zon	Depth in inches	Slope per cent	Gravel per cent	Mechanical Analysis			Moisture Release Characteristics in per cent			
				Sand per cent	Silt per cent	Clay per cent	1/3 atm	1 atm	15 atm	Available water
A_1	0-5		4.0	58	33	9	11.06	8.23	5.49	5.58
A_2	5-13		3.7	61	31	9	12.19	10.13	4.66	7.53
B_{21t}	13-34		5.3	53	28	19	17.04	13.04	7.86	9.18
B_{22t}	34-48		4.5	49	26	22	18.56	12.09	9.23	9.33
SOIL TYPE: GOLDSBORO LOAM (average of three profiles)										
A_1	0-3		2.2	49	44	7	22.48	13.27	4.49	17.99
A_2	3-10		2.6	47	42	11	20.18	12.64	3.92	16.26
B_{21t}	10-25		2.7	35	49	17	24.84	15.75	5.52	19.32
B_{22t}	25-44		2.8	29	47	24	28.77	19.81	7.88	20.88
SOIL TYPE: HERNDON LOAM (average of two profiles)										
A_1	0-3		27.06	48	42	11	26.71	20.69	9.24	17.47
A_2	3-8		27.44	54	33	14	20.81	17.76	4.90	15.91
B_{21t}	8-15		13.79	41	40	20	19.44	16.43	6.30	13.14
B_{22t}	15-29		8.76	26	32	42	31.48	26.86	14.47	17.01
SOIL TYPE: MYATT SILT LOAM.										
A_1	0-5		0.5	36	56	8	26.51	18.56	9.39	17.12
A_2	5-16		0.4	37	51	12	25.83	17.04	11.08	14.75
B_{21t}	16-33		0.9	28	53	19	20.15	11.48	13.61	6.54
B_{22t}	33-36		1.0	24	51	25	20.63	20.18	14.29	6.34

of geological sorting and morphological development.

In general, Bowie fine sandy loam, Herndon loam, Goldsboro loam and Myatt silt loam follow in the order of sand content in their profiles. The spread of this particle size between the maximum and minimum within the profile is greater in Herndon loam. Gravel in large amount is found in the Herndon loam as compared to other profiles. Myatt silt loam, Goldsboro loam, Herndon loam and Bowie fine sandy loam follow in the decreasing order of silt content. The spread of this particle size between the maximum and minimum within the profile is greatest in the Herndon loam. Herndon loam, Myatt silt loam, Goldsboro loam and Bowie fine sandy loam follow in decreasing order of clay content in their profiles. The spread between the maximum and minimum clay content within the profile is greatest in the Herndon loam.

The general trend in all these profiles is a decrease of sand and silt (except Goldsboro) particle and an increase of clay content as the depth is increased. This relationship suggests the possibility of eluviation of fine clay from A into the B horizons.

One of the most pertinent problems associated with plant growth studies has been that of deciding upon the % of available water required for optimum plant growth. Water is required by plants for transpiration, turgidity and metabolic process. Soil moisture also significantly affects the rate and suite of cations exchanged from the soil to the root. The moisture regime of the soils is influenced by such factors as organic matter and the amount of finer materials. Either or both of these factors improve the water holding capacity of the soil (74). The relationship between water content and soil water suction is not unique and depends on the previous history of water intake or withdrawal. It may be argued that moisture conditions will be indicated by soil type,

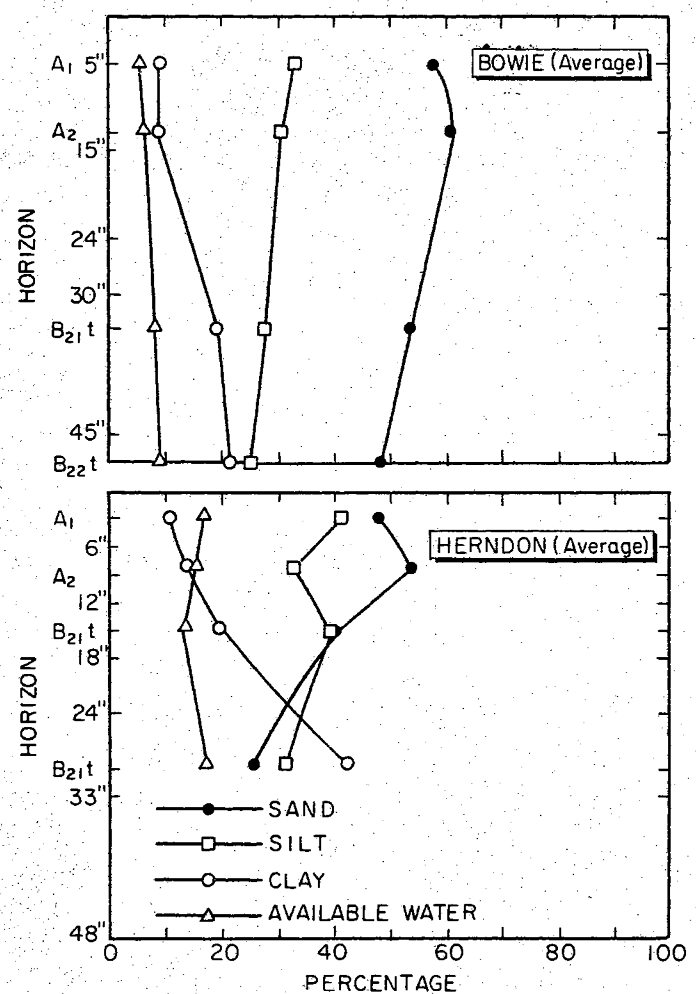


Figure 7. Particle Size Distribution of the Bowie and Herndon

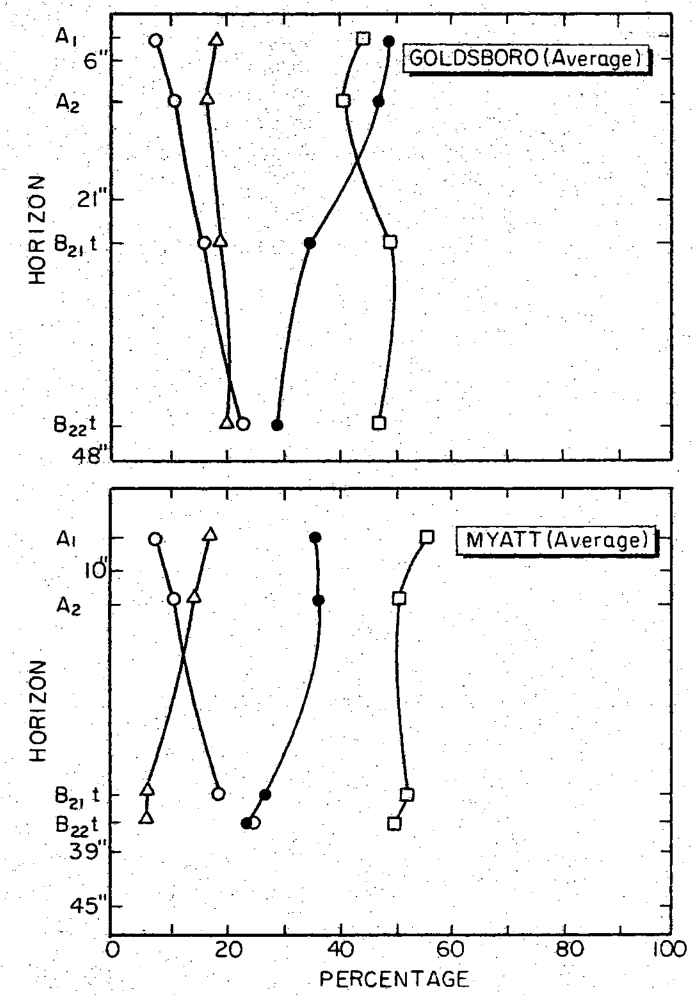


Figure 8. Particle Size Distribution of the Goldsboro and Myatt.

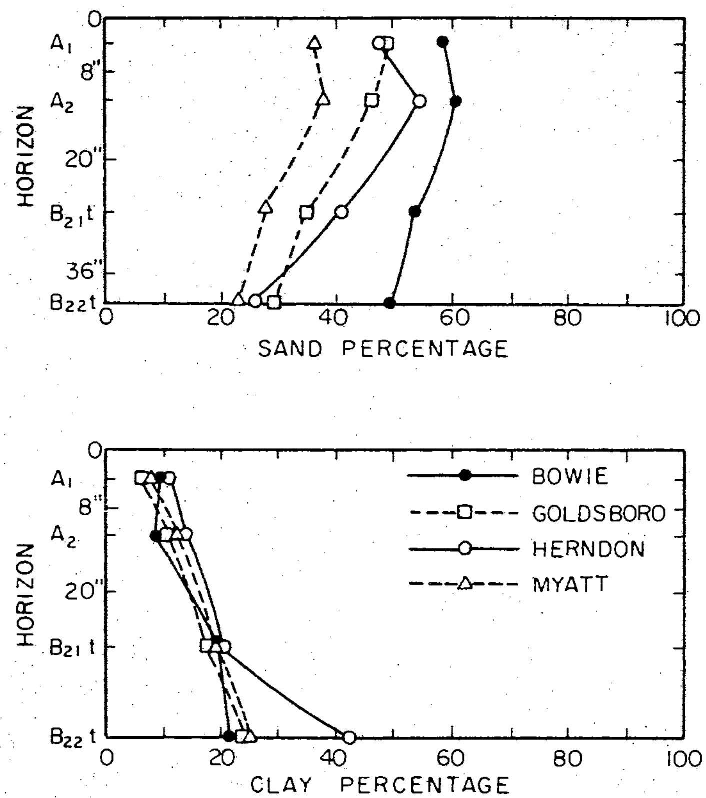


Figure 9. Comparison of Sand and Clay Distribution in Four Different Soil Types.

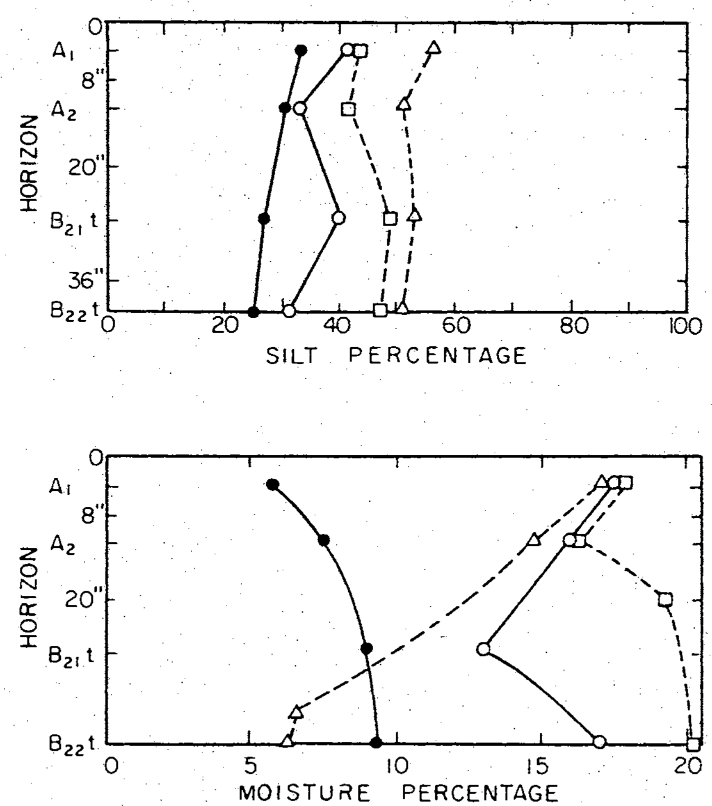


Figure 10. Comparison of Silt and Moisture Percentage in Four Different Soil Types.

slope and aspect. Slight change in slope on nearly level topography has much more effect on the profile character than an equal change on rolling topography. The most important effect of slope on soil formation is due to its influence on the moisture condition of the profile.

Moisture percentage at 1/3 atm, 1 atm, and 15 atm, and available moisture percentage for all soil horizons are given in Tables XIV to XVI. Averages of the moisture percentages for each soil series are furnished in Table VI and a comparison is shown in Figure 10. Variations in release characteristics reflect in difference content of organic matter and fine material contained in soil profiles.

Goldsboro loam, Herndon loam, Myatt silt loam and Bowie fine sandy loam follow in decreasing order of percent available moisture. Myatt silt loam, Goldsboro loam, Herndon loam and Bowie fine sandy loam follow in the decreasing order of finer material i.e. (silt + clay). Whereas Herndon loam, Myatt silt loam, Goldsboro loam and Bowie fine sandy loam follow in the order of content of clay. In percentage of nitrogen content they follow in decreasing order of Herndon, Goldsboro, Myatt and Bowie. Myatt silt loams are poorly drained and slowly permeable soils. Since Goldsboro loam, Herndon loam and Bowie fine sandy loam follow in the order of containing finer material in their profiles, it is natural for these soil profiles to follow in the same order when rating available water. Clay content of Herndon loam is higher in comparison to Goldsboro, but under field conditions Goldsboro loam may contain more available moisture. Herndon plots are situated on a slope of 12%. Goldsboro loam plots are located on 0-1% slopes. The total water determined from moisture release curve is usually higher for those soils high in clay and organic matter.

The results of exchangeable cations determinations for individual profiles are shown in Tables XVII to XIX. Average for each soil series are furnished in Table VII and illustrated in Figures 11 and 12. Bowie exchangeable calcium is dominant in the A horizon and whereas exchangeable hydrogen is dominant in the B horizon. The difference may be due to the variation in the calcium content of the litter of the trees growing on these sites. The calcium content is important in influencing pH values. Exchangeable hydrogen is slightly decreased in the A_2 horizons and again increased in quantity as the depth of the profile increases whereas exchangeable calcium followed a constantly decreasing trend. Exchangeable magnesium is slightly decreased in the A_2 horizon and increased in the B horizons. Exchangeable potassium, exchangeable sodium are present in small quantities as expected. Exchangeable potassium showed an increasing trend and whereas sodium showed slightly decreasing trend with depth. Total exchangeable cations decreased in A_2 horizons but increased in the B horizons. Exchangeable hydrogen is also increased in these horizons. Exchangeable bases (exclusive hydrogen) are decreased with depth. This type of trend due to the clay content and acidity of horizon. Overall in entire profile the exchangeable cations vary in the order of hydrogen 3.04 $>$ calcium 2.51 $>$ magnesium 2.05 $>$ sodium 0.29 $>$ potassium 0.31 m.e. /100 gm. This is due to the acidic reaction of different horizons (24).

In Goldsboro exchangeable calcium and hydrogen (except in one profile) are dominant in A & B horizons respectively. The trend of exchangeable hydrogen, calcium, magnesium and total exchangeable cations are given similar to the Bowie fine sandy loam. Similar reasons can be given in this regard for the entire profile and the exchangeable cations follow in the order of exchangeable hydrogen 2.99 $>$ calcium 1.92 $>$ magnesium 1.66 $>$ potassium 0.39 $>$ sodium 0.26 in m.e. /100 gm.

In Herndon, exchangeable hydrogen is dominant in all the horizons. It is slightly decreased in A_2 horizon and again increased in the B horizon as indicated in other profiles. Exchangeable calcium showed decreasing trend. Other exchangeable bases i.e., magnesium, potassium, sodium showed decreasing trend as the depth is increased. Total exchangeable cations and exchangeable bases are decreased in the A_2 and upper B horizons but again is increased in the lower B horizons. The exchangeable cations in the entire profile follow in the order of hydrogen 5.97 $>$ magnesium 3.15 $>$ calcium 2.47 $>$ sodium 0.54 $>$ potassium 0.44 in m.e. /100 gm.

In Myatt, exchangeable calcium is dominant only in the A_1 horizon and hydrogen is dominant in rest of the horizons. Exchangeable hydrogen and total exchangeable cations showed increased trend but whereas exchangeable calcium and magnesium showed decreasing trend. Exchangeable cations in the entire profile follow in the order of hydrogen 5.79 $>$ calcium 3.4 $>$ magnesium 2.72 $>$ sodium 0.39 $>$ potassium 0.38.

Myatt silt loam, Herndon loam, Goldsboro loam and Bowie fine sand loam follow in the order of decreasing exchangeable cations. There is not much difference between Myatt silt loam and Herndon loam. Herndon, Myatt, Goldsboro and Bowie follow in the decreasing order of clay content, whereas Herndon, Goldsboro, Myatt and Bowie follow in the decreasing order of nitrogen. In general these data indicate that where

TABLE VII

CHEMICAL PROPERTIES

SOIL TYPE: BOWIE FINE SANDY LOAM (average of six profiles)

Horizon	Depth	pH Paste 1:1	pH KCl	Exchangeable Cations M.e./100 gm.						C. E. C. M.e./100 gm
				H	Ca	Mg	K	Na	Total	
A_1	0-5	5.35	4.6	2.36	3.03	2.31	0.22	0.29	8.21	7.91
A_2	5-13	5.20	4.25	1.46	2.25	1.53	0.26	0.35	5.85	5.36
B_{21t}	13-34	4.95	3.9	3.49	2.22	2.08	0.28	0.29	8.36	7.52
B_{22t}	34-48	4.70	3.7	4.58	2.22	2.75	0.32	0.26	10.13	10.74
SOIL TYPE: GOLDSBORO LOAM (average of three profiles)										
A_1	0-3	5.3	4.5	3.89	3.03	2.80	0.39	0.33	10.44	10.16
A_2	3-10	5.3	4.25	2.65	2.37	2.23	0.26	0.35	7.86	8.12
B_{21t}	10-25	5.1	4.1	3.49	1.77	1.47	0.60	0.34	7.67	6.76
B_{22t}	25-44	4.9	3.75	4.65	3.00	2.24	0.40	0.27	10.56	10.23
SOIL TYPE: HERNDON LOAM (average of two profiles)										
A_1	0-3	4.95	4.6	6.16	4.55	3.76	0.36	0.61	15.44	14.25
A_2	3-8	4.95	4.3	4.99	2.25	2.29	0.34	0.54	10.41	9.81
B_{21t}	8-15	4.9	3.95	5.17	1.40	2.50	0.75	0.54	10.36	9.92
B_{22t}	15-29	4.7	3.8	7.59	1.70	4.02	0.30	0.48	14.09	15.39

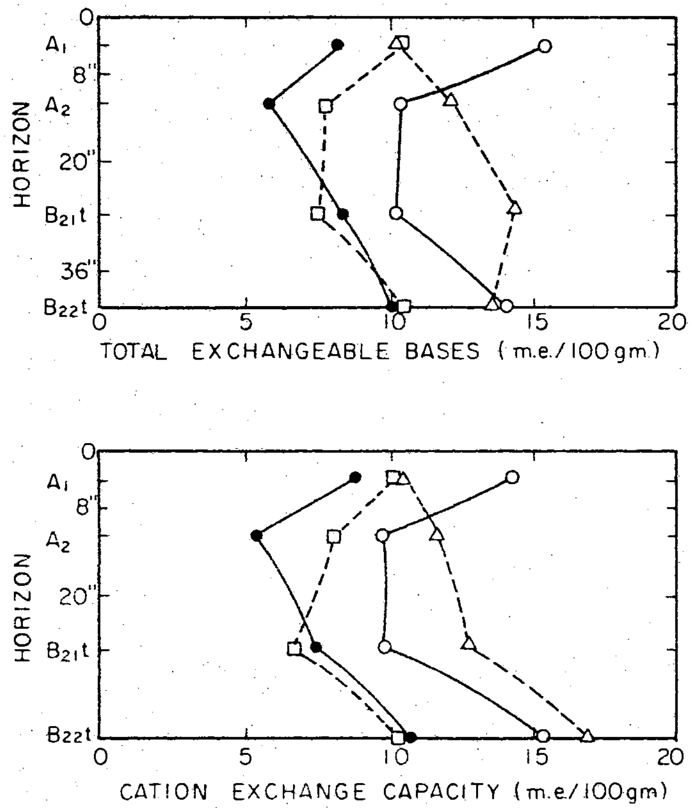


Figure 11. Comparison of Exchangeable Bases and C.E.C. in Four Different Soil Types.

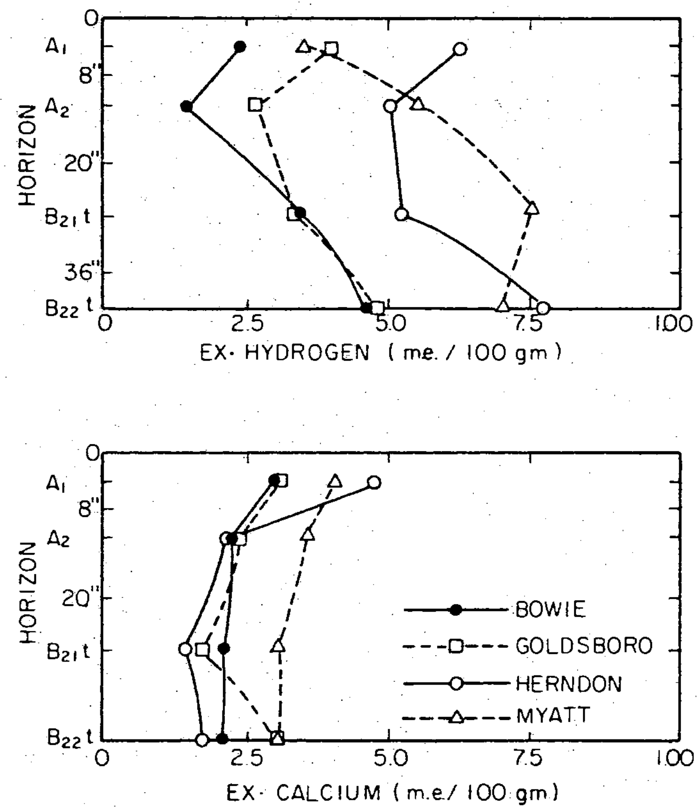


Figure 12. Comparison of Exchangeable Hydrogen and Calcium in Four Different Soil Types.

there is more clay and nitrogen, there more exchangeable cations are present, and the presence of more or less exchangeable hydrogen and calcium is related to the reaction of the soil horizons.

In addition to the above these profiles indicate in general the following trends. Exchangeable calcium is dominant in the A_1 horizon (except Herndon loam). This may be due to the variation in the calcium content of the litter of the trees growing on the sites. Exchangeable bases i.e. (Ca, Mg, K, Na) showed decreasing trend in A_2 in B_{21t} and again showed slightly increasing trend (except Bowie) in B_{22t} horizon. This may be due to the downward movement i.e., eluviation, of colloidal content from the A_2 horizon. It may be also due to the decrease of available moisture in the A_2 horizon in comparison with the A_1 horizon (except Bowie). Soil moisture may also significantly affect the rate and suite of cations exchanged from the soil to the plant root. The variation in the total amount of cation exchanged through the moisture range may be explained in part on the basis of differences in the pore size distribution between soil types (11). There is an increase of exchangeable hydrogen in the B_2 horizons which may be due to the acidity caused by accumulation of leached sesquioxides in these horizons. There is a slight increase of exchangeable bases in the lower B horizons (except Bowie). This may be due to accumulation of colloids. Results of C.E.C. of each plot is furnished in Tables XVII to XIX. Averages of each soil type are given in Table VII and shown in Figure 11.

Myatt silt loam, Herndon loam, Goldsboro loam and Bowie fine sandy loam follow in the decreasing order of C.E.C. In clay content they follow in order Herndon, Myatt, Goldsboro and Bowie. Herndon contained more clay and nitrogen than Myatt but the Myatt soil has a higher C.E.C.

This may be due to the presence of a different type of clay in the Myatt soil. It is clearly indicated that C.E.C. of these profiles depends on clay content, nitrogen and available moisture.

Soil reaction may affect plant development through its influence on the availability of certain elements required for growth. It indicates indirectly a number of soil fertility characteristics. Soil is acidic when it lacks the basic plant nutrients such as calcium, magnesium and potassium. Acid soil develops from parent material which is low in these nutrients or from which these bases have been leached. Phosphorus is changed to relatively insoluble forms in strongly acid soils. The activity of desirable soil microorganisms, particularly the nitrogen fixers and nitrifiers, is seriously depressed in strongly acid soils. A high amount of active hydrogen in normal soils is usually a reliable indication of the lack of basic plant nutrients such as calcium, magnesium and potassium. The pH is a measure of the resulting activity of the hydrogen ions when the soil is mixed with distilled water in a 1:1 ratio. Soil reaction data are presented in Tables XX to XXII. Averages of each soil type are presented in Table VIII and illustrated in Figure 13.

Nitrogen data are shown in Tables XIX to XXI. Averages of each soil series are furnished in Table VIII and shown in Figure 13. Plants absorb nitrogen as ammonium and nitrate ions. Most of the nitrogen in forest soil is bound up in organic tissues. However, since the foilage among the different species varies in the amount of calcium and nitrogen it contains, the quantities of these elements added to the forest floor under different stands varies considerably. Soil organic layers of forest soils are valuable diagnostic tools for timber and water shed

TABLE VIII

CHEMICAL PROPERTIES

SOIL TYPE: BOWIE FINE SANDY LOAM (Average of six profiles)

HORIZON	DEPTH	pH		NITROGEN PER CENT	AVAILABLE NUTRIENTS LBS. PER ACRE	
		KCl	Paste 1:1		Phosphorus	Potassium
A_1	0-5	4.6	5.35	0.081	8.83	112
A_2	5-13	4.25	5.20	0.025	5.66	81
B_{21t}	13-34	3.9	4.95	0.018	4.08	104
B_{22t}	34-48	3.7	4.70	0.015	4.53	140
SOIL TYPE: GOLDSBORO LOAM (average of three profiles						
A_1	0-3	4.5	5.3	0.069	10.12	83
A_2	3-10	4.25	5.3	0.033	5.65	67
B_{21t}	10-25	4.1	5.1	0.022	3.14	90
B_{22t}	25-44	3.75	4.9	0.020	3.77	113
SOIL TYPE: HERNDON LOAM (average of two profiles)						
A_1	0-3	4.6	4.95	0.189	47.13	340
A_2	3-8	4.3	4.95	0.081	31.11	275
B_{21t}	8-15	3.95	4.9	0.027	12.26	283
B_{22t}	15-29	3.80	4.7	0.039	3.77	227

management. They are amenable to change by modification of the vegetation on the site. Since nitrogen in the soil is closely correlated with organic matter content the same relative relationship holds for the nitrogen as for organic matter. The quality and nature of organic matter occurring at various depths in soils are dependent upon a number of environmental factors. The most clearly related factors are probably rainfall and type of vegetative cover.

Results of available phosphorus analyses of individual plots are shown in Tables XX to XXII. Average for each soil type is given in Table VIII and comparison is illustrated in Figure 14.

Phosphorus is decreased in quantity in all the profiles with depth. The organic matter indirectly enhances the availability of this element. With depth there is a decrease in pH and probably an increase in hydroxides of iron and aluminum. These oxides are colloidal in nature and phosphate ions are attracted and held to the surface of the particle in the form of a basic iron or aluminum phosphates. Herndon loam has more nitrogen and C.E.C. compared to the other profiles. It is an almost universal truism that mineral soils with high exchange capacity are more fertile than those with low cation exchange capacity. Myatt, Goldsboro and Bowie soil follow in an increasing order of available phosphorus.

Plants absorb potassium only in the form of the potassium ion. This absorption takes place from the soil solution. It is estimated that only 0.01% of the total potassium is in the exchangeable form. Potassium, even though plentiful in the unavailable form, must often be added to the soil to provide sufficient amounts in the available form (10).

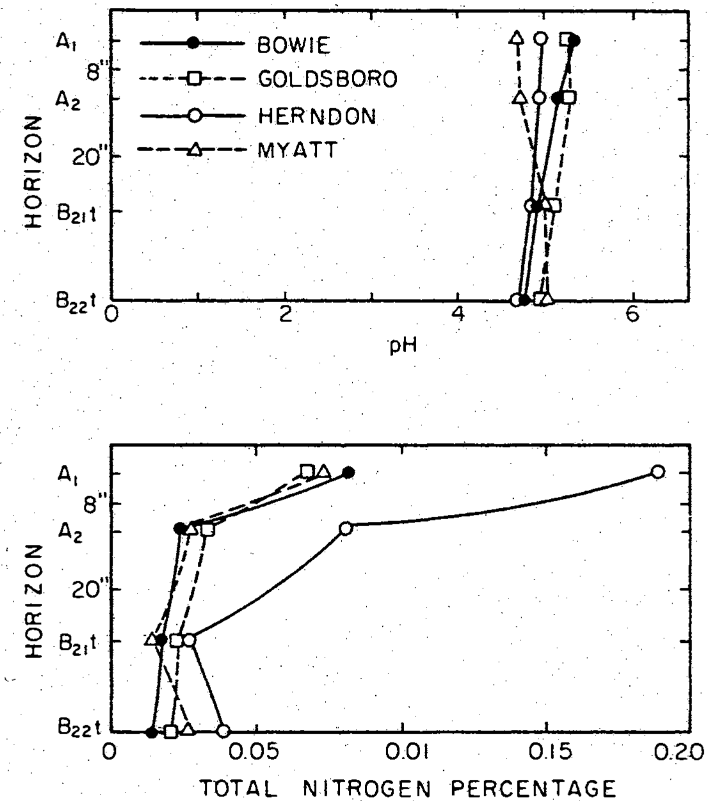


Figure 13. Comparison of pH, Nitrogen Percentage in Four Different Soil Types.

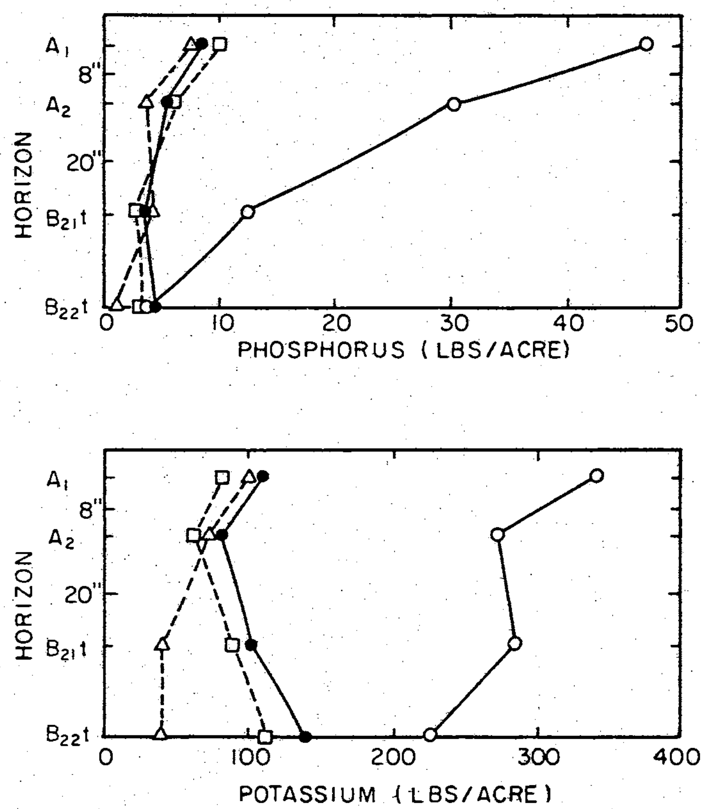


Figure 14. Comparison of Available Nutrients in Four Different Soil Types.

Results of available potassium of individual plots are shown in Tables XX to XXII. Average for each soil type is given in Table VIII and comparison is illustrated in Figure 14.

Herndon is highest in available potassium followed by Bowie, Goldsboro, Myatt. Myatt is poorly drained type of soil. Wetting and drying may be the cause for the lower availability of potassium in this soil. In the remainder of the soil the same causes may be used to explain the difference in potassium content as were used to explain difference in phosphorus content. All of these profiles showed a particular trend in having higher content of potassium in A_1 but decreased in A_2 horizons. Again, the quantity is increased in the B horizons with the exception of the Myatt soil.

Site Index of Shortleaf Pine and Soil Properties

Numerous studies have been conducted to test the relationship between physical, chemical and biological properties of soil and the growth of forests. Site quality is determined by soil properties and other features of the site which influence the quality and quantity of the growing space for tree roots. Success or failure in demonstrating significant relationships between soil properties and plant growth depends largely upon the investigator's ability to select for measurement and statistical tests the independent variables that are initially limiting or most limiting.

The growth of a tree is an expression or function of a number of factors, many of which are environmental. The more important factors of the environment are; temperature, humidity, rainfall, parent material, soil profile development, topography and depth to the water table. Environmental factors act and interact with vegetation through time upon the soil material and the final results are best expressed by the soil profile itself. This is most obvious in those areas where the soil is mature and has been developed in place for a long period of time.

In the first test of significance twenty-one soil variables were selected as independent variables and an attempt was made to correlate them with the site index of shortleaf pine as shown below. These variables are presented in Table XXIII.

In the second test of significance thirty-six of the most promising soil variables were selected and an attempt was made to correlate them with site index. These variables are presented in Table XXIV. Also an attempt was made to derive suitable regression equations for the site index of shortleaf pine versus thirty-six, twenty-one respectively for the Coastal Plain soils.

In this study of regression and correlation between soil properties and site index, variables are expressed in two ways; one was to express the concentration of a factor, and the second was to multiply this concentration of a factor by inches of the horizon possessing the concentration, this resulted in giving a weight of the factor present in a particular horizon or group of horizons.

Twenty-one soil variables in the first set are as follows:

1) depth, 2) slope, 3) gravel, 4) sand, 5) silt, 6) clay, 7) ex.hydrogen, 8) ex.calcium, 9) ex.magnesium, 10) ex.potassium, 11) ex.sodium, 12) C.E.C., 13) moist 1/3 atm, 14) moist 1 atm, 15) moist 15 atm., 16) available moisture, 17) % nitrogen, 18) available phosphorus, 19) available potassium, 20) pH (1:1 paste), 21) pH (KCl).

Thirty-six soil variables in the second set are as follows:

1) depth A, 2) depth (A+B), 3) texture of top soil, 4) Sand A x Depth A), 5) (silt A x depth A), 6) (clay A x depth A), 7) (nitrogen A x depth A), 8) $\frac{\text{(silt + clay of B)}}{\text{(field capacity of B)}}$ x (depth A), 9) (silt B x depth A), 10) (clay Bx depth A), 11) gravel in A, 12) sand in A, 13) clay in A, 14) (silt + clay) A 15) pH in A, 16) nitrogen % in A, 17) nitrogen % (A+B), 18) available phosphorus in A, 19) available potassium in A, 20) C.E.C. in A, 21) ex.(calcium + magnesium) in A, 22) ex.hydrogen in A, 23) gravel in B, 24) Sand in B, 25) clay in B, 26) (silt + clay) in B, 27) avail phosphorus B, 28) available potassium in B, 29) C.E.C. in B, 30) ex (calcium + magnesium) in B, 31) ex.hydrogen in B, 32) $\frac{\text{(silt + clay) in B}}{\text{(field capacity of B)}}$, 33) $\frac{\text{(silt + clay) in B}}{\text{depth B}}$, 34) $\frac{\text{(silt + clay) in B}}{\text{Depth A}}$, 35) soil series, 36) parent material.

Before discussing site index and soil variables, it is necessary to know about the correlation coefficient of these soil properties indicating the relationship between and among soil factors. Two additional soil variables i.e. (silt and clay), total exchangeable bases were added to the first test of significance and two soil variables i.e. soil series, parent material were omitted in the second test of significance for correlation studies. Results of the correlation coefficients of soil properties and significant values are presented in Tables X and XI correlations are discussed at appropriate places.

Previously it was mentioned that the site index was nothing more than a definition which stated that the average height of dominant and co-dominant trees at 50 years of age. Site index of shortleaf pine is calculated for each plot and presented in Table IX. At the same time site index curves are illustrated in Figures 15 to 18.

Site index was found to vary from 80 to 106 with an average of 94.83 ft. for Bowie, 92 to 104 with an average of 97.66 ft. for Goldsboro, 79 to 87 with an average of 83 ft. for Herndon and 102 ft. for Myatt. The mean site index was 94. Three better and three inferior plots in Bowie, two better and one inferior plots in Goldsboro, two inferior type plots in Herndon loam and one better type in Myatt silt loam were found in this area when mean site index was taken into consideration. Half of these plots contained better site indices and half of them contained inferior site indices.

The depth of the surface soil is a measure of the soil variable for occupancy by small roots. In general, the smaller roots (0.04 to 0.4") are concentrated in the layer of humus (A_1 horizon). An increasing thickness of the A_1 horizon is related to an increase in site quality. The thicker A_1 horizon contains a higher total supply of organic matter and mineral elements. The higher total supply of organic matter also improves the water holding capacity. Small roots are more heavily concentrated in the A horizon than in the sub soil. A deeper soil horizon permits a greater and more effective root system to develop, and as a result growth above the ground is more rapid. Depth of the surface soil or depth to the fine textured soil depth to least permeable layer or depth to mottling reflect on quantity of growing space which implies effective root depth for trees. The effects of increasing the soil depth on growth decreases beyond a certain point. An attempt was made in this study to evaluate the effect of the thickness of the A_1, A_2, B_{21t}, and B_{22t} individually and in combination versus site index.

TABLE IX

SITE INDEX OF SHORTLEAF PINE
IN SELECTED PLOTS

S.No.	Plot Number	Soil Type	Height of Trees	Average Height	Age of Trees	Average Age	Site Index
1	plot no. 6 (367)	Bowie fine sandy loam	92 92	92	39 35	37	106
2	plot no. 7 (371)	Bowie fine sandy loam	79 84	81.5	47 48	47.5	84
3	plot no. 8 (375	Bowie fine sandy loam	--	73.3	--	42.0	80
4	plot no. 11 (387)	Bowie fine sandy loam	--	95.0	--	51.0	95
5	plot no. 12 (392)	Bowie fine sandy loam	92 101 97	96.6	36 39 42	39.0	108
6	plot no. 13 (805)	Bowie fine sandy loam	85 94 80	86.3	42 45 37	41.3	96
7	plot no. 5 (358)	Goldsboro loam	96 98 92	95.3	41 41 42	41.3	104
8	plot no. 9 (379)	Goldsboro loam	--	79.6	--	37.0	92
9	plot no. 14 (808)	Goldsboro loam	88 81 80	83.0	38 35 37	36.6	97
10	plot no. 2 (350)	Herndon loam	--	74.6	--	44.3	79
11	plot no. 3 (354)	Herndon loam	87 89 82	86.0	48 50 48	48.7	87
12	plot no. 10 (383)	Maytt silt loam	--	88.7	--	37	102

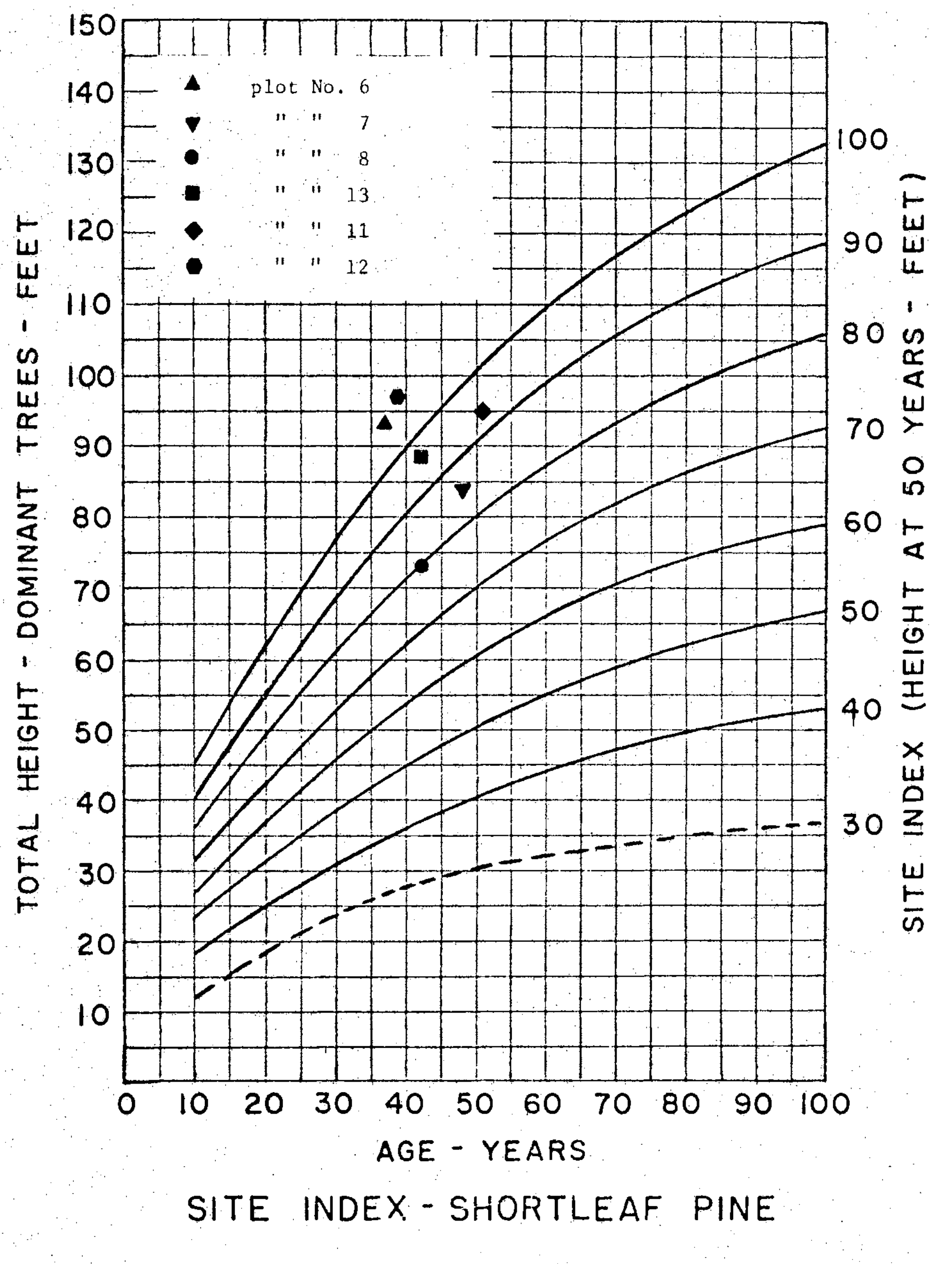
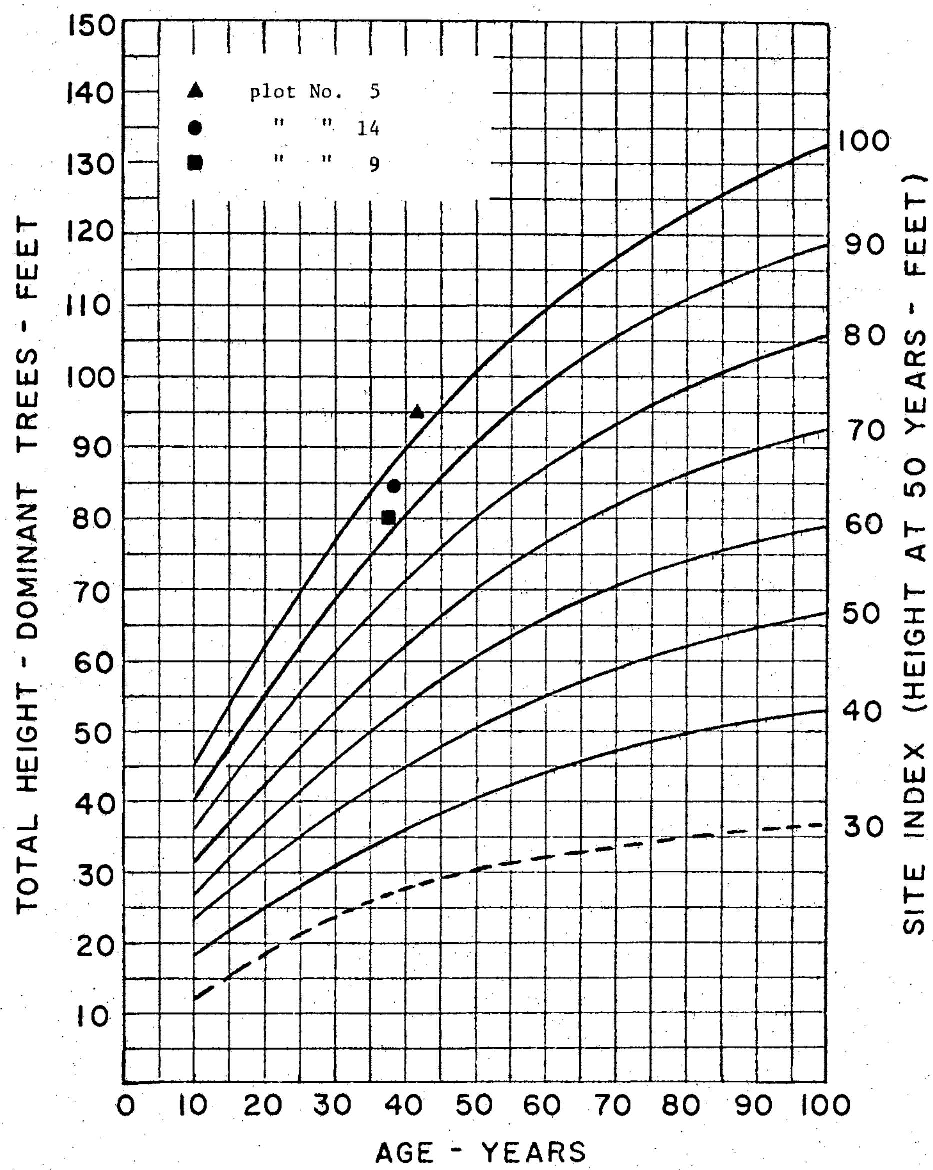


Figure 15. Site Index of Shortleaf Pine in Bowie Fine Snady Loam Plots.



SITE INDEX - SHORTLEAF PINE

Figure 16. Site Index of Shortleaf Pine in Goldsboro Loam Plots.

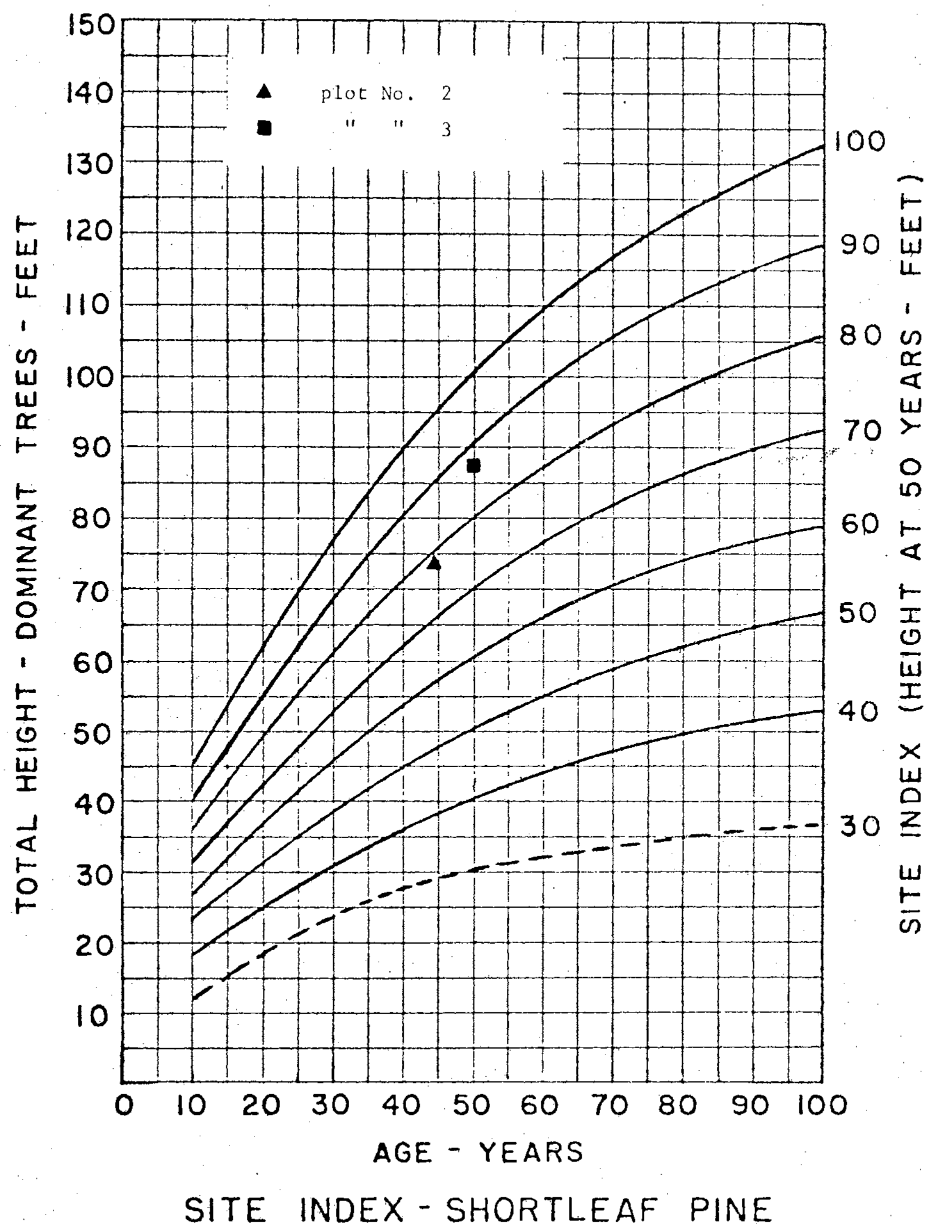


Figure 17. Site Index of Shortleaf Pine in Herndon Loam Plots.

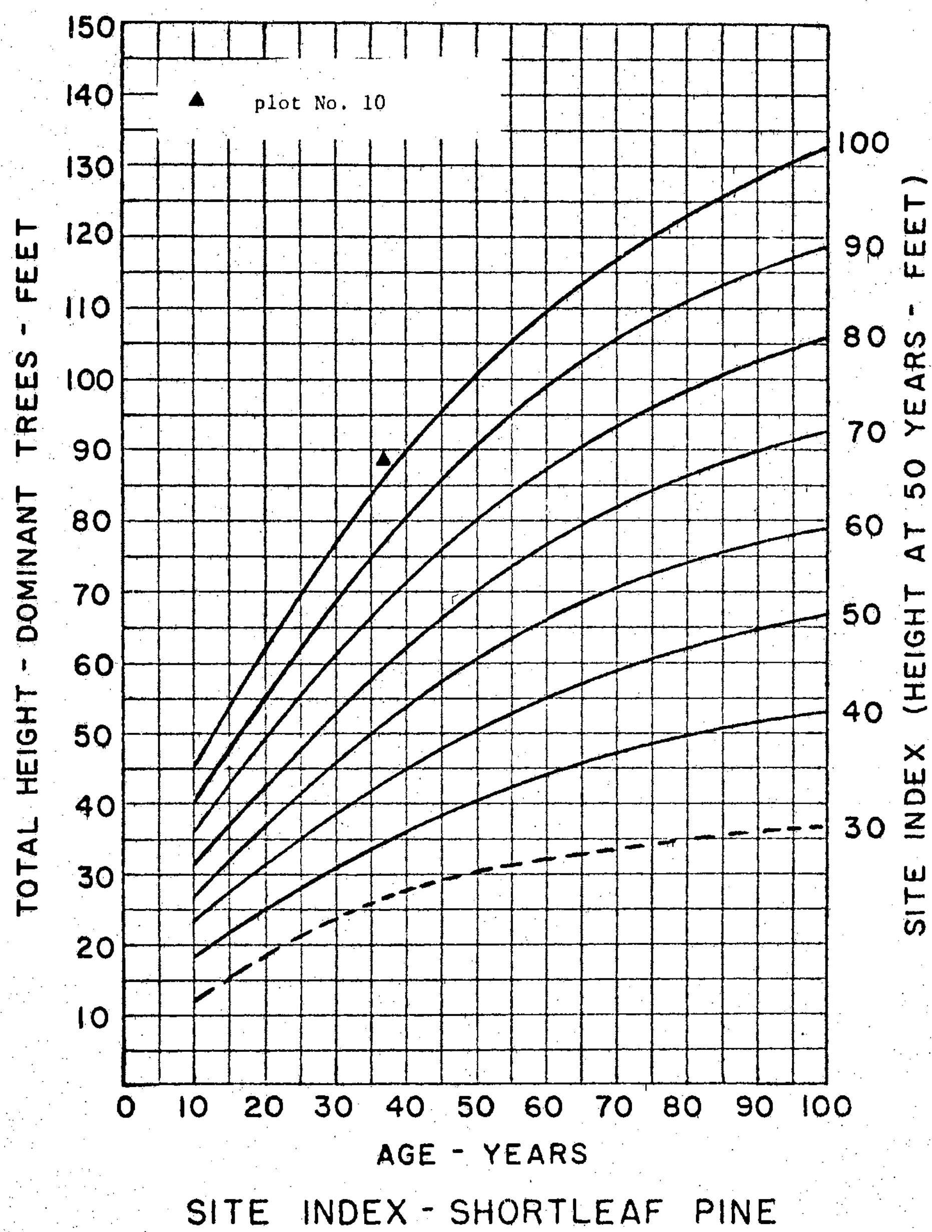


Figure 18. Site Index of Shortleaf Pine in Myatt Silt Loam.

TABLE X

CORRELATION COEFFICIENT AMONG SOIL PROPERTIES
(Significant values only)

S. No.	Variable	Variable	"r"
1	Depth	Gravel	-0.55912**
2	Depth	Sand	-0.54205**
3	Depth	Moisture 1/3 atm	-0.33189*
4	Depth	Moisture 1 atm	-0.40304*
5	Depth	Available water	-0.37999**
6	Depth	Nitrogen	-0.37065**
7	Depth	Available phosphorus	-0.38328**
8	Depth	Available potassium	-0.59503**
9	Slope	Silt + clay	0.36694**
10	Slope	Ex. magnesium	-0.49381**
11	Slope	Moisture 15 atm	0.29772*
12	Slope	Nitrogen	-0.41977**
13	Slope	Available phosphorus	-0.32886*
14	Slope	pH Paste 1:1	-0.36876**
15	Slope	pH KCl	-0.56044**
16	Gravel	Sand	0.69805**
17	Gravel	Ex. potassium	0.27951*
18	Gravel	Total ex. cations	0.48411**
19	Gravel	Slope	0.38406**
20	Gravel	C. E. C.	0.31376*
21	Gravel	Moisture 1 atm	0.380552**
22	Gravel	Nitrogen	0.409.01**
23	Gravel	Available phosphorus	0.51451**
24	Gravel	Available potassium	0.77517**
25	Sand	Total ex. cations	0.50271**
26	Sand	Nitrogen	0.61365**
27	Sand	Available phosphorus	0.83048**
28	Sand	Available potassium	0.81958**
29	Silt	Clay	-0.74568**
30	Silt	Silt + clay	-0.58367**
31	Silt	Ex. hydrogen	-0.99529**
32	Silt	Ex. calcium	-0.43190**
33	Silt	Ex. potassium	-0.35233*
34	Silt	Slope	-0.56783**
35	Silt	C.E.C.	-0.54231**
36	Silt	Moisture 1/3 atm	-0.78838**
37	Silt	Moisture 1 atm	-0.77812**
38	Silt	Moisture 15 atm	-0.49374**
39	Silt	Available water	-0.610370**
40	Silt	pH Paste 1:1	0.51486**

*Significant at .05 level
**Significant at .01 level

TABLE X — Continued

S. No.	Variable	Variable	r
41	Silt	pH KCl	0.46884**
42	Clay	Ex. hydrogen	0.73372**
43	Clay	Slope	0.28602*
44	Clay	Moisture 1/3 atm	0.60150**
45	Clay	Moisture 1 atm	0.45021**
46	Clay	Moisture 15 atm	0.66316**
47	Clay	Available water	0.61644**
48	Silt & Clay	Ex. hydrogen	0.59123**
49	Silt & Clay	Ex. calcium	0.52936**
50	Silt & Clay	Ex Potassium	0.35084*
51	Silt & Clay	Slope	0.49887**
52	Silt & Clay	C. E. C.	0.57607*
53	Silt & Clay	Moisture 1/3 atm	0.44356**
54	Silt & Clay	Moisture 1 atm	0.61262**
55	Silt & Clay	Moisture 15 atm	0.66316**
56	Silt & Clay	Nitrogen	-0.3387*
57	Silt & Clay	pH paste	-0.46031**
58	Silt & Clay	pH KCl	0.54744**
59	Ex.Hydrogen	Ex. calcium	0.43661**
60	Ex.Hydrogen	Ex. potassium	0.34241*
61	Ex.Hydrogen	Slope	0.56377**
62	Ex.Hydrogen	C. E. C.	0.54408**
63	Ex.Hydrogen	Moisture 1/3 atm	0.79123**
64	Ex.Hydrogen	Moisture 1 atm	0.78119**
65	Ex.Hydrogen	Moisture 15 atm	0.50063**
66	Ex.Hydrogen	Available water	0.61015**
67	Ex.Hydrogen	pH paste	-0.52398**
68	Ex.Hydrogen	pH KCl	-0.48688**
69	Ex.Calcium	Slope	0.47549**
70	Ex.Calcium	C. E. C.	0.53746**
71	Ex.Calcium	Moisture 1/3 atm	0.43565**
72	Ex.Calcium	Moisture 1 atm	0.53668**
73	Ex.Calcium	Moisture 15 atm	0.50078**
74	Ex.Calcium	pH paste	-0.44891**
75	Ex.Calcium	pH KCl	-0.44954**
76	Ex.Magnesium	Ex. potassium	0.48024**
77	Ex.Magnesium	Slope	0.37838**
78	Ex.Magnesium	C. E. C.	0.30037*
79	Ex.Magnesium	Nitrogen	0.47558**
80	Ex.Magnesium	Available Phosphorus	0.34002*
81	Ex.Magnesium	pH KCl	0.46289*
82	Ex.Potassium	Slope	0.69200**

*Significant at .05 level
**Significant at .01 level

TABLE X — Continued

S. No.	Variable	Variable	r
83	Ex. potassium	C. E. C.	0.72435**
84	Ex. potassium	Moisture 1/3 atm	0.33466*
85	Ex. potassium	Moisture 1 atm	0.42529**
86	Ex. potassium	Moisture 15 atm	0.30773*
87	Ex. potassium	Nitrogen	0.29923*
88	Ex. potassium	Available phosphorus	0.29467*
89	Ex. potassium	Available potassium	0.44324**
	Ex. Na	Nil	
90	Total ex. cations	Nitrogen	0.34366*
91	Total ex. cations	Available phosphorus	0.44069*
92	Total ex. cations	Available potassium	0.44328**
93	Slope	C. E. C.	0.89002**
94	Slope	Moisture 1/3 atm	0.51350**
95	Slope	Moisture 1 atm	0.63143**
96	Slope	Moisture 15 atm	0.55953**
97	Slope	Available water	0.28413*
98	Slope	Nitrogen	0.32086*
99	Slope	Available potassium	0.46993**
100	C. E. C.	Moisture 1/3 atm	0.49723**
101	C. E. C.	Moisture 1 atm	0.63205**
102	C. E. C.	Moisture 15 atm	0.62694**
103	C. E. C.	Available potassium	0.43290**
104	Moisture 1/3 atm	Moisture 1 atm	0.89692**
105	Moisture 1/3 atm	Moisture 15 atm	0.36965**
106	Moisture 1/3 atm	Available water	0.89655**
107	Moisture 1/3 atm	Available potassium	0.30563*
108	Moisture 1/3 atm	pH paste 1:1	-0.50022**
109	Moisture 1/3 atm	pH KCl	-.037584**
110	Moisture 1 atm	Moisture 15 atm	0.49834**
111	Moisture 1 atm	Available water	0.77246**
112	Moisture 1 atm	Available potassium	0.45234**
113	Moisture 1 atm	pH paste 1:1	-0.50407**
114	Moisture 1 atm	pH KCl	-0.36412**
115	Moisture 15 atm	pH paste 1:1	-0.44732**
116	Moisture 15 atm	pH KCl	-0.45033**
117	Nitrogen	Available phosphorus	0.82295**
118	Nitrogen	Available potassium	0.59291**
119	Nitrogen	pH	0.45651**
120	Available phos.	Available potassium	0.79225**
121	Available phos.	pH KCl	0.34011*
122	pH paste 1:1	pH KCl	0.86496**

*Significant at .05 level
**Significant at .01 level

TABLE XI

CORRELATION COEFFICIENT AMONG SOIL PROPERTIES (2nd Set)
(Significant Values only)

S. No.	Variable	Variable	"r"
1	Depth of A horizon	Sand A x Depth A	0.72318**
2	Depth of A horizon	Silt A x Depth A	0.78880**
3	Depth of A horizon	(Silt + Clay) of BxDepth A / Field Capacity of B	0.79197**
4	Depth of A horizon	Silt B x Depth A	0.68710*
5	Depth of A horizon	Clay B x Depth A	0.69550*
6	Depth of A horizon	Gravel in A	-0.61778*
7	Depth of A horizon	pH of A	-0.68312*
8	Depth of A horizon	Available K in A	-0.73966**
9	Depth of A horizon	Ex. (Ca+Mg) in A	-0.68833*
10	Depth of A horizon	Gravel in B	-0.63023*
11	Depth of A horizon	Available P in B	-0.61185*
12	Depth of A horizon	Available K in B	-0.58432*
13	Depth of A horizon	Ex. (Ca+Mg) in B	-0.62237*
14	Depth of A horizon	(Silt + Clay) of B / Depth of A	-0.83855**
15	Depth (A+B)	C.E.C. of A	-0.58630*
16	Depth (A+B)	Ex. (Ca+Mg) in A	-0.63461*
17	Depth (A+B)	Ex. (Ca+Mg) in B	-0.77373**
18	Texture of Top Soil	Silt A x Depth A	0.60946*
19	Texture of Top Soil	Clay A x Depth A	0.61816*
20	Texture of Top Soil	Silt B x Depth B	0.60797*
21	Texture of Top Soil	Sand in A	-0.77243**
22	Texture of Top Soil	Silt + Clay in A	0.77261**
23	Sand A x Depth A	Clay in A	-0.72368**
24	Sand A x Depth A	C.E.C. in A	-0.71819**
25	Sand A x Depth A	Ex. (Ca+Mg) in A	-0.60306*
26	Sand A x Depth A	(Silt + Clay) of B / Depth of A	-0.80537*
27	Silt A x Depth A	Clay in A x Depth A	0.79308**
28	Silt A x Depth A	(Silt + Clay)of BxDepth A / Field Capacity of B	0.62576**
29	Silt A x Depth A	Silt B x Depth A	0.94380**
30	Silt A x Depth A	Sand in A	-0.70151*
31	Silt A x Depth A	(Silt + Clay) in A	0.71829**
32	Silt A x Depth A	pH of A	0.76142**
33	Clay in A x Depth A	(Silt+Clay) of BxDepth A / Field Capacity of B	0.64122*
34	Clay in A x Depth A	Silt in B x Depth A	0.75695**

*Significant at .05 level
**Significant at 0.01 level

TABLE XI — Continued

S. No.	Variable	Variable	r
35	Clay in A x Depth A	Sand in A	-0.74037**
36	Clay in A x Depth A	Clay in A	0.63072*
37	Clay in A x Depth A	(Silt+Clay) in A	0.73694**
38	Clay in A x Depth A	pH of A	0.75730**
39	Nitrogen A x Depth A	pH of A	-0.61269*
40	Nitrogen A x Depth A	Nitrogen in A	0.63458*
41	Nitrogen A x Depth A	Nitrogen in (A+B)	0.67692*
42	Nitrogen A x Depth A	(Silt+Clay) of B / Depth B	0.66505*
43	(Silt+Clay)of BxDepA / Field Capacity B	pH of A	-0.60999*
44	(Silt+Clay)of BxDepA / Field Capacity B	Available K in A	-0.65051*
45	(Silt+Clay)of BxDepA / Field Capacity B	Available K in B	-0.62676*
46	(Silt+Clay)of BxDepA / Field Capacity B	Ex.(Ca+Mg) in B	-0.60708*
47	(Silt+Clay)of BxDepA / Field Capacity B	(Silt+Clay) in B / Field Capacity B	-0.87209**
48	(Silt+Clay)of BxDepA / Field Capacity B	(Silt+Clay) in B / Depth A	0.77407**
49	Silt B x Depth A	Sand in A	-0.73159**
50	Silt B x Depth A	(Silt+Clay) in A	0.74334**
51	Silt B x Depth A	pH of A	-0.71143**
52	Silt B x Depth A	Sand in B	-0.66133*
53	Silt B x Depth A	(Silt+Clay) in B	0.66522*
54	Gravel in A	Nitrogen in A	0.92771**
55	Gravel	Nitrogen in (A+B)	0.92101**
56	Gravel in A	Available p in A	0.93166**
57	Gravel in A	Ex. (Ca+Mg) in A	0.64408*
58	Gravel in A	Gravel in B	0.89855**
59	Gravel in A	Available p in B	0.82061**
60	Gravel in A	Available K in B	0.87115**
61	Gravel in A	Ex. (Ca+Mg) in B	0.64200*
62	Gravel in A	(Silt+Clay) in B / Depth A	0.76172**
63	Sand in A	Clay in A	-0.72852**
64	Sand in A	(Silt+Clay) in A	-0.99930**
65	Sand in A	pH of A	0.59038*
66	Sand in A	Sand in B	0.81561**
67	Sand in A	(Silt+Clay) in B	-0.81943**
68	Sand in A	(Silt+Clay) in B / Depth A	-0.58343**

*Significant at 0.05 level
**Significant at 0.01 level

TABLE XI — Continued

S. No.	Variable	Variable	"r"
69	Clay in A	(Silt+Clay) in A	0.70684*
70	Clay in A	C.E.C. in A	0.61671*
71	(Silt+Clay) in A	pH of A	-0.59639*
72	(Silt+Clay) in A	Sand in B	-0.82091**
73	(Silt+Clay) in A	(Silt+Clay) in B	0.82461**
74	(Silt+Clay) in A	(Silt+Clay in B / Depth B	0.58956*
75	Nitrogen in A	Nitrogen in (A+B)	0.98123**
76	Nitrogen in A	Available p in A	0.94716**
77	Nitrogen in A	Ex.(Ca+Mg) in A	0.58958*
78	Nitrogen in A	Gravel in B	0.83547**
79	Nitrogen in A	Available p in B	0.80708**
80	Nitrogen in A	Available K in B	0.87124**
81	Nitrogen in A	(Silt+Clay) in B / Depth A	0.72882**
82	Nitrogen (A+B)	Available p in A	0.93249**
83	Nitrogen (A+B)	Gravel in B	0.82309**
84	Nitrogen (A+B)	Available p in B	0.75284**
85	Nitrogen (A+B)	Available K in B	0.82438**
86	Nitrogen (A+B)	(Silt+Clay) in B / Depth A	0.70492*
87	Available p in A	Gravel in B	0.89317**
88	Available p in A	Available p in B	0.88322**
89	Available p in A	Available K in B	0.77530**
90	Available p in A	(Silt+Clay) in B / Depth A	0.77591**
91	Available K in A	Ex. (Ca+Mg) in A	0.74672**
92	Available K in A	Ex. (Ca+Mg) in B	0.66561*
93	Available K in A	(Silt+Clay) in B / Depth A	0,73664**
94	C.E.C. in A	Ex. (Ca+Mg) in A	0.75614**
95	C.E.C. in A	Sand in B	-0.64709*
96	C.E.C. in A	(Silt+Clay) in B	0.64902*
97	C.E.C. in A	Ex. (Ca+Mg) in B	0.64173*
98	C.E.C. in A	(Silt+Clay) in B / Depth B	0.64266*
99	C.E.C. in A	(Silt+Clay) of B / Depth A	0.76631**
100	Ex.(Ca+Mg) in A	Available p in B	0.59184*
101	Ex.(Ca+Mg) in A	Available K in B	0.64821*
102	Ex.(Ca+Mg) in A	Ex. (Ca+Mg) in B	0.86785**
103	Ex.(Ca+Mg) in A	(Silt+Clay) in B / Depth A	0.73315**

*Significance at 0.05 level
**Significance at 0.01 level

TABLE XI — CONTINUED

S. No.	Variable	Variable	"r"
104	Gravel in B	Available p in B	0.86021**
105	Gravel in B	Available K in B	0.71596**
106	Sand in B	(Silt+Clay) in B	-0.99980**
107	Sand in B	(Silt+Clay) in B / Depth B	-0.75790**
108	Clay in B	C.E.C. in B	0.58904*
109	Clay in B	Ex. (Ca+Mg) in B	0.64481*
110	(Silt+Clay) in B	(Silt+Clay) in B / Depth B	0.75738**
111	Available p in B	Available K in B	0.71498**
112	Available p in B	(Silt+Clay) in B / Depth A	0.65124*
113	Available K in B	(Silt+Clay) in B / Depth A	0.64136*
114	C.E.C. in B	(Silt+Clay) in B	0.74012**
115	Ex. (Ca+Mg) in B	(Silt+Clay) in B / Depth A	0.69213*

*Significant at 0.05 level
**Significant at 0.01 level

Depth was negatively correlated with other soil properties like gravel, sand, available moisture, nitrogen, available phosphorus and available potassium. Depth (A+B) was negatively correlated with exchangeable (calcium + magnesium) in the A_1 and C.E.C. in the A. There was a weak positive correlation found between site index and the A_1 horizon but a negative correlation was found with A_2 and B_{21t}. No correlation was found for the site vs B_{22t} and also when all the horizons were combined. Depth A and (A+B) were tested separately for correlation with site index. Though no correlation was found between them, Figures 19 & 20 indicate some positive correlation with an increase. Site index begun to fall when the depth of the A increased more than 13" and depth of (A+B) increased more than 60". Similar results of no correlation with depth has been reported by others (34, 4, 100).

The gravel content of the soil undoubtedly affects site index under some conditions on lower slopes, which usually have fairly deep soils. According to Coile (20) the content of stones in a soil if it rises above 20% by volume, results in reduction in the site index value. On upper slopes particularly those of limited soil depth, a high stone content appears to reduce the value of the site index.

Gravel percentage was correlated with other properties like slope, sand, exchangeable potassium, total exchangeable cations, C.E.C., moisture at 1/3 atm., % nitrogen, available phosphorus and available potassium.

A negative correlation was found between site index and gravel in the A_1, A_2, B_{21t} and B_{22t} horizons. When all the horizons were combined this effect was masked. Again gravel in the A and in the B horizons were tested separately with thirty-six soil variables but no significant relation was found. These results were supported by Doolittle (37). However, an increase in gravel causes a decrease in site index as shown by the data reported in Figure 21. Young (106) reported the white pine site index was decreased as gravel % in the A increased.

Sand was correlated with total exchangeable cations, nitrogen %, available phosphorus, available potassium and gravel. Sand in the A was positively correlated with sand in the B, pH of the A and negatively correlated with clay in the A, (silt + clay) in the B and (silt + clay) in the B/depth A. The percentage of each horizon was tested individually. A positive correlation was found between site index and B_{21t} and B_{22t} horizons. When all the horizons were combined no relation occurred. Sand in the A, sand in the B and (Sand A x depth A) were tested separately. Positive correlation was found between % sand in the A and site index, as shown in Figures 22 to 24. Similar results of positive correlation was reported by Zahner (108) and Pawluk (74). Their reasons being that small roots will grow whenever conditions of temperature, aeration, moisture and fertility are favorable. The small roots tend to be concentrated in the upper part of the mineral soil and as well as in the H layers of the Ao horizon. These zones afford maximum aeration and are the first to benefit by the average light rain. Sandy loam surface soil is generally a well aerated environment for growth of pine roots, but may be limited by reduced metabolic activities in the roots and by reduced absorption of water and minerals as a result of the low oxygen and high CO_2 environment often found in poorly aerated soils.

Silt was positively correlated with pH and negatively correlated with slope, clay, (silt + clay), calcium, potassium, C.E.C.

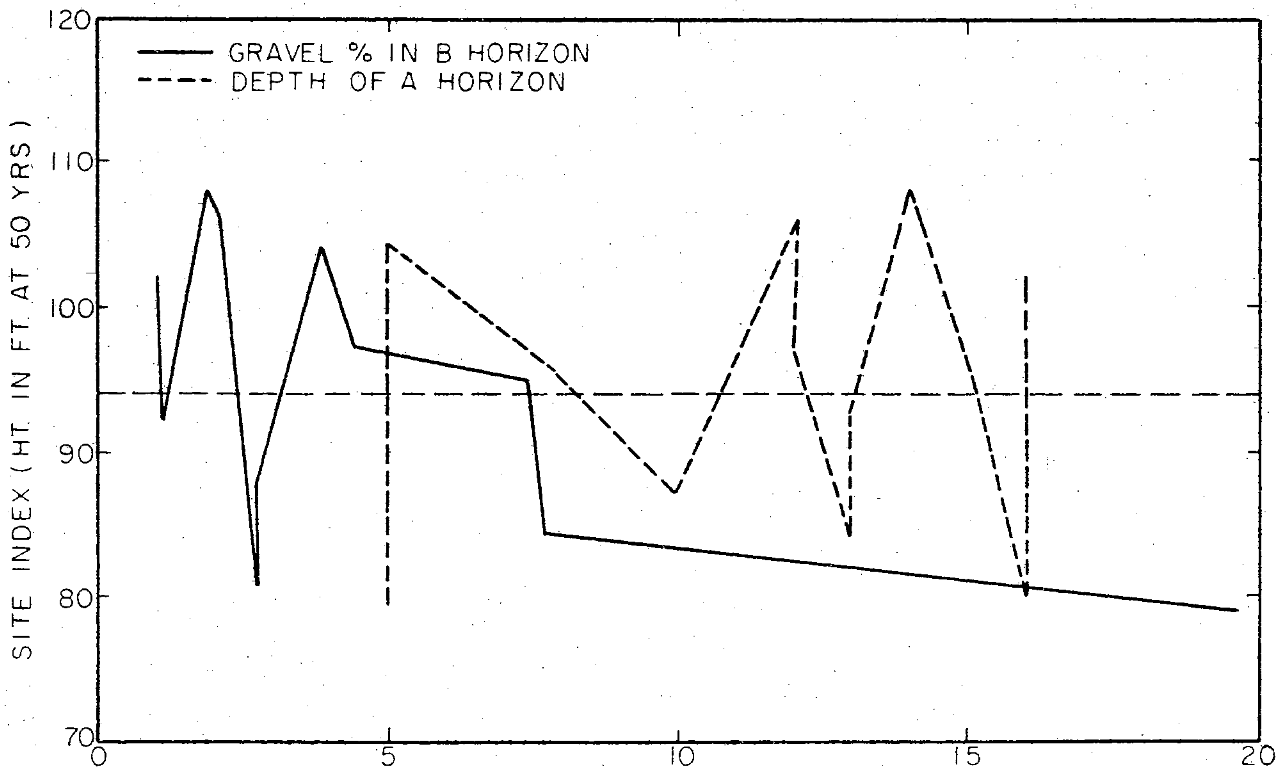


Figure 19. Relationship of Site Index to Selected Soil Variables.

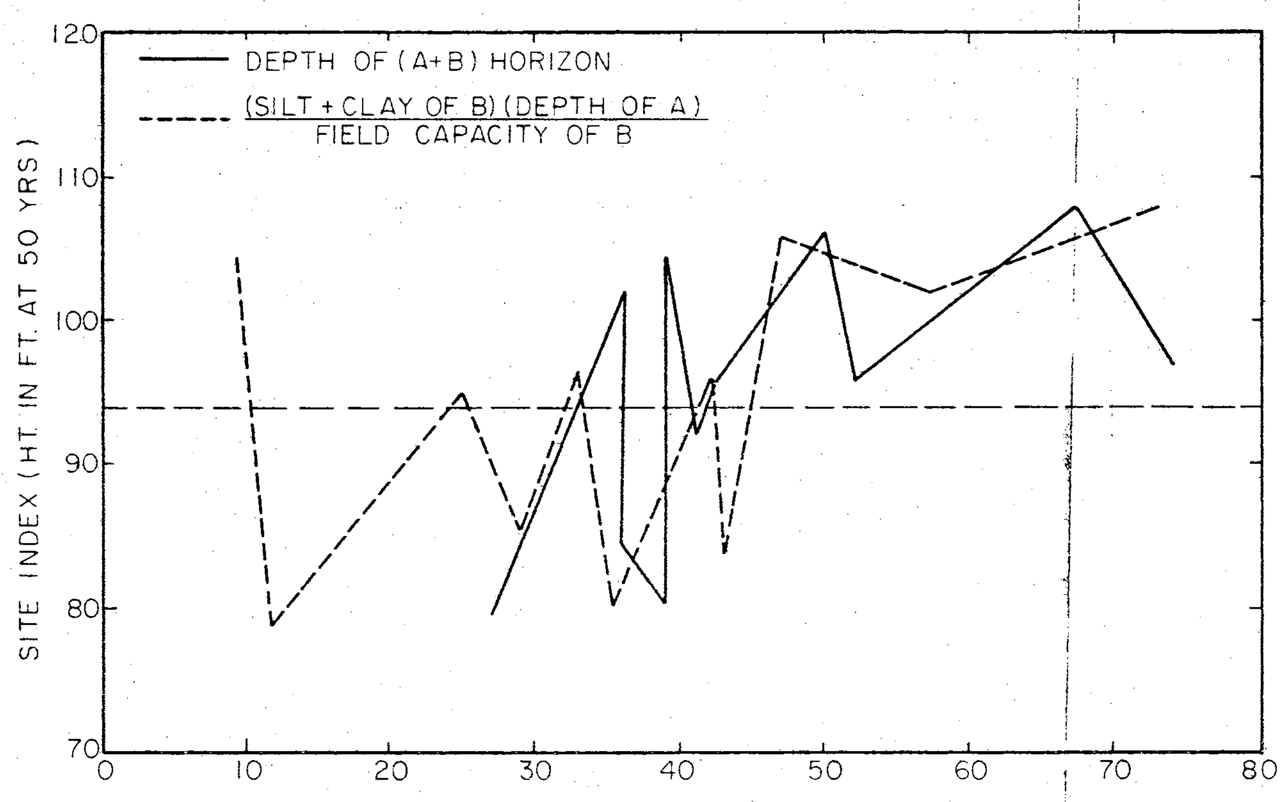


Figure 20. Relationship of Site Index to Selected Soil Variables.

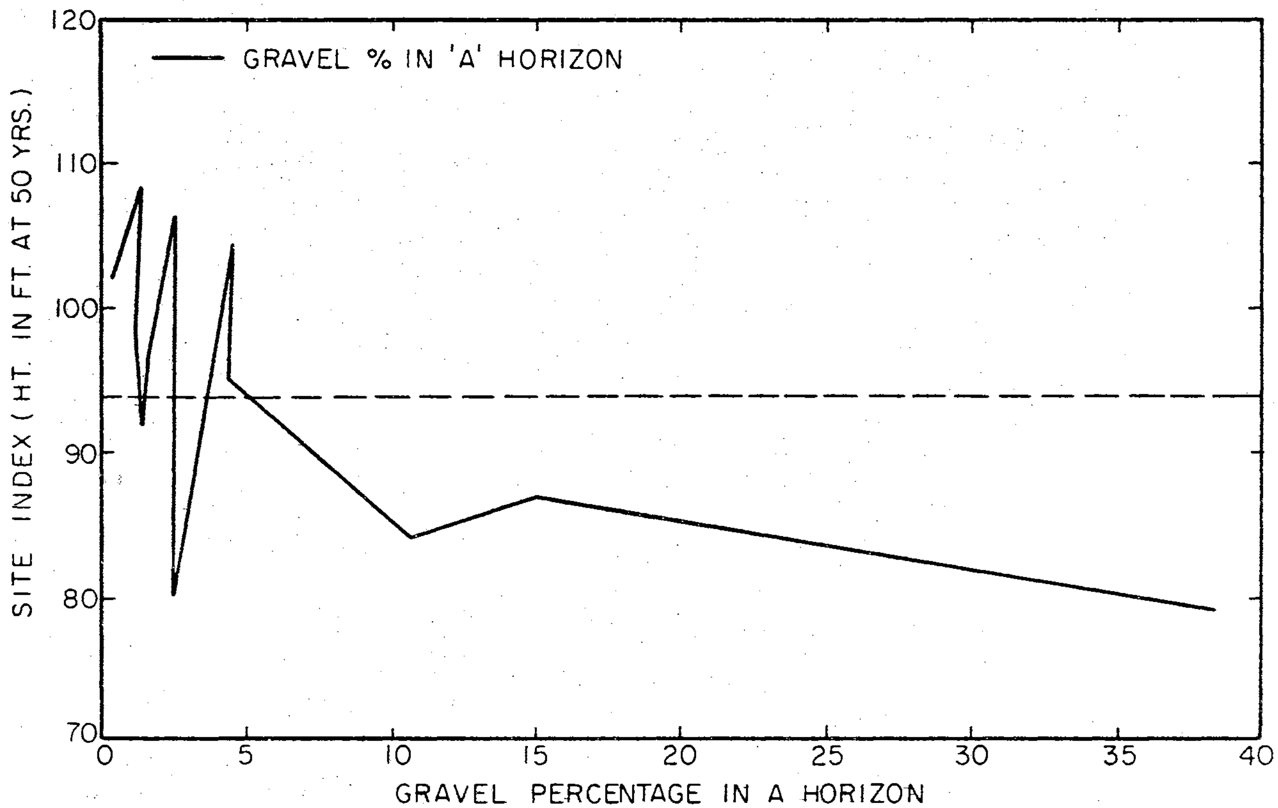


Figure 21. Relationship of Site Index to Gravel Percentage in A Horizon.

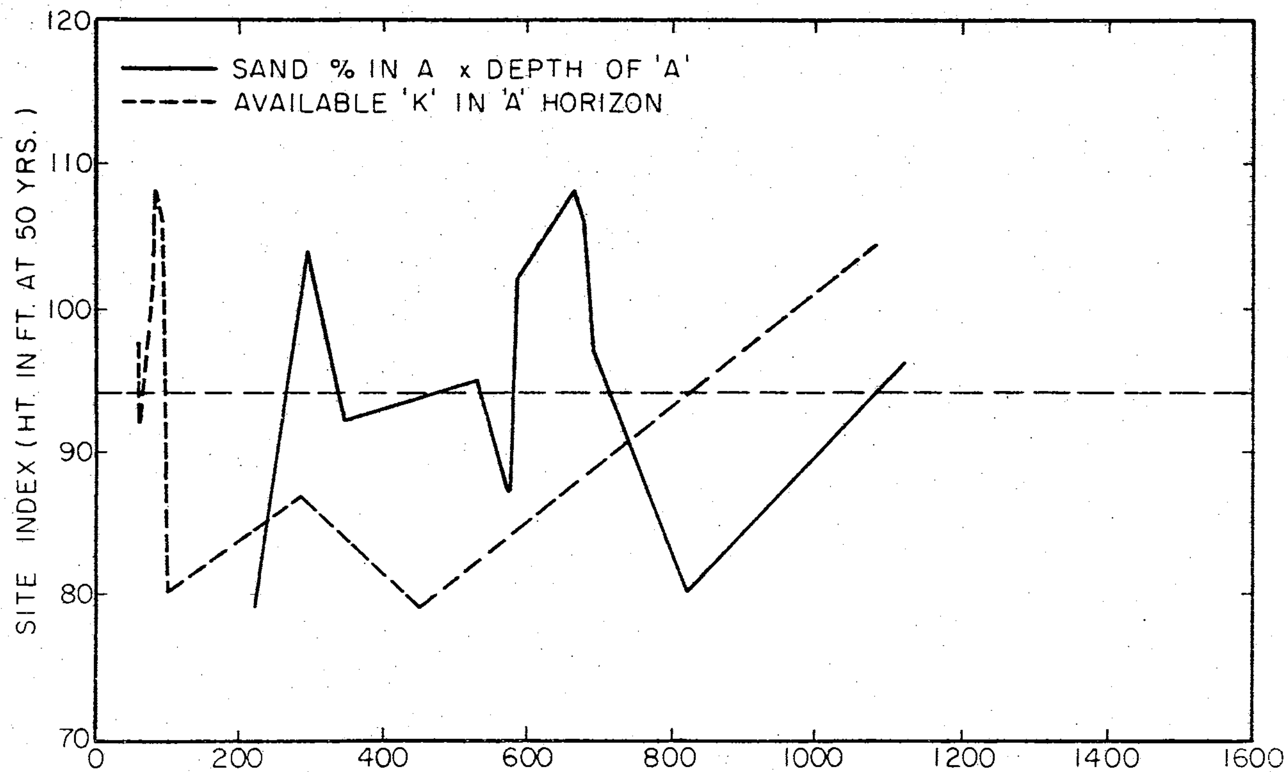


Figure 22. Relationship of Site Index to Selected Soil Variables.

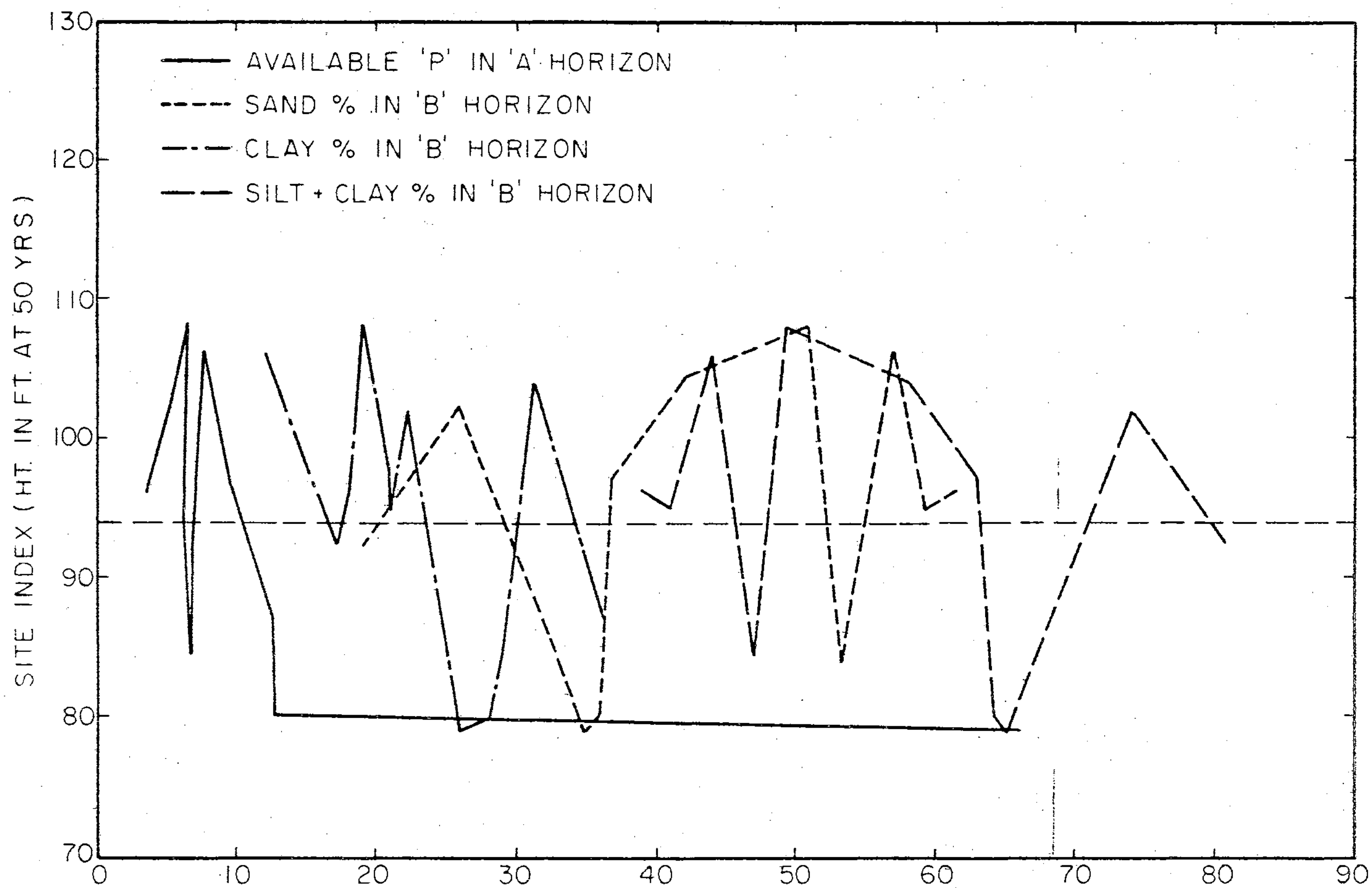


Figure 23. Relationship of Site Index to Selected Soil Variables.

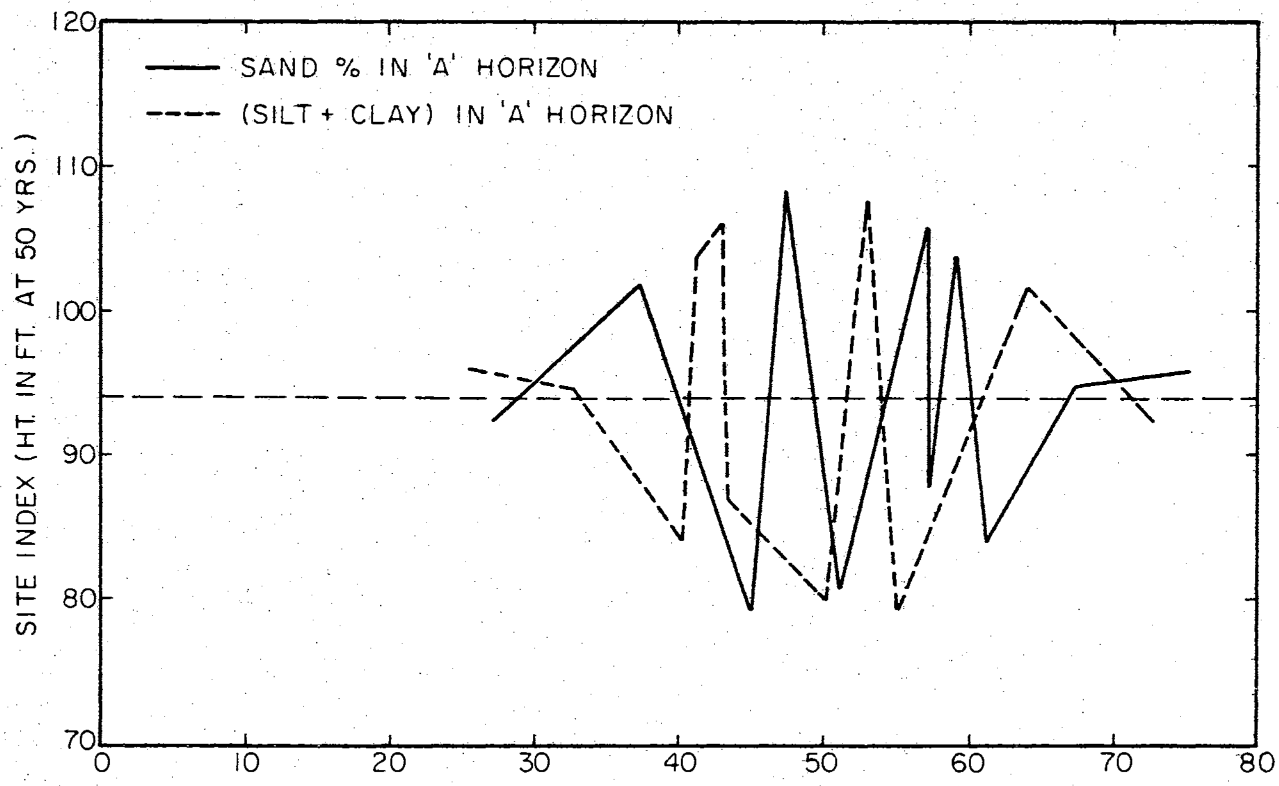


Figure 24. Relationship of Site Index to Selected Soil Variables.

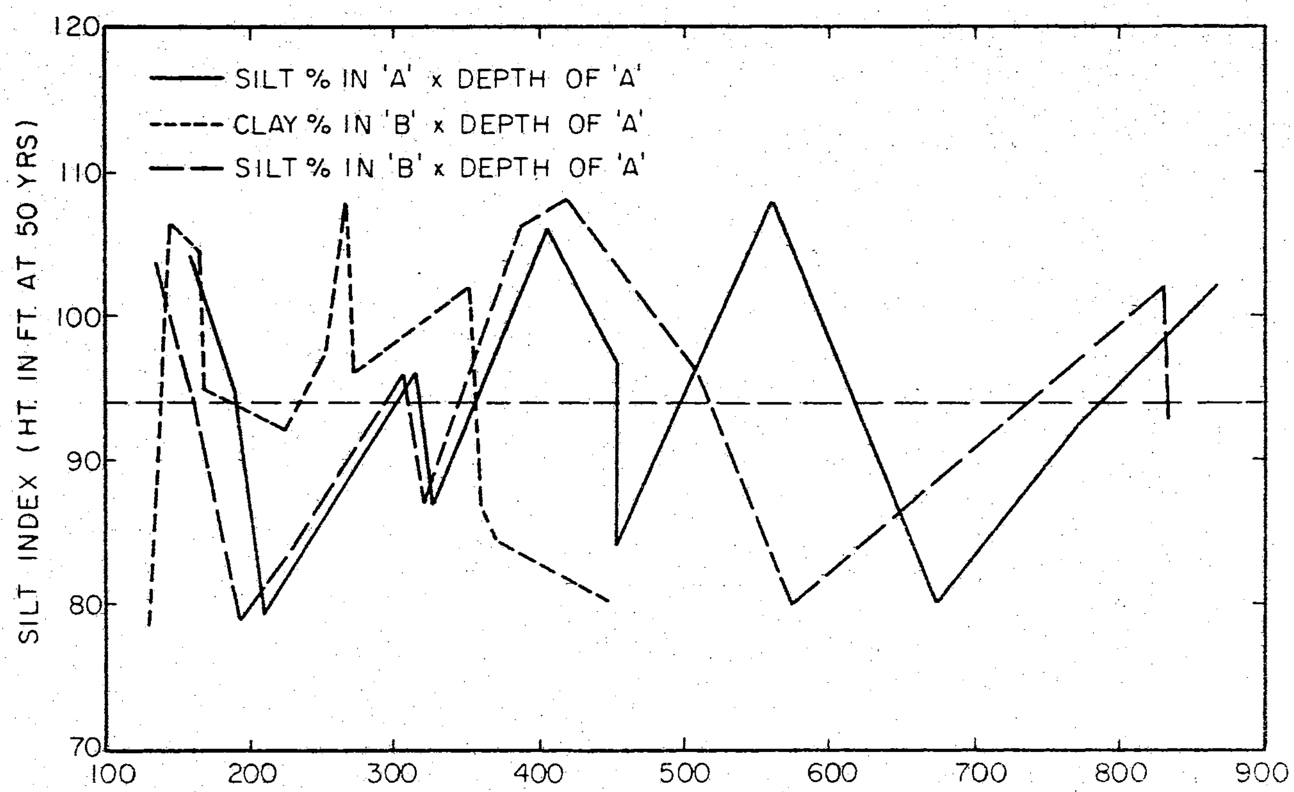


Figure 25. Relationship of Site Index to Selected Soil Variables.

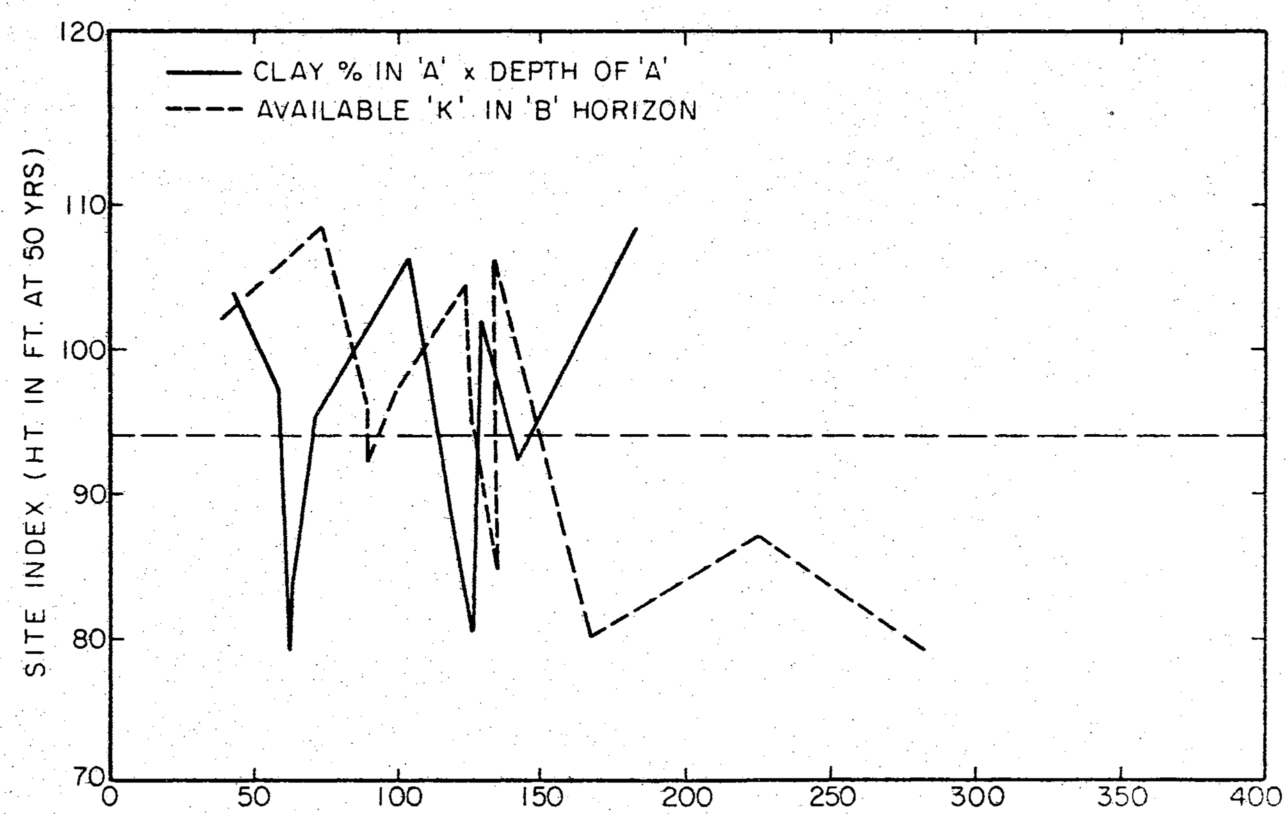


Figure 26. Relationship of Site Index to Selected Soil Variables.

and available water. Silt percentage versus site index was tested in each horizon and a combination of all these horizons. Silt % was also tested as % silt in the A_1, (silt in A X depth A), (silt in B x depth A) versus site index. No correlation was found with any of the soil variables. Figure 25.

The clay fraction of the soil is the most active textural class with respect to availability of soil moisture and soil nutrients. Consequently, soils with small or moderate amount of clay, site quality is likely to be related directly to clay content. However, soils with high clay content might show an increased relationship of clay % to site quality, because of unfavorable physical properties associated with large amounts of clay. Clay was positively correlated with other soil properties like slope, hydrogen, available water and negatively correlated with silt. Clay in each horizon and in combination was tested with site index. A positive correlation was found in the A_1 and A_2 horizons, which is in agreement with Turner (96) who worked with pine growth in Arkansas. This was not correlated when all the horizons were combined. Clay in A, clay in B, (clay A x depth A), (clay in B x depth A), were tested with site index. No significant correlation was obtained. However Figures 23, 25, 26, 30 indicate that the % clay shows a positive trend to a certain amount and then the site index began to decrease.

The colloidal content is widely recognized by soil investigators as being a very important factor influencing moisture holding capacity, cation exchange, absorption and general soil tilth. (silt + clay) in the A, was significantly correlated with other soil properties like (silt + clay) in the B, $\frac{\text{(silt + clay) in B}}{\text{depth B}}$, texture of top soil, (sand A x depth A), silt B x depth A) and clay in the A. It was negatively correlated with pH of the A, sand in A and sand in the B. Whereas (silt + clay) in the B was correlated with $\frac{(\text{silt + clay in B}}{\text{depth B}}$, (sand B X Depth A), (silt + clay) in A, C.E.C. in A, C.E.C. in B, gravel in B, but (silt + clay in B was negatively correlated with sand A and clay B.

No significant correlation was found between site index and (silt + clay) in A and (silt + clay in B. Site index was increased slightly with an increase of (silt + clay) in A and B and then the site index is dropped off as shown in Figures 23 & 24.

It is generally considered that moisture is one of the most limiting factors in forest tree growth and soil moisture is correlated with soil texture. In this study an attempt was made to correlate site index with texture of the top soil. Texture of the top soil was significantly correlated with other properties of soil like (silt A x depth A), (clay A x depth A), (silt B x depth A), (silt + clay) in A and inversely correlated with sand. Site indices, corresponding to three surface soil textures namely sandy loam, loam and silt loam, whose average site index was 94, 93 and 102 respectively showed no positive significant correlation.

Water relations in soil occupy a position of outstanding importance because of their influence on the various physical chemical and biological properties of soils. Water serves as a solvent and medium of transport for plant nutrients and supplies an essential need of all living organisms. Even the richest soils as judged by mineral nutrient content fail to support forests unless the minimum water requirements are satisfied. The primary factors determining soil water relations

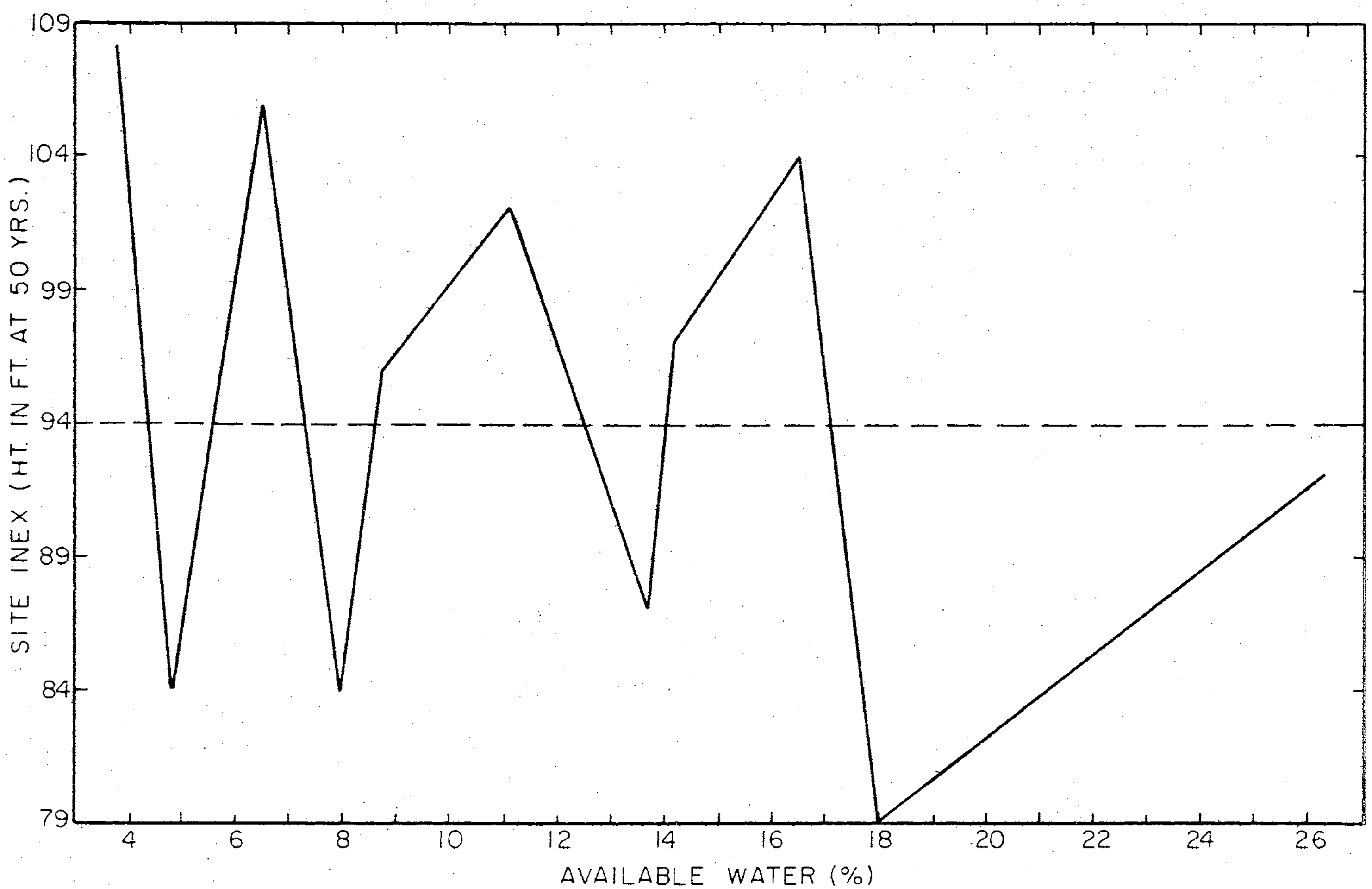
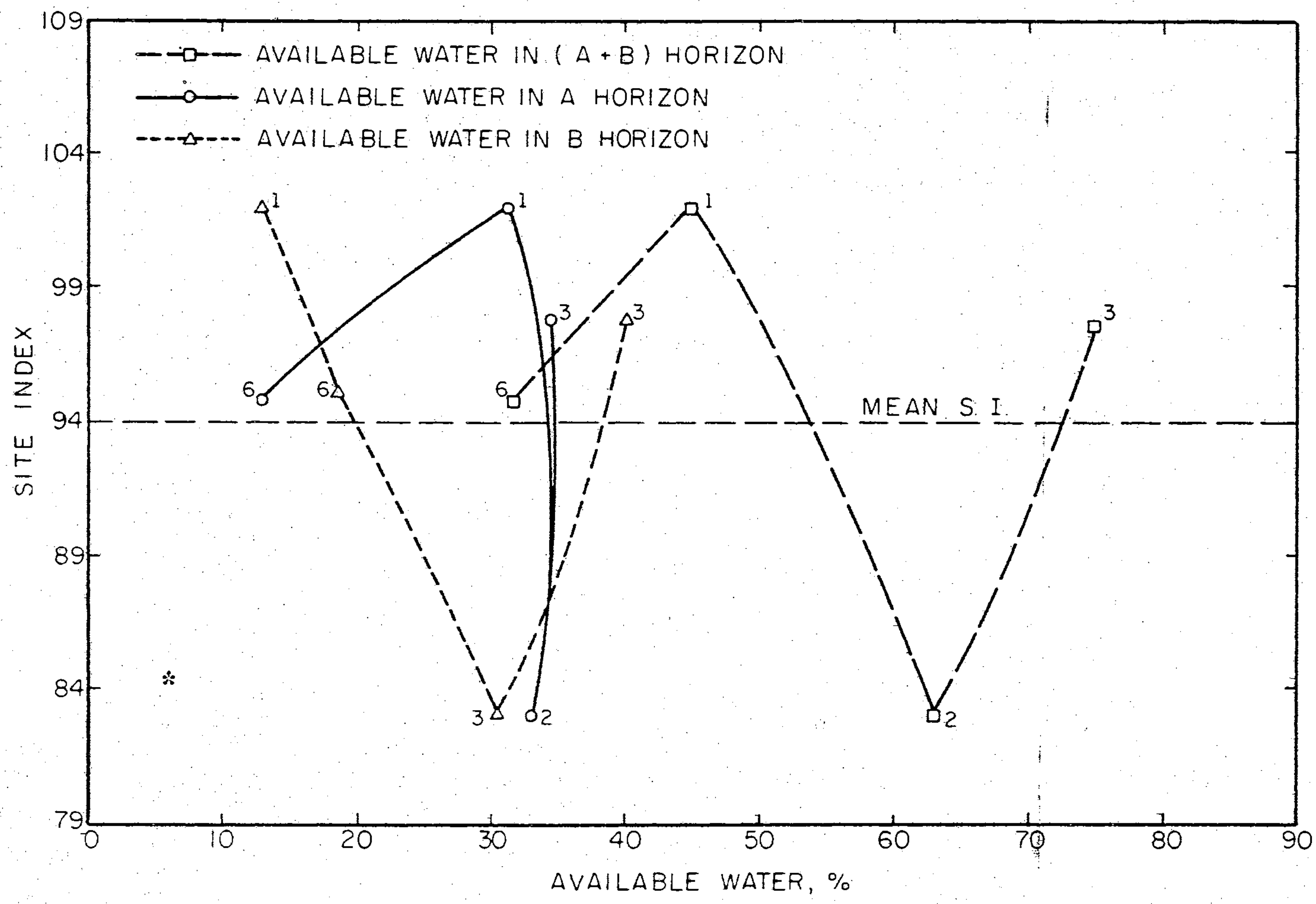


Figure 27. Relationship of Site Index to Available Water.



*Each numerical represents number of plots and average value.

Figure 28. The Relation of Site Index to Available Water in A, B, and (A+B) Horizons.

are climate, topography, nature of the soil and vegetation. The moisture regime of the soil is influenced by such factors as an increase in organic matter content and the amount of finer material either or both of these factors improve the waterholding capacity of the soil.

Available water in this study was correlated with other soil properties like clay, C.E.C., moisture at 1/3 atmospheric (atm.) moisture at 1 atm, moisture at 15 atm and slope. Moisture percentage at 1/3, 1 and 15 atm were tested in each horizon and in combination. Available moisture was inversely significantly correlated with site index. This type of relationship was also strongly indicated as shown in Figures 27 & 28. An increase of available moisture in the A horizon and in the (A + B) horizon up to 30 and 45% caused an increase of site index 94 to 102 respectively and then it dropped off when the moisture is increased as shown in Figures 27 & 28. An inverse relation between site quality and the total available moisture was obtained for the B horizon as indicated in Figures 27, 28, 40. Similar type of results were obtained by Coile (17) and Gaiser (40).

The chemical composition of the soil is influenced by the parent material, biological activity, climate, topography and time. pH was positively correlated with slope, silt, nitrogen % and negatively correlated with (Silt + clay), calcium, moist 1/3 atm., moisture 1 atm. and moisture at 15 atm. Soil reaction of each horizon was tested with site index but no relation was found between them. Similar type of results were reported by Hicock (51), McGee (72), Trimble (95), Knudsen (20) and Zahner (108). The better site indices in general occurred on soils where the pH was above 5 as shown in Figure 32, although this is not a significant difference.

C.E.C. was indirectly related to total replaceable cations, organic matter and concentration of clay. It has been shown that a decrease in base saturation may reflect a decrease in soil fertility, therefore, it would obviously affect the growth potential of a tree site. (74,106). C.E.C. was correlated with available water, gravel, silt, (silt + clay), hydrogen, calcium, magnesium, potassium and slope. C.E.C. of the A horizon was correlated with (calcium + magnesium) in the A, (calcium + magnesium) in the B, (silt + clay) in the B, clay in the A. $\frac{\text{(silt + clay) in the B}}{\text{depth B}}$, $\frac{\text{(silt + clay) in the B}}{\text{depth A}}$ and was inversely related to depth (A + B) and (sand A x depth A). C.E.C. of each horizon and combination of horizons was tested with site index but no relation was found. A significant correlation was found between the site index and C.E.C. of the A horizon. Organic matter and clay are important for holding moisture and available nutrients there a higher C.E.C. in the surface soil influences site index; similar type of results were obtained by Youngberg (106) and Pawluk (74).

Hydrogen, calcium, magnesium, potassium and sodium content of each horizon and in combination were tested with site index but no significant correlation was found between any of these variables with site index. Exchangeable (calcium + magnesium) in the A, (calcium + magnesium) in B were tested but no significant relation was obtained. Similar type of results between exchangeable calcium, magnesium and site index were obtained by Tarrant (94) with Douglas fir site quality. Probably the nutrient supply of these soils may not be a limiting factor in tree growth. Hydrogen in the A, exchangeable hydrogen in the B were tested with site index but no significant correlation was found between them. These data were supported by Pawluk (74) who

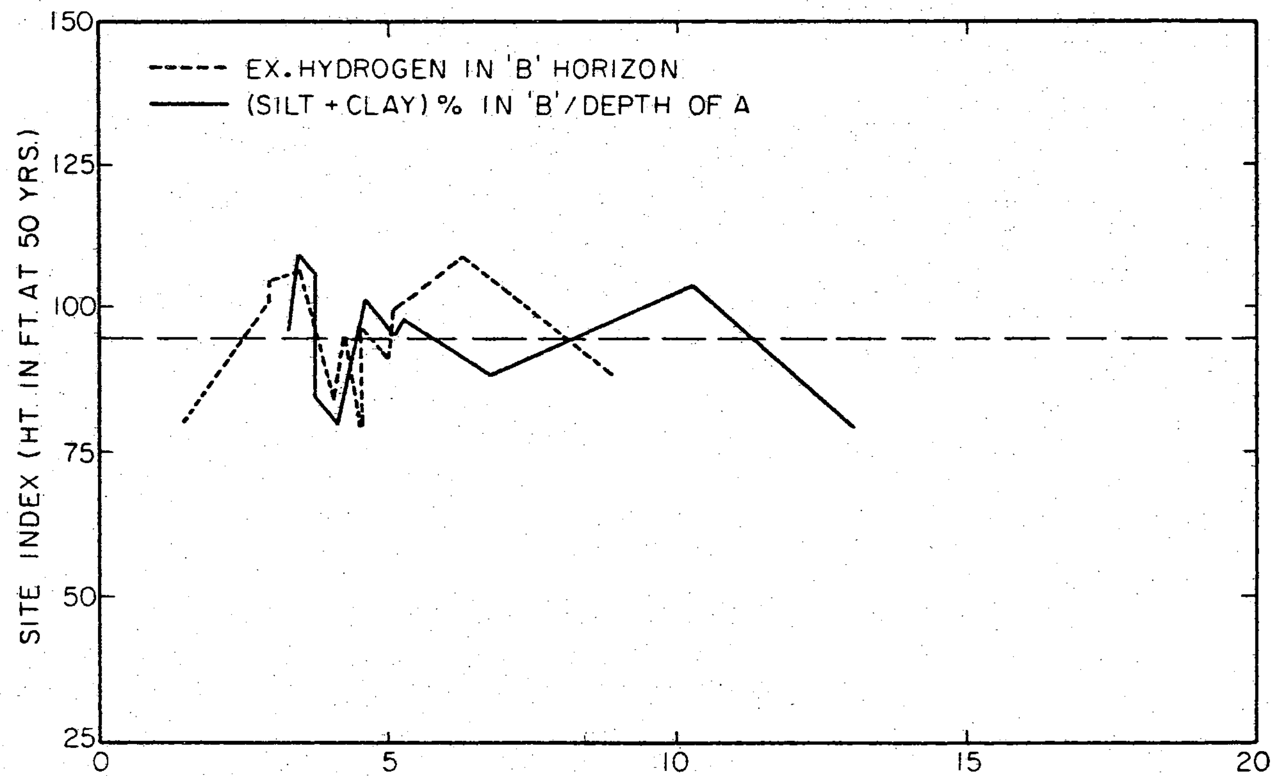


Figure 29. Relationship of Site Index to Selected Soil Variables.

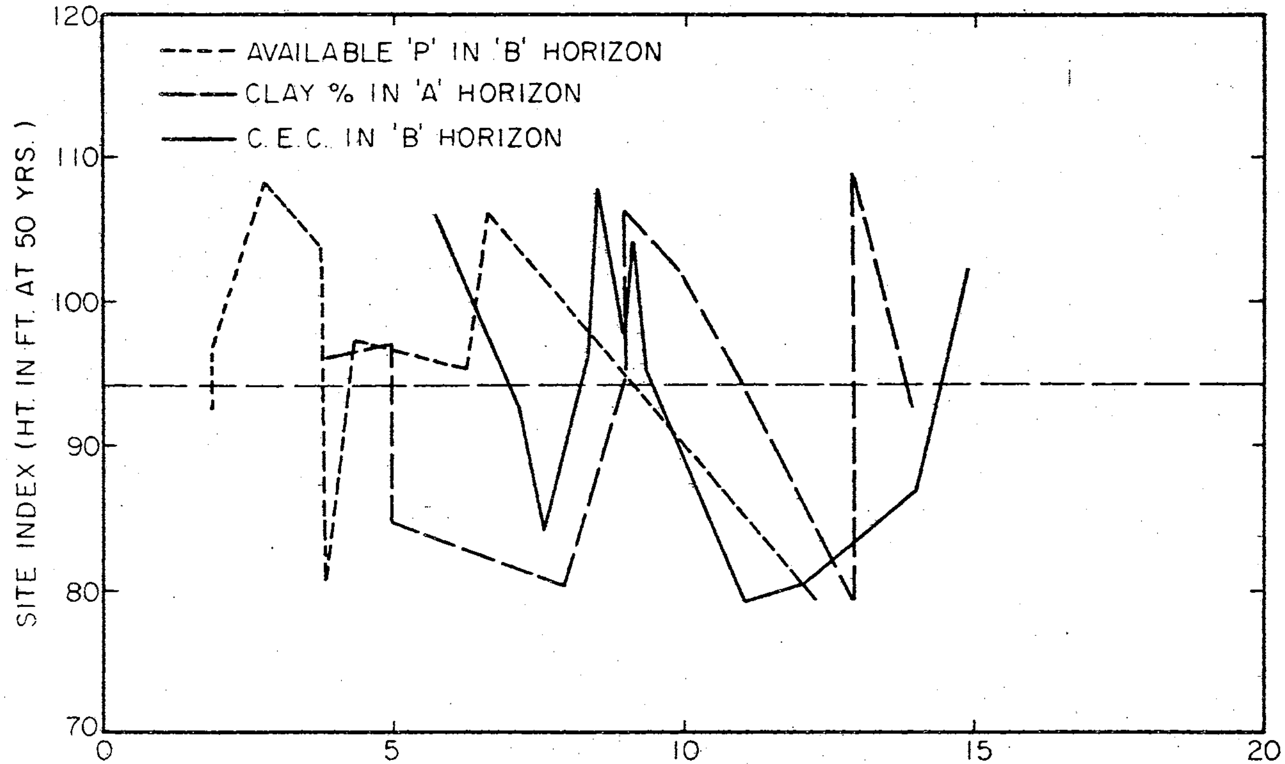


Figure 30. Relationship of Site Index to Selected Soil Variables.

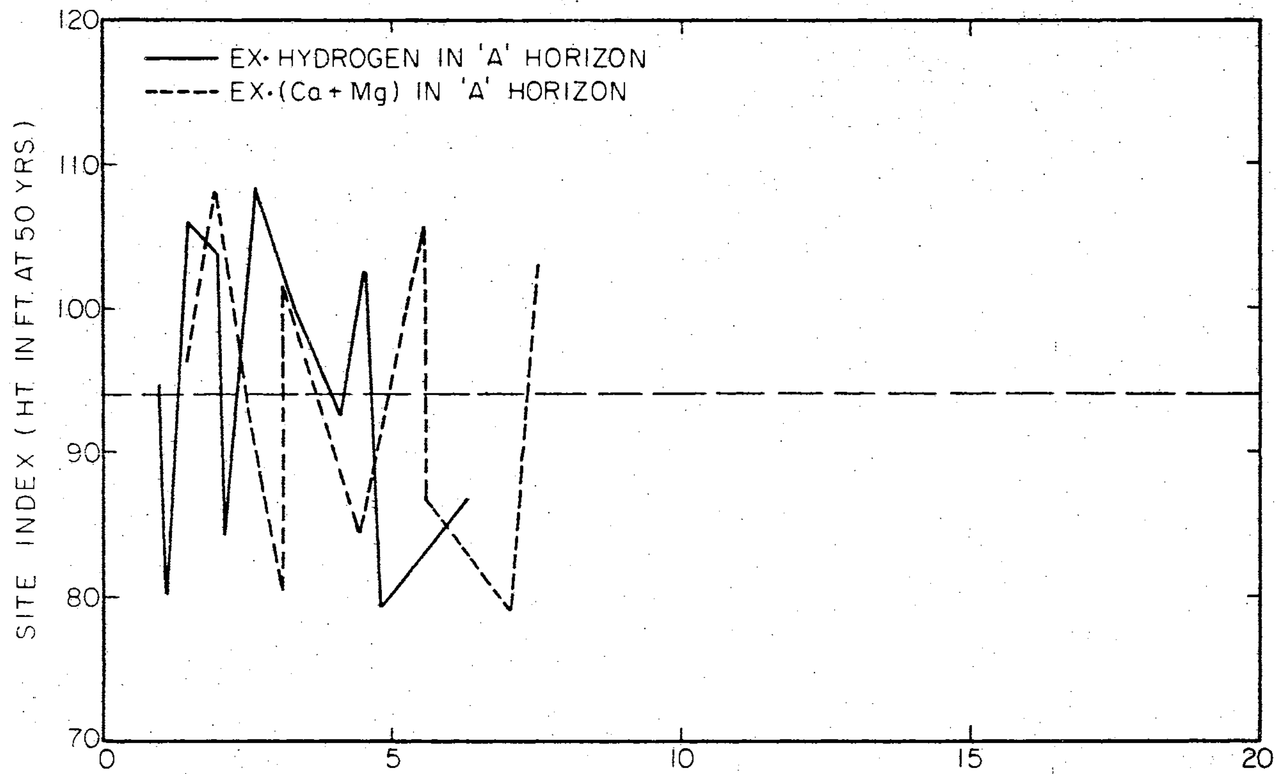


Figure 31. Relationship of Site Index to Selected Soil Variables.

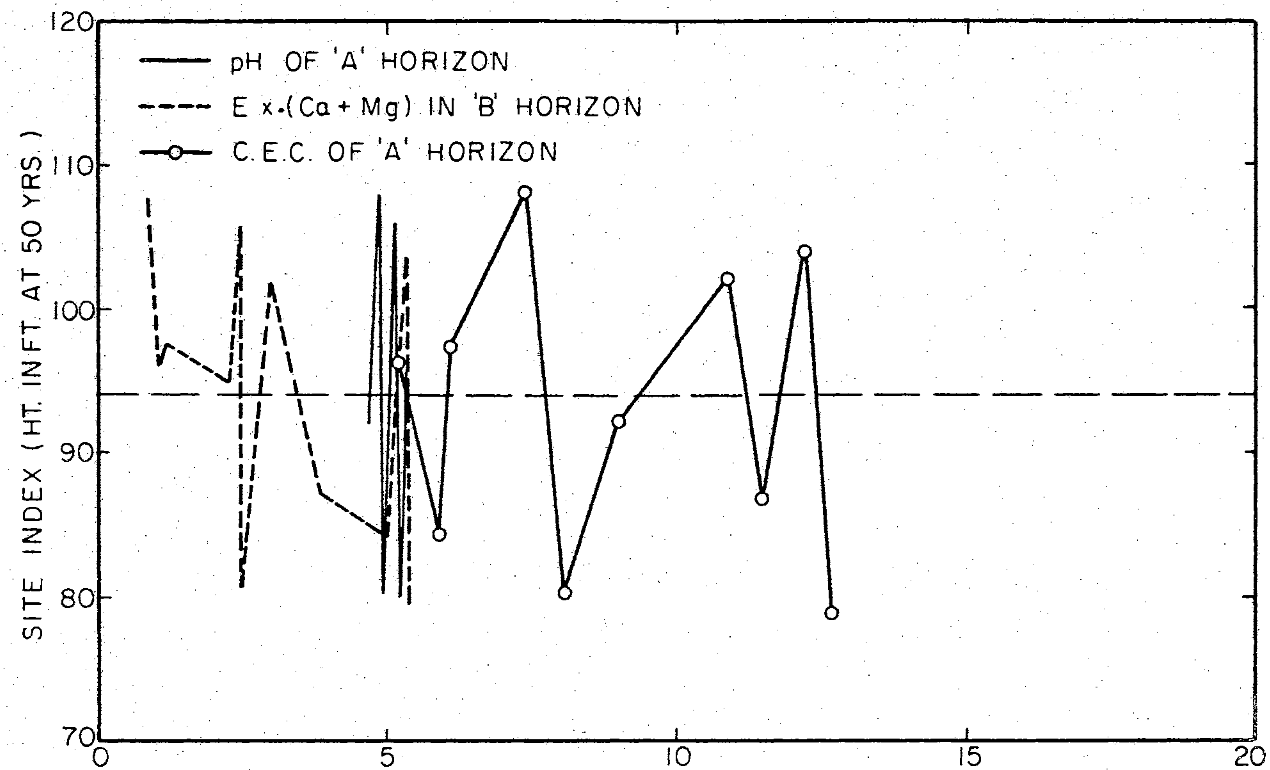


Figure 32. Relationship of Site Index to Selected Soil Variables.

worked with growth of Jack pine.

Nitrogen is one of the important elements essential for normal plant growth and reproduction. Nitrogen content of the soil was positively correlated with available phosphorus, available potassium, pH, gravel, sand, exchangeable magnesium, exchangeable potassium and exchangeable cations, but negatively correlated with depth, slope, (silt + clay).

Nitrogen was tested in each horizon and also as a nitrogen index i.e. (nitrogen % in A x depth A) with site index as shown by Figures 53, 54 and 60. These findings may indicate that increasing nitrogen percentage in the A may reflect and have an affect on other soil factors which may cause unfavorable conditions for growth. These soils are acidic in nature and the addition of nitrogen through the litter may cause more acidic conditions which may have an affect on tree growth. Similar results were reported by Madison (69) and Pawluk (74) who worked with Red and Jack pine respectively. Several other researchers (20), (33), (35), have reported a negative correlation between organic matter and site index.

The pines appear to make smaller demands on the mineral nutrient capital of soil than to any other trees. There appears to be a tendency for all species to absorb relatively large amounts of calcium. The uptake of this element usually exceeds that of magnesium, potassium, phosphorus.

Available phosphorus was correlated with other soil properties like available potassium, gravel, sand, magnesium potassium and total exchangeable cations. It was negatively correlated with depth and slope. Available phosphorus in the A was correlated with gravel in B, available potassium in B, $\frac{\text{(silt + clay) in B}}{\text{depth A}}$, gravel in A and nitrogen % in A.

Significant correlation at the 05 level was found between site index and the available phosphorus in the A as shown in Figures 23, 30 and 42. Pawluk (80) obtained a significant relation between phosphorus in the A_2 and site index of Jack pine.

Available potassium was correlated with other soil properties including gravel, sand, total exchangeable cations, C.E.C., moisture at 1/3 atm, nitrogen, phosphorus, slope and inversely related to depth and pH. Available potassium significance was tested like phosphorus. A correlation was found between available potassium and site index as shown by Figures 35, 36 and 40.

The relation between $\frac{\text{(silt + clay) \% of B horizon}}{\text{depth of A}}$ on site index was also tested by statistical methods. The reasoning being that the development of the fine textured soil depth index is based on the belief that site quality is a function of the amount and quality of the growing space for tree roots in the soil. In the case of soils which have highly differentiated profiles with respect to texture, structure and consistence, the depth of the surface soil and certain physical properties of the subsoil become pertinent factors in determining the volume and quality of growing space for tree roots. Texture-depth indices less than 2 or greater than 8 indicate poor sites. Highest site indices are found where the texture depth index of the soil is between 4 and 6. This would represent a soil with 12" of A horizon and B horizon containing 60% (silt + clay) (20). This variable was correlated with other soil variables like depth A,

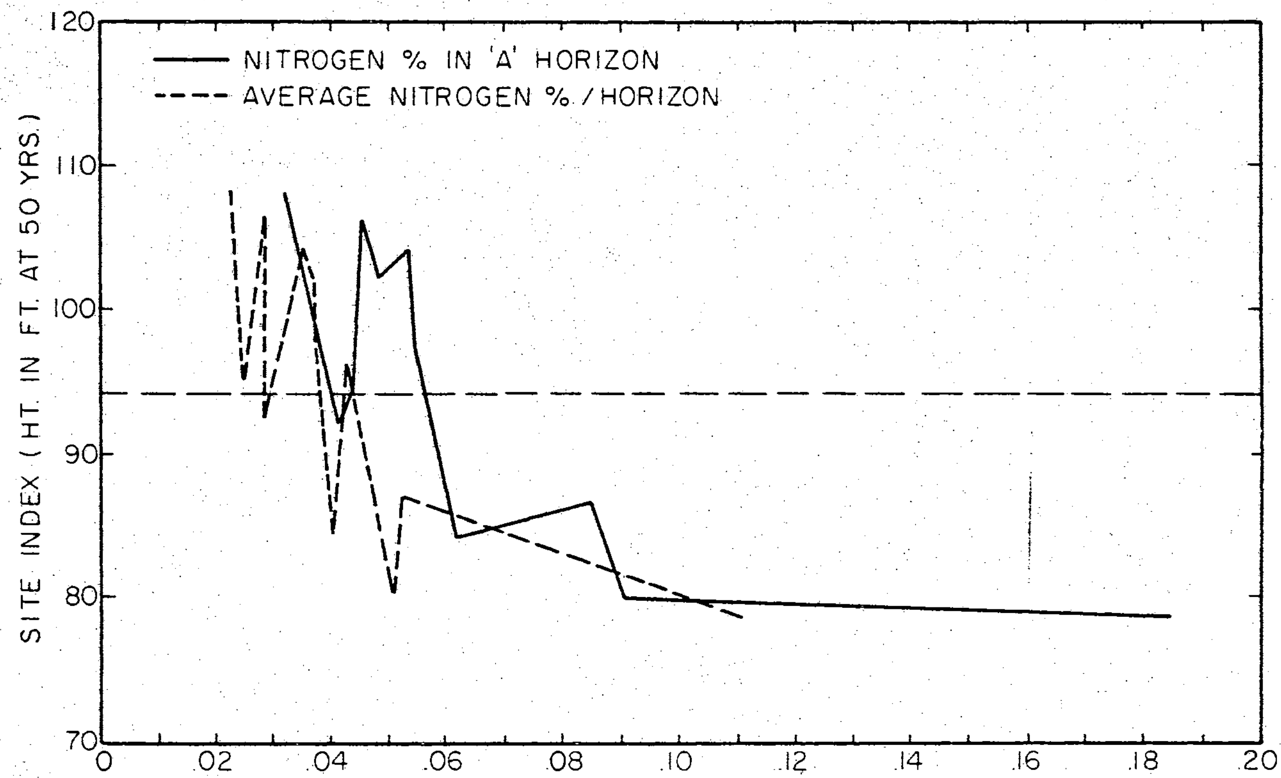


Figure 33. Relationship of Site Index to Selected Soil Variables.

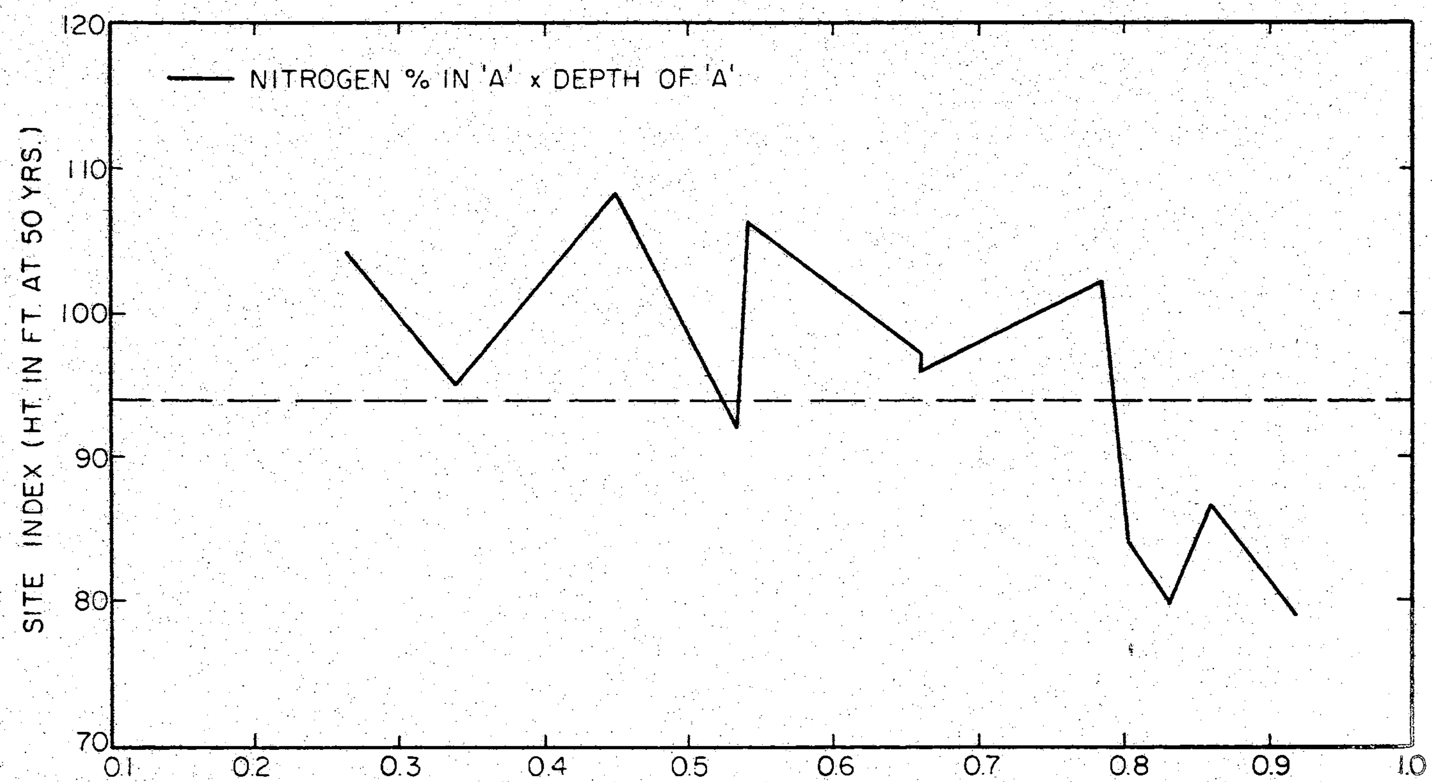


Figure 34. Relationship of Site Index to Nitrogen Percentage X Depth of A Horizon.

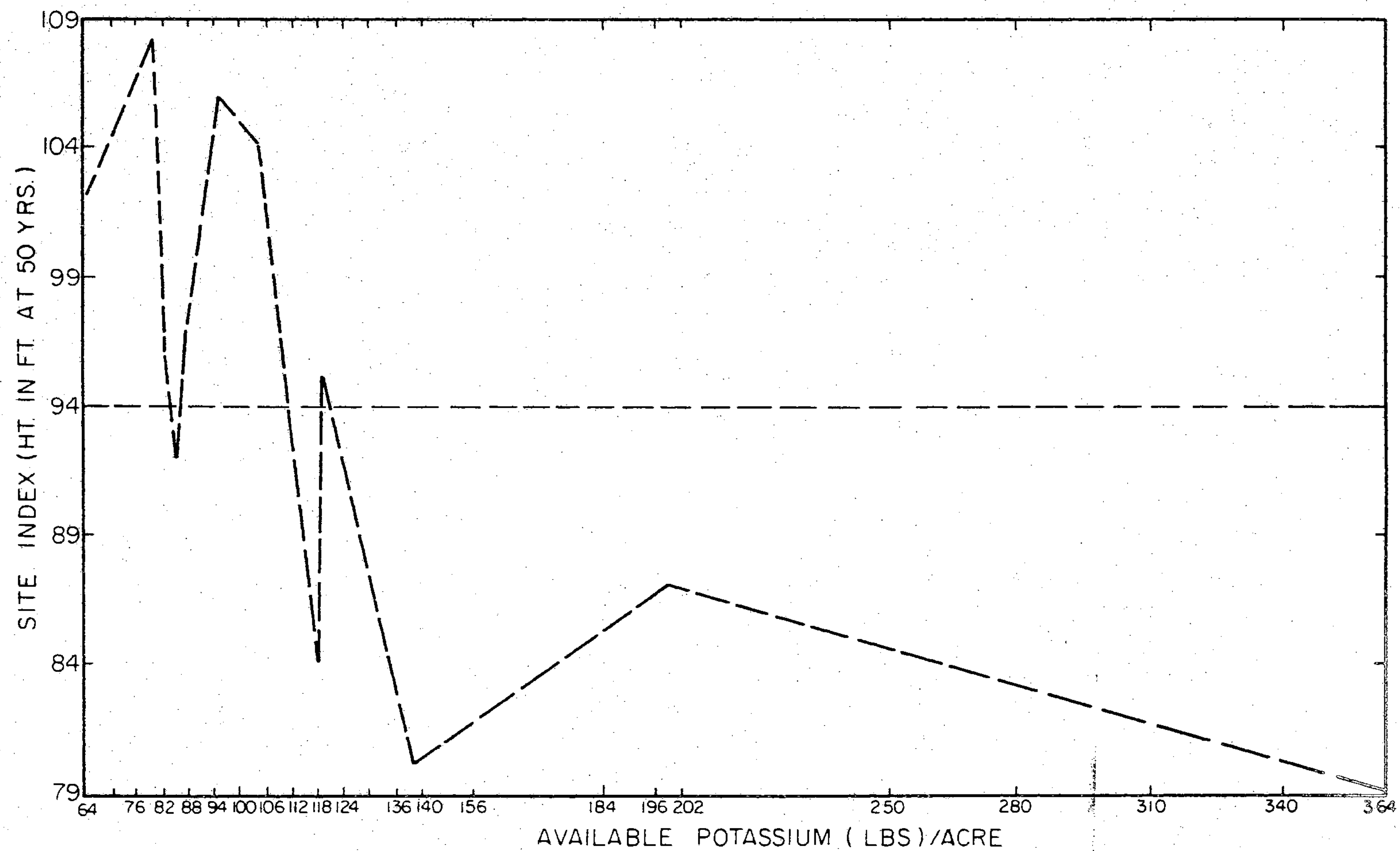
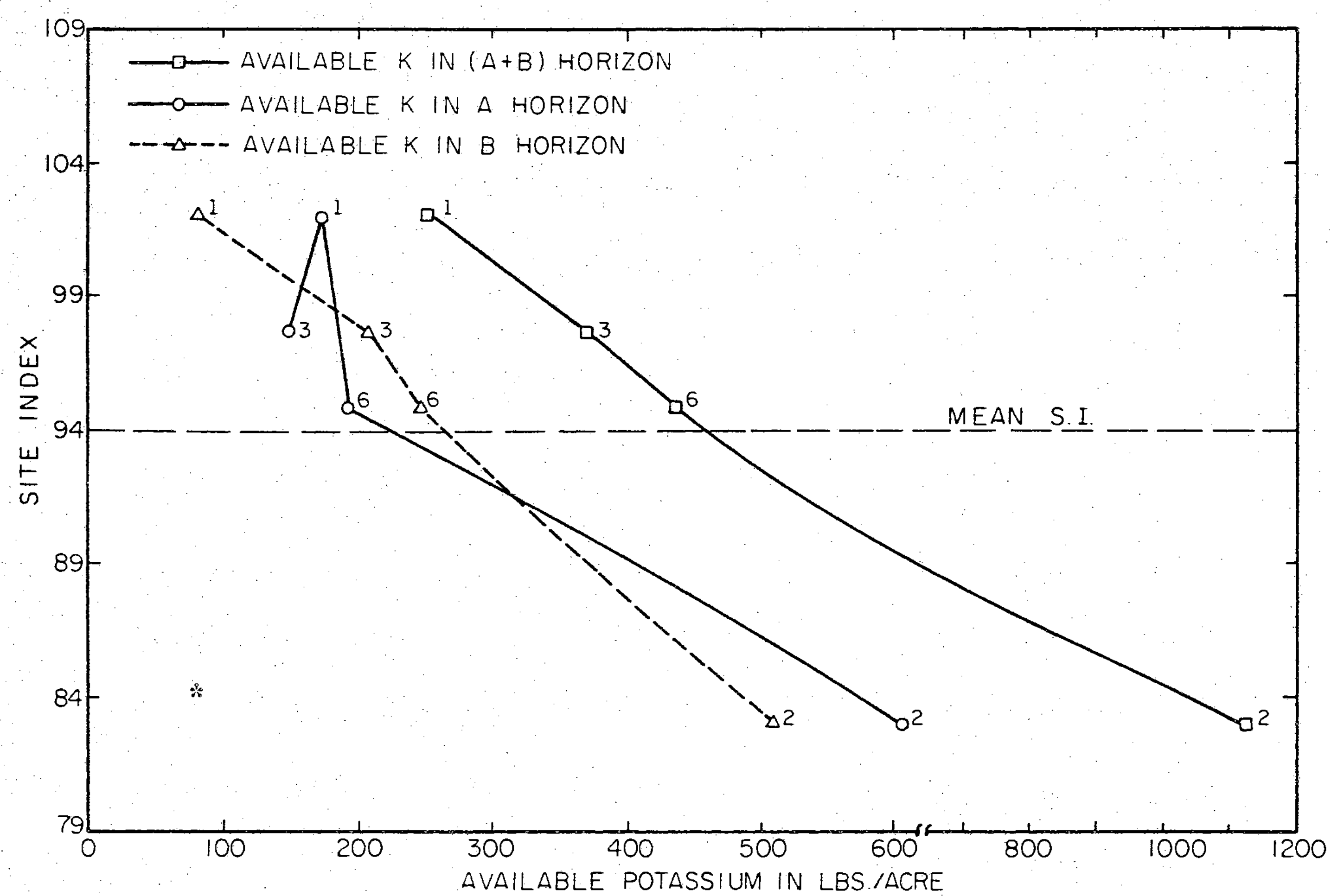


Figure 35. The Relation of Site Index to Available Potassium.



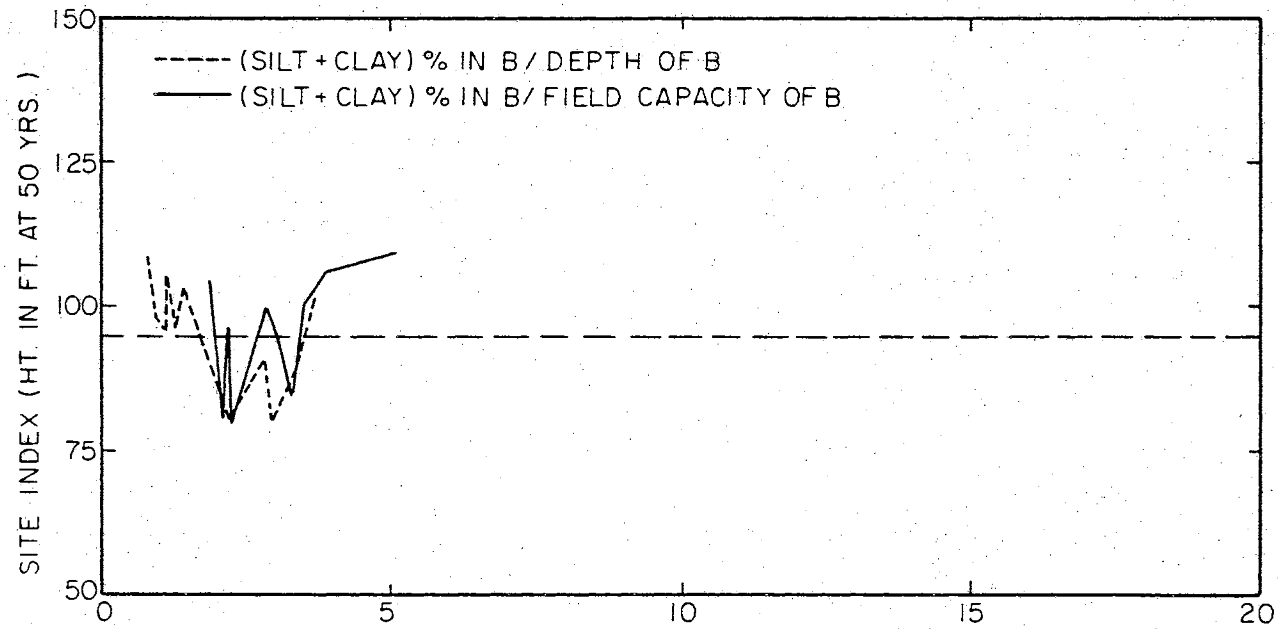
*Each numerical represents number of plots and average value.

Figure 36. The Relation of Site Index to Available Potassium.

(sand A x depth A), $\frac{\text{(silt + clay) of B}}{\text{field capacity of B}}$ x depth A, gravel in the A, and nitrogen for each horizon. Available phosphorus in the A, available potassium in the A, C.E.C. in the A, (calcium + magnesium) in the A, available phosphorus in the B, available potassium in the B and (calcium + magnesium) in B.

An attempt was made to evaluate the relation between the texture-depth index and site index. Though no significant correlation was found between them, Figure 29 indicates that the higher site indices 105 & 108 were found when the texture-depth indices were between 4 & 6 respectively, which is concurrent with the above findings.

Water absorption, retention, movement and availability depends on subsoil and are important factors affecting the growth of tree roots. These properties also influence soil aeration or gas exchange between the atmosphere and the air space within the soil. No relation was obtained between the $\frac{\text{(silt + clay) in B}}{\text{field capacity of B}}$ soil variable and site index. The depth of the surface soil was a measure of the soil available for occupancy by small roots. Many investigators have shown that the depth of the surface soil influences the site index for the southern pines, especially loblolly and shortleaf pine (58). This variable $\frac{\text{(silt + clay) in B}}{\text{field capacity of B}}$ x (depth A) was correlated with (calcium + magnesium) in the B, $\frac{\text{(silt + clay) in the B}}{\text{field capacity of the B}}$, $\frac{\text{(silt + clay) in the B}}{\text{depth A}}$. It was negatively correlated with available potassium in the A & in B. This independent variable was positively correlated with site index. A clear linear relationship or a positive correlation between this variable with growth of tree was obtained as shown in Figures 20 and 41.



Figuer 37. Relationship of Site Index to Selected Soil Variables.

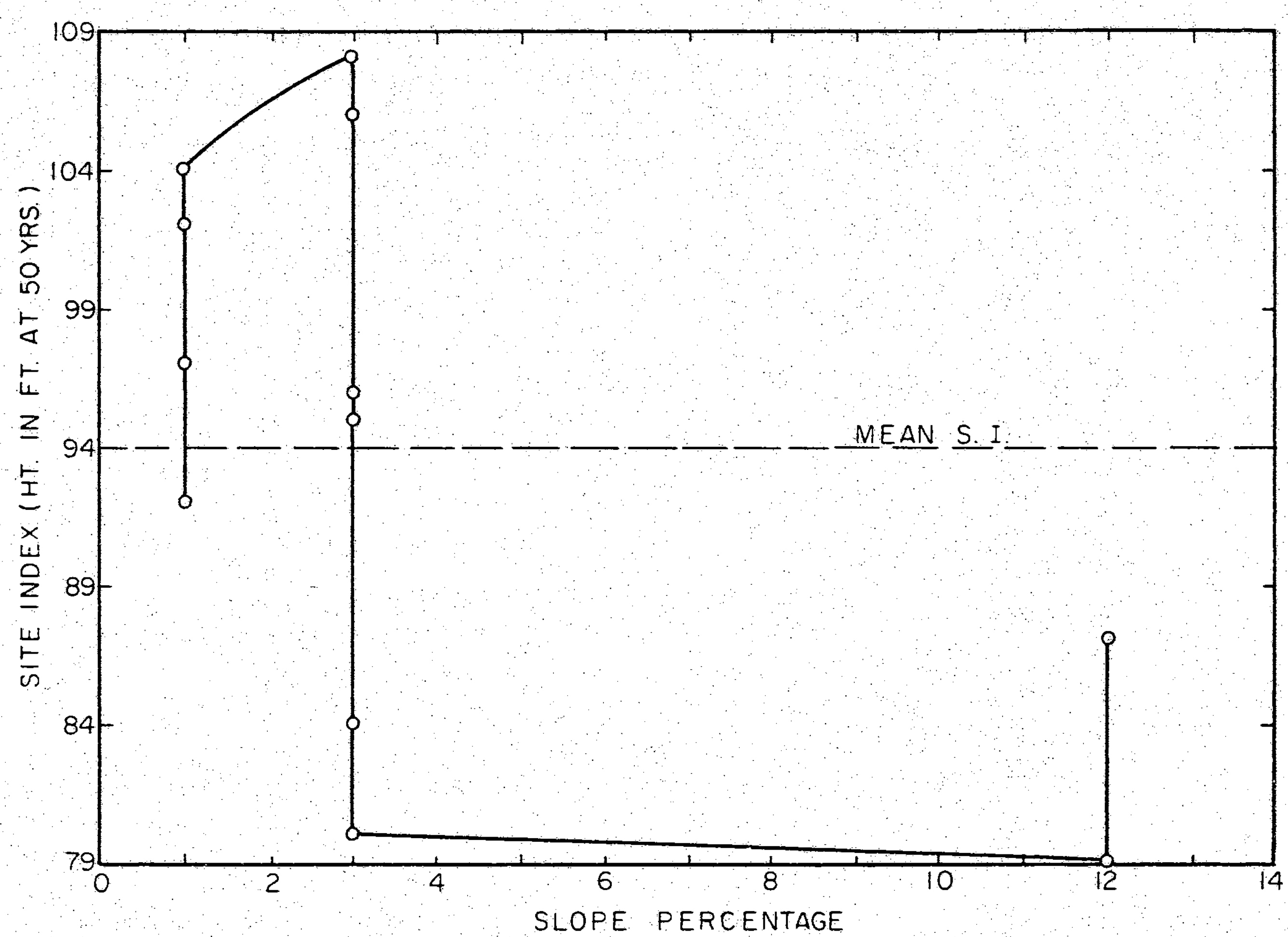
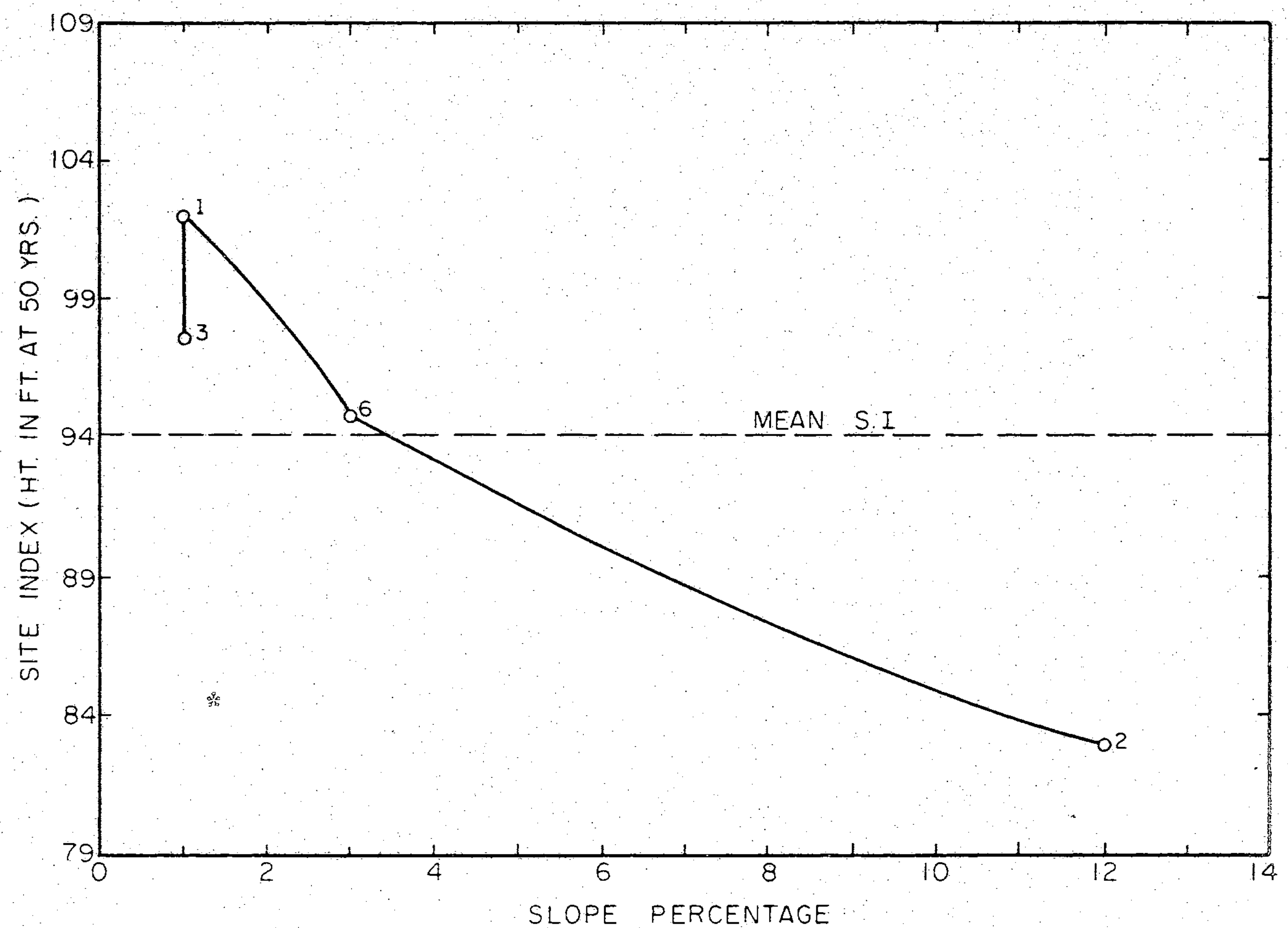


Figure 38. The Relation of Site Index to Slope Percentage.



*Each numerical represents number of plots and average value.

Figure 39. The Realtion of Site Index to Slope Percentage.

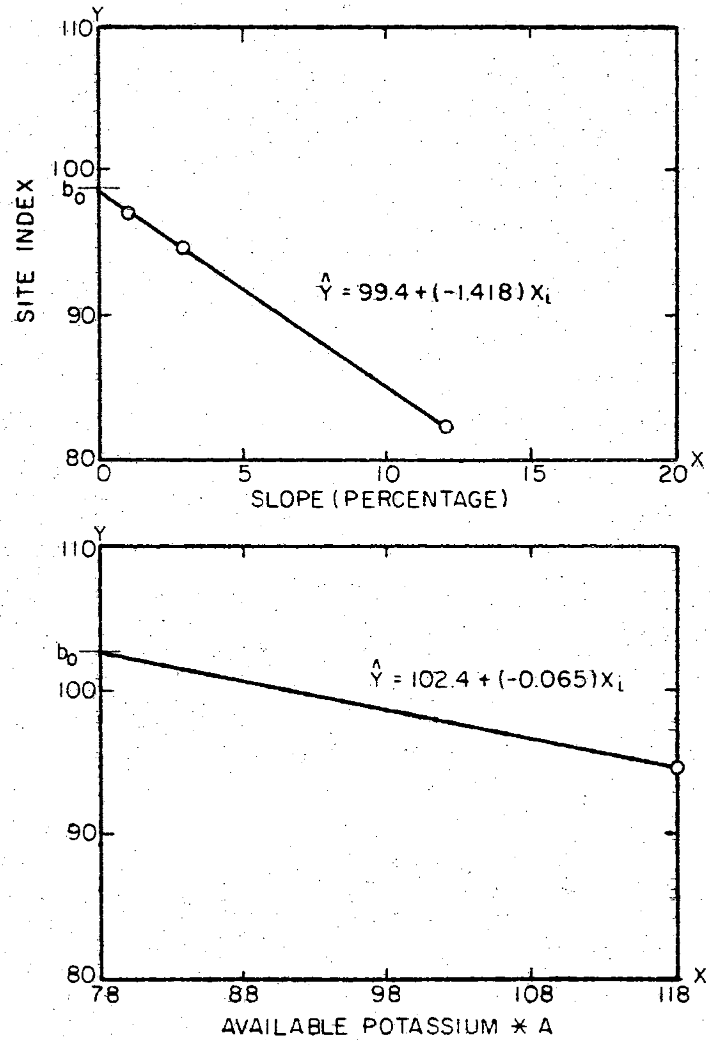


Figure 40. Linear Correlation Curves.

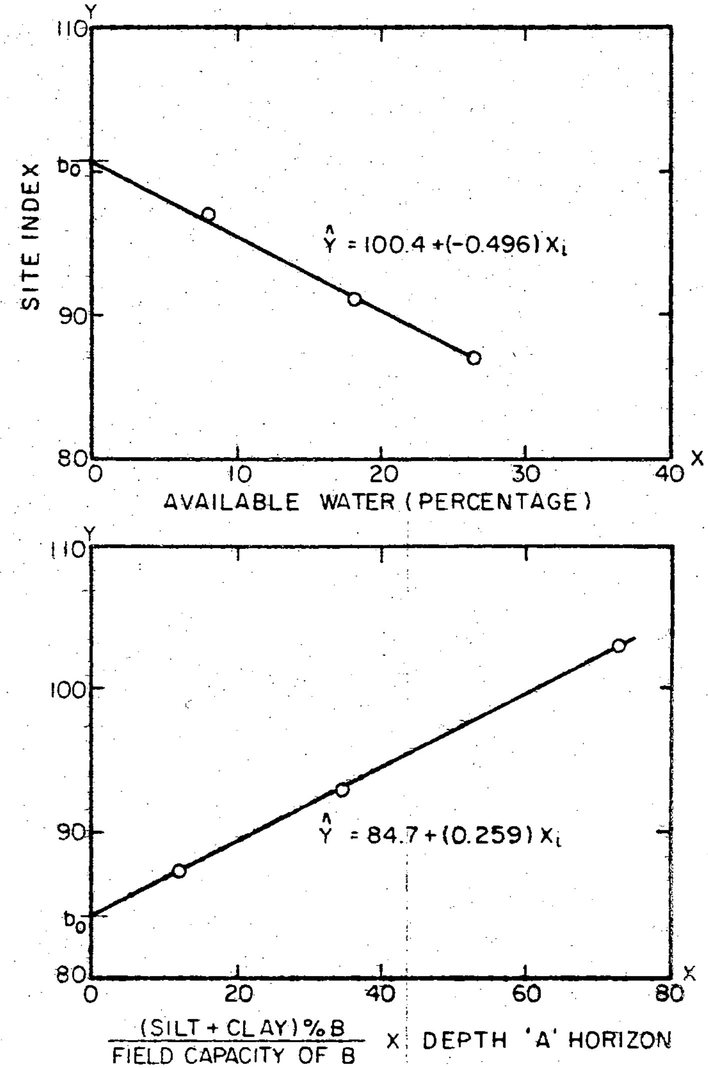


Figure 41. Linear Correlation Curves.

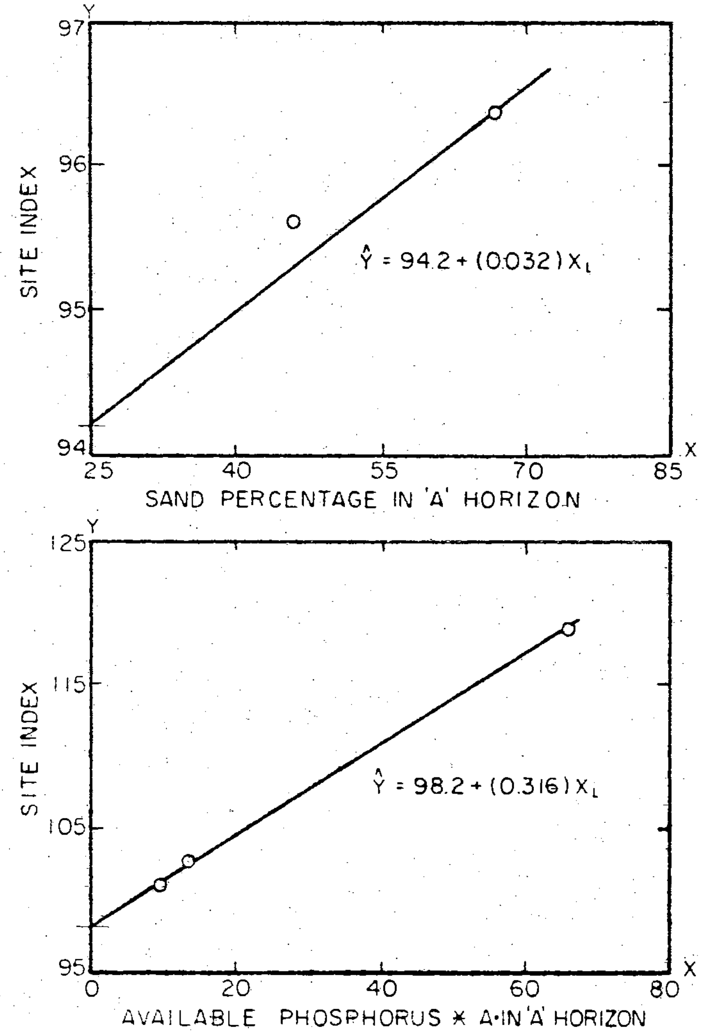


Figure 42. Linear Correlation Curves.

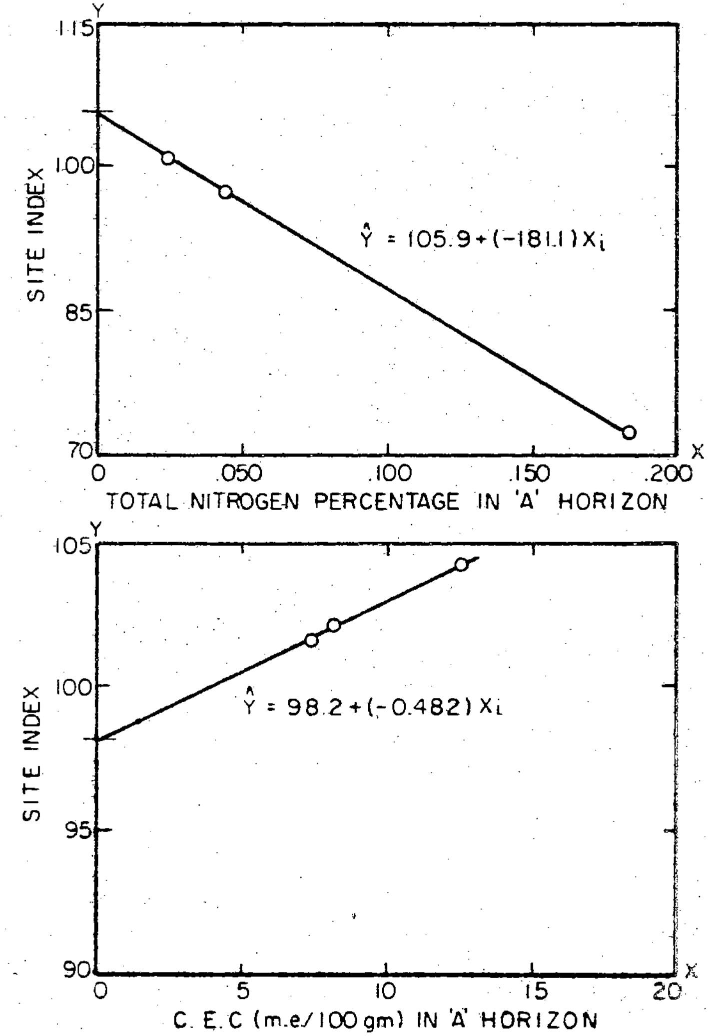


Figure 43. Linear Correlation Curves.

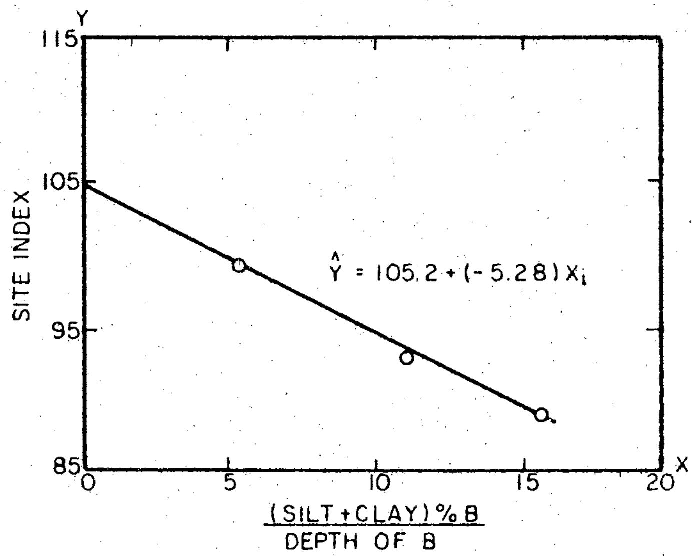


Figure 44. Linear Correlation Curve

Depth of B is also as important as depth of A horizon. As the tree becomes larger the character of the subsoil may exert greater influence on its growth. The amount of finer material, i.e., the (silt + clay) fraction in the soil is directly correlated with waterholding capacity and water availability. The effect of (silt + clay) content is more pronounced in the more sandy soils; apparently a content of 8 to 10% (silt + clay) is adequate for growth of slash pine (6). Having a larger amount of (silt + clay) in the B horizon adversely affects tree growth for want of aeration and drainage. An inverse relation was found between this variable $\frac{\text{(silt + clay) in B}}{\text{depth of B}}$ and site index as shown in Figures 37 & 44.

The effect of topographic differences on growth is of primary importance and appears to be the relationship of soil and topographic characteristics which affect water movement and storage. Land is usually classified by its exposure or it is partitioned into ridges, slopes and bottom lands. Ridges and upper slopes are drier and generally poorer sites than gentle slopes and terraces. Lower slopes have a greater potential supply of water than upper slopes with the same precipitation.

Slope was correlated with other soil properties like (silt + clay), pH, gravel, clay, hydrogen, calcium, magnesium, potassium and negatively correlated with nitrogen, available phosphorus, etc. Slope % was tested statistically for each plot against site index. Slope was negatively correlated with site index, i.e., an increase of slope % resulted in a decreasing site index value. The highest site index was found when the slope was 1% and the lowest site index was found when the slope was 12%. A linear relationship is shown in Figure 40 and other Figures 38 & 39 clearly show a negative correlation. Such results have been supported by numerous workers (35, 36, 40, 95, 108).

An attempt was made to correlate soil parent material and soil series with site index but no significant correlation was obtained.

Twenty-one soil variables were selected and an attempt was made to correlate them by formulating regression or predicting equations with site index. These twenty-one variables were divided into two separate sets, one containing eleven variables and another set containing twelve variables. These two sets of variables were tested for each horizon ie. A_1, A_2, B_{21t} and B_{22t} and regression equations were derived. This was done to isolate promising soil properties which may be responsible for desirable shortleaf pine growth. All of the particulars connected with the regression equations are presented in Tables XXV to XXVII. Five soil properties in the A_1, five in the A_2, ten in the B_{21t} and four in the B_{22t} were correlated by this procedure. The most promising were depth, slope, gravel, clay, sand and sodium with the second set of variables and three soil properties in the A_1, three in the A_2, four in the B_{21t} and one in the B_{22t}. The most promising of these were available water, phosphorus, nitrogen and available potassium. All of the four horizons were combined for the first set of variables and run by the stepwise multiple regression procedure, and two strong soil properties, slope and calcium were isolated for the final run. Similarly three soil properties, i.e., slope, available water, and potassium of B horizons were isolated in the second set for final run. These five properties, i.e., two from the first set and three from the second set were combined and rerun with the stepwise multiple regression procedure in order to obtain a predicting equation for Coastal

Plain soils of Oklahoma as follows;

Site Index i.e. Y = 106.16403 - 0.82979 (slope percentage) - 0.38993
(S.P.) (available moisture)** - 0.02989 (potassium)*

Available moisture was significant at the 01 level whereas available potassium was significant at 05 level of significance.

In the second instance thirty-six of the most promising and suitable variables were selected. None of these variables were included in the twenty-one variables tested above. All the 36 variables were split into three sets each containing 12 variables. Particulars in regard to details are presented in Table 28. An attempt was made to correlate each set of variables against site index of shortleaf pine through stepwise multiple regression. In the first set two soil variables, i.e. (nitrogen in A x depth A) were negatively correlated at the 01 level and $\frac{\text{(silt + clay) of B}}{\text{field capacity of B}}$ x depth A) were significant at the 05 level. In the second set nitrogen in the A was significant at the 01 level. Phosphorus in the A was significant at the 05 level although a significant relationship was not shown a trend between sand in the A and site index and between C.E.C. and site index was obtained. In the final set potassium in the B horizon significantly correlated at the 05 level. The variable, $\frac{\text{(silt + clay) of B}}{\text{depth B}}$, was not significantly correlated with site index, however, a negative trend was observed.

All of these eight variables as reported above were combined and rerun by stepwise multiple regression in order to correlate them with site index and to derive a regression equation as shown below;

$$\text{Site Index, i.e. } y_{(S.P.)} = 81.03079 + 0.17751 \frac{(\text{silt + clay}) \text{ of B}}{\text{field capacity of B}} \times \text{depth A}$$

$$+ 0.20162 \text{ (sand in A)} - 437.86739 \text{ (nitrogen in A)}$$

$$+ 0.65072 \text{ (phosphorus in A horizon)}$$

$$+ 2.70938 \text{ (C.E.C. of A)}$$

$$- 3.17156 \frac{(\text{silt + clay}) \text{ of B}}{\text{depth B}}$$

Finally two suitable and promising predicting equations were derived for determination of site index of shortleaf pine grown in Coastal Plain soils of southeast Oklahoma. Each of these two equations can be utilized at the convenience of the forester or soil scientist. However, the second equation appears to be promising and may be a better predictive equation.

1) $$\text{Site Index i.e. } y_{(S.P.)} = 106.16403 - 0.82979\,(x_1) - 0.38993\,(x_2)^{**} - 0.02989\,(x_3)^{*}$$

where
x_1 = slope percentage
x_2 = available moisture in A_2 horizon
x3 = available potassium in B horizons

2) $$\text{Site Index i.e. } Y_{(S.P.)} = 81.03079 + 0.17751\,(x_1) + 0.20162\,(x_2) - 437.86739\,(x_3) + 0.65072\,(x_4) + 2.70938\,(x_5) - 3.17156\,(x_6)$$

where
$X_1 = \frac{(\text{silt + clay}) \text{ of B}}{\text{field capacity of B}} \times \text{depth of A horizon}$

x_2= sand % in A horizon

x3 = nitrogen % in A horizon

x_4 = available phosphorus in A horizon

x_5 = C.E.C. of A horizon

$x_6 = \frac{(\text{silt + clay}) \text{ of B horizon}}{\text{depth of B}}$

Distribution and Frequency of Forest Trees

Since very early times it has been recognized that there is a close relationship between vegetation and climate. The close identification of climate and vegetation is the consequence of thousands of centuries of plant differentiation and adaptation. Since plants first appeared upon the earth, they have been subjected to the influence of climate. Through the elimination of non-adapted species and through the frequent origin of new forms (mutant) many different types of plants have become adapted to widely different climatic conditions. Locally the climax may not exist at all because of edaphic (soil) conditions or because fire has destroyed the dominant vegetation and it has not had sufficient time to become reestablished. Under such conditions it may appear as though the vegetative climax has been reached, but the only true climax is the climatic climax. Edaphic, biotic, fire and all other "so called" climaxes are capable of partial or complete explanation on the basis of the climatic climax (7).

Every plant is a product of the conditions under which it grows and is therefore a measure of an environment. It indicates in general, and often also in a specific manner, what other species would do if grown in the same place. However, plant communities are more reliable indicators than individual plants. Each plant and community moreover bring together a more or less definite soil and climate (101). Because of this adaptation each major climatic region has a dominant vegetation group made up of several plant species each of which is adjusted to the climate of that region (7). Parent material also affects tree growth within the same climate region. The soil type and soil characteristics affect the vegetative cover, distribution and development of trees. (39, 47). The question arises, however, as to why different forest tree species with different frequencies occur in the same climatic region.

Chandler (14) replied to this question as follows:

1) The distribution of the trees may have been accidental originally, but once established they have continued to reproduce themselves and have made the site more or less favorable, depending on the species present.

2) There may be differences in the soil characteristics which have not been discovered as yet.

3) The water conditions as determined by topography may have been influential in determining the distribution of tree species.

It is also true that edaphic factors also play a major role although plant association, seed mobility, biotic and fire factors are also important in explaining the distribution and frequency of forest tree species. Keeping in view the above factors a second study was undertaken to investigate the relation between soil properties and frequency of tree species and a statistical study was also made in an effort to determine if a correlation existed among tree species and soil properties.

Twenty-eight tree species and thirty-one regeneration seedlings were present in study area. This study was primarily concerned with the frequency of tree species vs soil properties. Different tree species, their frequency and regeneration seedlings are presented in Tables XXIX to XXXII and Figures 45, 46. Simple linear correlation studies of twenty-two tree species were undertaken in order to measure the degree of association among them. Significant values of this study

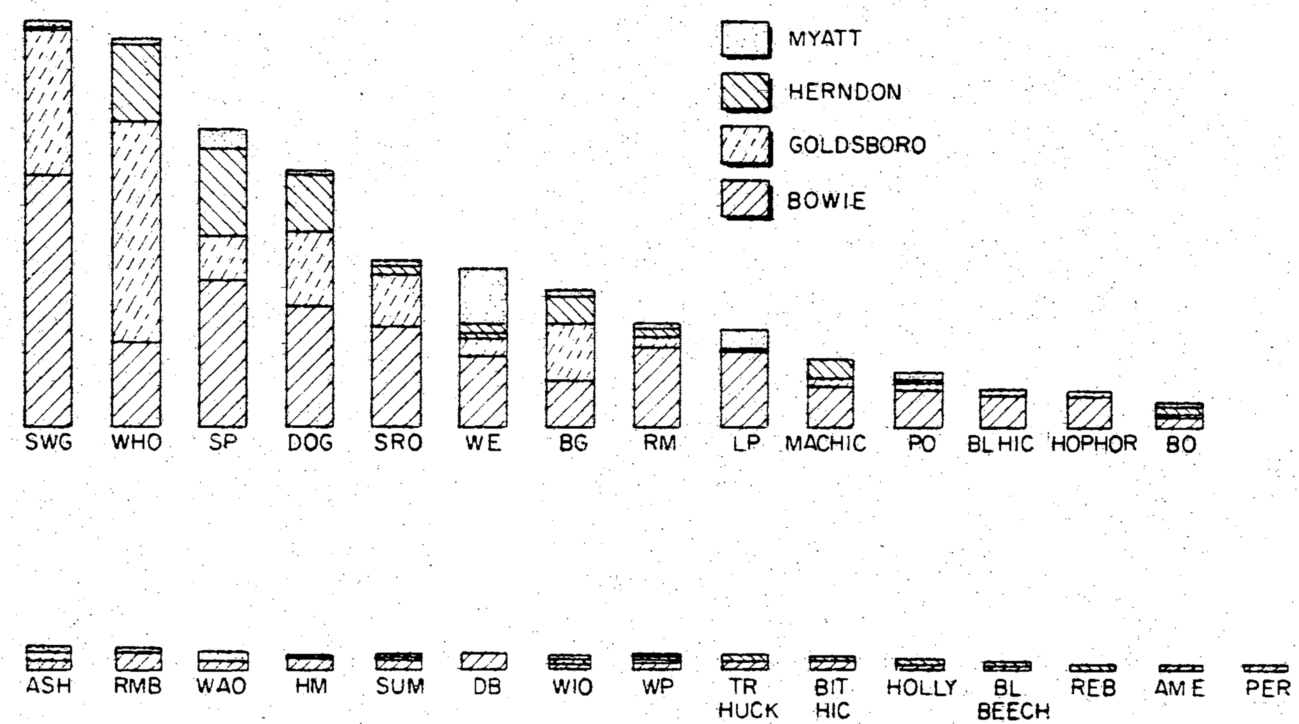


Figure 45. Tree Species and Their Frequency in Decreasing Order.

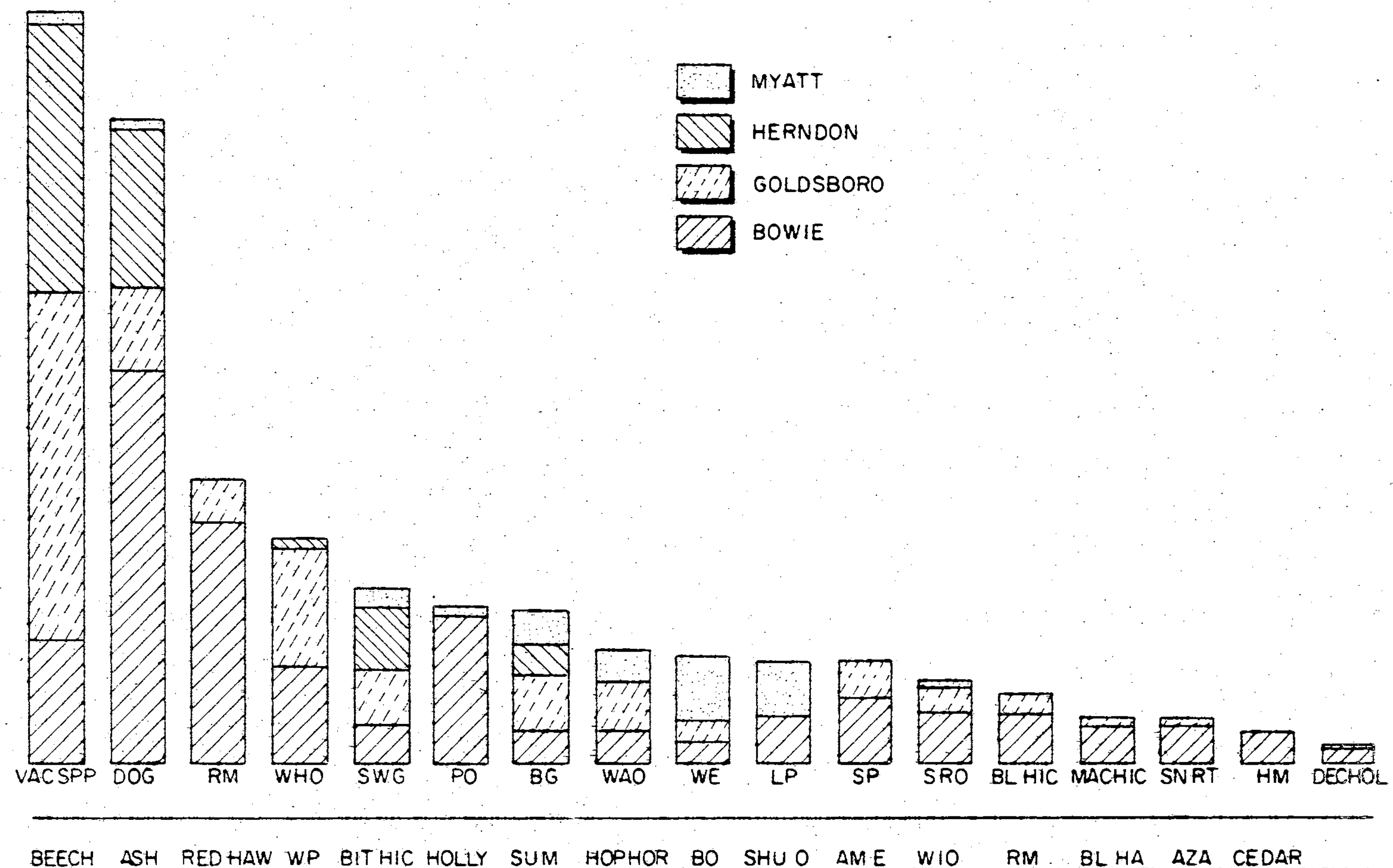


Figure 46. Regeneration Frequency in Decreasing Order.

are presented in Table XII.

Simple linear correlation studies were also undertaken to measure the degree of association between soil properties and tree species of the following, significant values are presented in Table XXII.

1. shortleaf pine, 2. white oak, 3. southern red oak, 4. dogwood, 5. black oak, 6. black gum, 7. red maple, 8. black hickory, 9. mockernut hickory, 10. blueleech, 11. winged elm, 12. sweet gum, 13. post oak, 14. wild plum, 15. tree huckleberry, 16. ash, 17. red mulberry, 18. holly, 19. willow oak, 20. loblolly pine, 21. water oak, 22. sumac, 23. depth in inches, 24. slope percentage, 25. gravel, 26. sand, 27. silt, 28. clay, 29. exchangeable hydrogen, 30. exchangeable clacium, 31. exchangeable magnesium, 32. exchangeable potassium, 33. exchangeable sodium, 34. total exchangeable bases, 35. C.E.C., 36. moist at 1/3 atm, 37. moist 1 atm, 38. moist 15 atm, 39. available water, 40. nitrogen %, 41. available phosphorus, 42. available potassium, 43. pH paste 1:1, 44. pH, KCl.

These twenty-eight species which were present in the study area are reported in Tables XXIX and XXX. Shortleaf pine, white oak, southern red oak, black oak, post oak, dogwood, black gum, red maple, winged elm, sweet gum and wild plum were present on all of the 12 plots present in the study area.

The most frequent species on Bowie fine sandy loam in order of decreasing frequency were southern red oak, post oak, red maple, winged elm, tree huckleberry, shummards oak, red mulberry, American elm, persimmon, deerberry, sumac and holly. Shortleaf pine, white oak, southern red oak, red maple, winged elm, sweet gum were present in all of the six Bowie soil plots, whereas redbud was not present in any of them. American elm, persimmon, deerberry, were present only in Bowie fine sandy loam plots and not on any other type of soil.

Shortleaf pine, white oak, southern red oak, dogwood, black gum, red maple, sweet gum were present in all the three plots of Goldsboro loam. Water oak, bitternut hickory, bluebeech, redbud, tree huckleberry, American elm, persimmon, deerberry, were not present in all of these plots. The most frequent species on the Goldsboro loam in order of decreasing frequency were sweet gum and red maple.

Shortleaf, white oak, southern red oak, black oak, dogwood, black gum, Mockernut hickory were present in both the plots of Herndon loam. Loblolly pine, water oak, black hickory, bitternut hickory, ash, hophorn beam, red mulberry, American elm, persimmon, deerberry, sumac, holly were not present in these plots. The most frequent species on the Herndon loam in order of decreasing frequency were shortleaf pine, white oak, dogwood, mockernut hickory, and redbud.

Out of the above 28 species black hickory, mockernut hickory, blue beech, redbud, tree huckleberry, hophornbeam, red mulberry, American elm, persimmon, vacc spp, holly were not present in Myatt silt loam. The most frequent species on the Myatt silt loam in order of decreasing frequency were loblolly pine, post oak, willow oak, water oak, winged elm, white oak.

Simple Linear Correlation Studies

Twenty-two soil properties were tested for correlation significance with twenty-two tree species, and all twenty-eight species were tested for correlation significance among themselves. Correlation coefficient significant values between tree species and soil properties and correlation coefficients among tree species are presented in Tables XII and XIII.

There was a significant correlation between shortleaf pine and soil properties like slope, nitrogen, phosphorus and potassium. A significant correlation was also found between shortleaf pine with other species like loblolly, vacc spp and white oak. A negative significant correlation obtained with wild plum.

No significant relation was found between white oak soil properties, however, there was a trend of increasing frequency with increase of nitrogen. A significant correlation was also found between white oak and with winged elm, holly, but it was negatively significantly correlated with black oak and water oak.

There was a significant correlation found between southern red oak exchangeable magnesium, but a positive trend was shown with gravel, silt, phosphorus, potassium and a negative trend was shown with sand and clay. A significant correlation was also found between southern red oak with other species like winged elm, holly, mockernut hickory.

No significant correlation was found either between dogwood and soil properties and also with other species.

Significant correlation was found between black oak and pH. This species was also significantly correlated with bluebeech, sumac and persimmon. A negative significant correlation was obtained with white oak, loblolly pine.

No significant correlation was found between black gum and soil properties but trend was shown with exchangeable hydrogen and calcium.

TABLE XII

CORRELATION COEFFICIENT AMONG FOREST TREE SPECIES
(Soil Properties (Significant Values Only)

S. No.	Variable	Variable	"r"
1	Shortleaf Pine	Slope	0.80009**
2	Shortleaf Pine	Nitrogen	0.74740**
3	Shortleaf Pine	Available phosphorus	0.70666**
4	Shortleaf Pine	Available potassium	0.70680**
5	White oak	Winged elm	0.92099**
6	White oak	Black oak	0.963*
7	White oak	Water oak	1.0000**
8	S. Red oak	Holly	1.0000**
9	S. Red oak	Ex. magnesium	0.99463**
10	Black oak	Beech	1.0000**
11	Black oak	Sumac	0.99911*
12	Black oak	pH KCl	0.69557*
13	Black gum	Sweet gum	0.87606**
14	Black gum	Water oak	-0.99154**
15	Red maple	Available water	0.63822*
16	Black hickory	Beech	-0.99795*
17	Black hickory	Ex. magnesium	-0.65296*
18	Black hickory	Nitrogen	-0.64828*
19	Mockernut hickory	Beech	1.0000**
20	Mockernut hickory	Ash	0.97502*
21	Bluebeech	Ex. hydrogen	-0.993*
22	Winged elm	Loblolly pine	-1.0000**
23	Winged elm	Sweet gum	0.729*
24	Sweet gum	Holly	1.0000**
25	Sweet gum	Willow oak	0.85490*
26	Post oak	C.E.C.	-0.67809*
27	Wild plum	Moisture 1/3 atm	0.60798*
28	Wild plum	Available water	0.71741**
29	Tree huckleberry	Water oak	1.0000**
30	Tree huckleberry	pH KCl	0.96225*
31	Willow oak	Loblolly pine	1.0000**
32	Willow oak	Sumac	1.0000**
33	Water oak	Ex. hydrogen	-0.94402*
34	Water oak	Ex. sodium	0.679*
35	Water oak	Moisture 1/3 atm	-0.817*
36	Water oak	Moisture 15 atm	-0.817*
37	Depth	Slope	0.78581**
38	Depth	Silt	0.63269*
39	Depth	Nitrogen	0.77437**
40	Depth	Available phosphorus	0.70841**
41	Depth	Available potassium	0.87204**
42	Slope	Nitrogen	0.90124**

*Significant at .05 level
**Significant at .01 level

TABLE XII — Continued

S. No.	Variable	Variable	"r"
43	Slope	Available phosphorus	0.94153**
44	Slope	Available potassium	0.95513**
45	Gravel	Sand	-0.96080**
46	Gravel	Clay	-0.99707**
47	Gravel	Total ex. bases	-0.70182**
48	Gravel	C.E.C.	-0.63716*
49	Gravel	Moisture 1/3 atm	-0.86766**
50	Gravel	Moisture 1 atm	-0.81044**
51	Sand	Clay	0.95863**
52	Sand	Total ex. bases	0.58098*
53	Sand	Available water	0.74390**
54	Silt	Ex. magnesium	0.51640*
55	Silt	Total ex. bases	0.680907*
56	Silt	C.E.C.	0.71802**
57	Silt	Moisture 1/3 atm	0.67478*
58	Silt	pH Paste 1:1	0.73513**
59	Clay	C.E.C.	0.65796*
60	Clay	Moisture 1/3 atm	0.88771**
61	Clay	Moisture 1 atm	0.83072**
62	Clay	Available water	0.76031**
63	Ex. hydrogen	Total ex. bases	0.69773*
64	Ex. hydrogen	pH paste	-0.72419**
65	Ex. calcium	Ex. magnesium	0.65562*
66	Ex. calcium	Total ex. bases	0.61529*
67	Ex. calcium	C.E.C.	0.71776**
68	Ex. calcium	Moisture 1/3 atm	0.57159*
69	Ex. calcium	Moisture 1 atm	0.65918*
70	Total ex. bases	C.E.C.	0.90457**
71	Total ex. bases	Moisture 1/3 atm	0.66587*
72	Total ex. bases	Moisture 1 atm	0.82507**
73	Total ex. bases	pH Paste 1:1	-0.57226*
74	C.E.C.	Moisture 1/3 atm	0.68935*
75	C.E.C.	Moisture 1 atm	0.83539**
76	C.E.C.	Moisture 15 atm	0.63955*
77	Moisture 1/3 atm	Moisture 1 atm	0.92257**
78	Moisture 1/3 atm	Available water	0.92994**
79	Moisture 1 atm	Available water	0.79793**
80	Nitrogen	Available phosphorus	0.92167**
81	Nitrogen	Available potassium	0.93843**
82	Available phosphorus	Available potassium	0.94033**
83	pH paste 1:1	pH KCl	0.64000*

*Significant at .05 level
**Significant at .01 level

TABLE XIII

CORRELATION COEFFICIENT AMONG FOREST TREE SPECIES
(Significant Values Only)

S. No.	Variable	Variable	"r"
1	Shortleaf Pine	White oak	0.85710*
2	Shortleaf Pine	Wild plum	-1.0000**
3	Shortleaf Pine	Loblolly pine	1.0000**
4	Shortleaf Pine	Vacc spp	1.0000**
5	White oak	Black oak	-0.96309*
6	White oak	Winged elm	0.92099*
7	White oak	Horse mint	-1.0000**
8	S. Red oak	Mockernut hickory	1.0000**
9	Black oak	Beech	1.0000**
10	Black oak	Loblolly pine	-1.0000**
11	Black oak	Persimmon	0.99587*
12	Black oak	Sumac	0.99911*
13	Black gum	Wild plum	-1.0000**
14	Red maple	Wild plum	-1.0000**
15	Black hickory	Beech	-0.99795*
16	Black hickory	Vacc spp	1.0000**
17	Mockernut hickory	Beech	1.0000**
18	Mockernut hickory	Hophornbeam	0.97502**
19	Mockernut hickory	Loblolly pine	-1.0000**
20	Winged elm	Redbud	0.72869**
21	Winged elm	Wild plum	-1.0000**
22	Winged elm	Loblolly pine	1.0000**
23	Winged elm	Vacc spp	1.0000**
24	Winged elm	Water oak	1.0000**
25	Redbud	Wild plum	-1.0000**
26	Redbud	Holly	1.0000**
27	Redbud	Vacc spp	1.0000**
28	Sweet gum	Wild plum	1.0000**
29	Sweet gum	Ash	0.96093*
30	Sweet gum	Vacc spp	1.0000**
31	Post oak	Wild plum	1.0000**
32	Post oak	Loblolly pine	-1.0000**
33	Post oak	Vacc spp	-1.0000**
34	Ash	Hophornbeam	0.94281*
35	Ash	Horse mint	1.0000**
36	Willow oak	Persimmon	1.0000**
37	Willow oak	Water oak	1.0000**
38	Willow oak	Sumac	1.0000**
39	Loblolly pine	Bitternut hickory	1.0000**
40	Persimmon	Horse mint	1.0000**
41	Water oak	Horse mint	1.0000**

*Significant at 0.05 level
**Significant at 0.01 level

Black gum was also significantly correlated with sweet gum, but a negative correlation was obtained with wild plum, loblolly, water oak, vacc spp.

A significant correlation was found between red maple and available moisture but it was negatively correlated with wild plum and loblolly pine.

A negative significant correlation was found between black hickory and exchangeable magnesium, nitrogen. A negative significant correlation was obtained with blue beech.

An increasing trend was found between mockernut hickory and exchangeable calcium, exchangeable magnesium and moisture at 1/3 atm. Mockernut hickory was also significantly correlated with loblolly pine and vacc spp.

A negative significant correlation was found between blue beech and exchangeable hydrogen. It was also significantly correlated with black oak, black hickory, and mockernut hickory.

No significant correlation was found between winged elm and soil properties but a negative trend was observed with exchangeable potassium. Winged elm was also significantly correlated with redbud, loblolly pine, water oak, vacc spp, sweet gum, white oak, southern red oak but negatively correlated with wild plum.

Negative trend was found between sweet gum and depth, exchangeable magnesium, available phosphorus. A significant correlation was also found between sweet gum and holly, wild plum, loblolly pine, vacc spp, black gum, winged elm, willow oak and ash.

A significant correlation was found between redbud* and with other species like holly, vacc spp, winged elm, but negatively correlated with wild plum.

A negative significant correlation was found between post oak and C.E.C. This species was correlated with wild plum. A negative trend was observed between post oak and loblolly pine, vacc spp.

A significant correlation was found between wild plum and available moisture. Correlation was also found with shortleaf pine, black hickory, sweet gum, post oak and inversely related with black gum, red maple, winged elm, redbud.

A significant positive correlation was observed between tree huckleberry and pH. Trend was observed with slope, available potassium and exchangeable sodium. This tree species was correlated with oak.

A positive trend was found between ash and slope, exchangeable calcium, pH, but negative trend was observed with exchangeable potassium. Ash was also significantly correlated with hophorn beam, persimmon, mockernut hickory, and sweet gum.

No correlation was found between red mulberry, either with soil properties, nor tree species.

A significant correlation was found between hophorn beam* and mockernut hickory, ash, and trend was shown with Holly, persimmon.

A positive trend was found between holly and nitrogen, exchangeable potassium, but a negative trend was shown with silt. Holly significantly correlated with white oak, southern red oak, redbud, sweet gum.

A positive trend was found between willow oak and exchangeable potassium and a negative trend with magnesium. A significant correlation was found between willow oak and persimmon, water oak, sumac loblolly pine and sweet gum.

A trend was found between loblolly pine and sand, exchangeable calcium, exchangeable magnesium and a negative trend was found with exchangeable hydrogen and sodium. It was significantly correlated with water oak, bitternut hickory, black hickory, winged elm, sweet gum, and willow oak. Loblolly pine was inversely related with black oak, black gum, red maple, post oak and mockernut hickory.

A negative significant correlation was found between water oak exchangeable hydrogen, and positive trend with pH and negative trend with exchangeable sodium. Water oak was also correlated with mockernut hickory, winged elm, tree huckleberry, willow oak, loblolly pine and inversely related with white oak, black gum.

A significant correlation was found between American elm* and black oak, ash, willow oak.

A significant correlation was found between persimmon* and black oak, ash, willow oak.

A significant correlation was found between frequency of vacc spp*and other tree species like black hickory, winged elm, red bud, sweet gum, and inversely related with black gum and mockernut hickory.

A positive trend was found between sumac and gravel and negative trend was observed with silt, available phosphorus, exchangeable hydrogen. Sumac was also correlated with black oak and willow oak.

Bitternut hickory* was correlated significantly with the loblolly pine.

Each soil property and the frequency of the species that each one of these properties that are related are shown as follows:

---

* omitted in the correlation coefficient between soil properties and tree species.

Depth: sweet gum

Slope: shortleaf pine, white oak, tree huckleberry, ash.

Gravel: Southern red oak, black oak, sumac.

Sand: Southern red oak, black oak, loblolly pine.

Silt: Southern red oak, post oak, holly, sumac.

Clay: Southern red oak, black oak.

Exchangeable hydrogen: Black gum, blue beech, loblolly pine, water oak, sumac.

Exchangeable calcium: Black gum, mockernut hickory, ash, willow oak.

Exchangeable magnesium: Southern red oak, black hickory, mockernut hickory, sweet gum.

Exchangeable potassium: Black oak, bluebeech, winged elm, ash, willow oak.

Exchangeable sodium: Blue beech, tree huckleberry, loblolly pine, water oak.

Total exchangeable cations: Water oak.

C.E.C.: Black hickory, winged elm, post oak, water oak.

Available water: Red maple, blue beech, wild plum.

Nitrogen: Shortleaf pine, white oak, black hickory, holly.

Available phosphorus: Shortleaf pine, southern red oak, sweet gum, sumac.

Available potassium: Shortleaf pine, southern red oak, tree huckleberry.

pH: Black oak, post oak, tree huckleberry, ash, water oak.

Significant correlation of loblolly pine was found with eleven other tree species, water oak with eight, winged elm with eight, sweet gum with eight, wild plum with seven, vacc spp with seven, mockernut hickory with seven, white oak with six, black oak with six, black gum with five, willow oak with five, southern red oak with three and lastly post oak was correlated with three other tree species as shown in Table XIII.

In conclusion edaphic factors in addition to other ecological factors, play significant role in affecting valuable tree species frequency in this area especially shortleaf pine and white oak, which are affected by slope percentage; southern red oak, black oak, post oak, loblolly pine which are affected by texture; black gum, loblolly pine, water oak, willow oak, sweet gum, post oak which are affected by exchangeable cations and C.E.C.; red maple, bluebeech, wild plum are affected by available water; Shortleaf pine, white oak, southern red oak, sweet gum, black oak, post oak and water oak which are affected by nitrogen and available nutrients.

CHAPTER V

SUMMARY AND CONCLUSIONS

Foresters as well as Agronomists and those engaged in soil research are interested in appraising the productivity of different classes of soil. Often as many as four to six site factors may be meaningful in terms of wood production of a given species of tree and two or three are likely to be of paramount importance. Scientific forestry, no less than scientific farming, must be based on a knowledge of the productive potential of the land (92). With intensification of forest management has come the need for acre by acre classification of site quality. Approximately 4.8 million acres of the total 5.5 million acres was classified as commercial forest land in eastern Oklahoma. Shortleaf pine, is one of the four pine species commonly referred to as Southern yellow pine. It comprises about 1/4 of the total volume of pine timber in the South which is shown in Figure 3.

The present investigation has been designed to study the utilization of soil properties for site evaluation with the following specific objectives.

1) To determine the relationship between soil properties and site index of shortleaf pine (*pinus echinata* Mill) in order to estimate the growing capacity of the Coastal Plain soils of Southeastern Oklahoma.
2) To investigate the causes for the distribution of forest

tree species in this region.

The three sections of the state listed have unique topographic features which influence the development of natural vegetation, part of Southeast Oklahoma contains the Gulf Coastal Plain. The study area is located in the vicinity of Broken Bow, in McCurtain County, Oklahoma as shown by Figures 1 and 2.

The soils included in this study represent four soil types namely Bowie fine sandy loam, Goldsboro loam, Herndon loam and Myatt silt loam. Bowie fine sandy loam, Herndon loam, Goldsboro loam and Myatt silt loam follow in decreasing order of sand, Myatt silt loam, Goldsboro loam, Herndon loam and Bowie fine sandy loam follow in the decreasing order of silt, Herndon, Myatt, Goldsboro and Bowie follow in the decreasing order of clay content. The general trend in all these profiles is a decrease of sand, silt (except in Goldsboro) particle and an increase of clay content as the depth is increased. This relationship suggests the possibility of eluviation of fine clay from the A horizon into the B horizon. Goldsboro loam, Herndon loam, Bowie fine sandy loam and Myatt silt loam follow in the decreasing order of finer material, it is but natural for these profiles to follow in the same order when rating available water. Moisture release curves in general indicate that more available water contained in the horizons where the clay content, finer material or organic matter is present. Presence of less or more of exchangeable hydrogen and calcium is related to the reaction of the horizon. It also indicates that exchangeable calcium is dominant in the A_1 horizon (except in Herndon), exchangeable bases (calcium, magnesium, potassium, sodium) show decreasing trend in the A_2, $B_{21}t$ horizons, and increasing trend in B_2 horizons. Higher C.E.C. is found in the A_1 than in the A_2. This suggests that C.E.C. depends on clay content, nitrogen percentage and available moisture. There is a decreasing trend of pH and nitrogen as the depth progressed. Chemical studies also indicate that these profiles are low in available nutrients except Herndon loam.

Site index is the measure of all effective factors of site, climate, biotic and physiographic as well as edaphic factors. Site index alone is, at best, a measure of site potential for specific geographic or genetic strain of a species. Regression analysis indicated that the growth of shortleaf pine is related to slope percentage, available moisture, available phosphorus in A, C.E.C. of A and variables like $\frac{\text{(Silt+Clay) of B}}{\text{Field capacity of B}} \times \text{Depth of A}$, $\frac{\text{(Silt+Clay) of B}}{\text{Depth of B}}$.

Two suitable predicting equations are derived for determination of site index of shortleaf pine grown in Coastal Plain soils of Southeast Oklahoma.

1) Y (Site Index) = 106.16403-0.82979(slope)-0.38993(available moisture in A_2 horizons)**-0.02989(available potassium in B horizons)*

2) Y (Site Index) = $81.03079+0.17751 \frac{\text{(Silt+Clay)}}{\text{Field capacity of B}} \times$ Depth of A+0.20162(% sand in A)-437.86739(% nitrogen in A)+0.65072(Available phosphorus in A)*+ 2.70938(C.E.C. of A)*-$3.17156\frac{\text{(Silt+Clay)of B}}{\text{Depth of B}}$

**Significant at 1% level
*Significant at 5% level

The question naturally arises however, as to why different tree species and with different frequencies occur in the same climatic regions. Edaphic factors in addition to ecological factors, play a great part in influencing the frequency of the valuable tree species as shown in this study. This investigation shows that factors like slope percentage affects the frequency of shortleaf pine and white oak. Soil texture affects Southern red oak, black oak, post oak, loblolly pine. Exchangeable cations in the soil and C.E.C. affect the distribution of black gum, loblolly pine, water oak, willow oak, sweet gum and post oak. Available soil moisture affects red maple, bluebeech, wild plum; nitrogen and available nutrients that of shortleaf pine, white oak, southern red oak, sweet gum, black oak and post oak.

Similarly significant correlation of shortleaf pine was found with 11 other tree species: water oak with 8, winged elm with 8, sweet gum with 8, wild plum with 7, Vacc spp with 7, Mockernut hickory with 7, white oak with 6, black oak with 6, black gum with 5, willow oak with 5, southern red oak with 3, and lastly post oak is correlated with 3 other tree species.

Suggestions For Future Research Work

I. It is suggested to take more number of plots for study especially for this type of research work. It is also suggested to take some more soil properties in addition to the present one, like age, I.W. values, bulk density, clay fraction especially Kaolin, Montmorillonite and Illite (so far this aspect of research has not been done), all topographic features, important soil morphological features, altitude rainfall, frost free days (if there are any differences) fire effect (if present). All these properties must be correlated with S.I. of desired tree species, on each different soil type found in Coastal Plain soils to derive predicting equation for each one of them & combine all of them to get final regression equation for the entire area.

1. Shortleaf pine, 2. Loblolly pine, 3. Post oak, 4. Red oak, 5. Black oak, 6. White oak, 7. Willow oak, 8. Water oak, 9. Red

gum, 10. Black gum are the important forest tree species which are valuable from the viewpoint of commercial and other utilities distributed in Coastal Plain soils which is about 500 thousand acerage in area.

II. Comprehensive study of the relationship of soil properties and site index of these species is suggested. It will not be time consuming because soil profiles and soil properties are common to many species only extra work which is required to take site indices of these species and run stepwise multiple regression for each species.

III. Another piece of research work which is suggested here is to study the relationship of site indices of ten tree species referred to above, so that when the site of one species is known for a given piece of land it is possible to determine by use of equations or chart, the site index for one or all the other nine species.

If the aforesaid valuable research is undertaken I am sure farmers and industrialists will be benefited much in kind and cash and also one aspect of the research work will be completed and it will be on a par with other states where research is being carried out with soil properties and growth of forest trees.

LITERATURE CITED

1. Alexander, L. T. et al. 1939. Minerals present in soil colloids, estimation in some representative soils. Soil Sci. 48:273-279.
2. Alway, F. J. and P. R. McMiller. 1933. Interrelationships of soil and forest cover on Star Island, Minn. Soil Sci. 36:281-295.
3. Applequist, M. B. 1959. Soil site studies of southern Hard woods. 8th Annual forestry symposium: Southern Forest Soils. Louisiana State University Press. 49-63.
4. Arend, J. L. and J. Odell. 1948. Oak sites in the Arkansas Ozarks. Ark. Agri. Expt. Sta. Bull. 484, pp. 42.
5. Auten, J. T. 1937. Site requirements of yellow poplar. Central States for Expt. Sta. 32, pp. 13.
6. Barnes, L. R. and C. W. Ralston. 1955. Soil factors related to growth and yield of Slashpine plantation. Agri. Exp. Sta. Bull. University of Florida, 559:17 pp.
7. Blumenstock, D. I., and C. W. Thornthwaite. 1941. Climate and the world pattern. Climate & Man Year Book of Agriculture. 98-127 & 1071-1075.
8. Bray, R. H. 1948. Correlation of soil tests with crop responses to added fertilizer with some fertilizer requirements, Diagnostic techniques for soils and crops. Ame. Pot. Inst. Washington, D. C. 53-86.
9. Bray, R. H. and L. T. Kurtz. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.
10. Brower, D. L. 1966. A correlation of soil type and soil profile chemical characteristics. M. S. Thesis. University of Missouri.
11. Brown, D. A. 1953. Cation exchange in soils through the moisture range saturation to the wilting percentage. Soil Sci. Soc. Ame. Proc. 17:92-96.
12. Carmean, W. H. 1954. Site quality for Douglas-fir in southern Washington and its relation to precipitation, elevation and physical properties of soil. Soil Sci. Soc. Ame. Proc. 18:330-334.

13. _____________., 1961. Soil survey refinements needed for accurate classification of black oak site quality in southeastern Ohio. Soil Sci. Soc. Ame. Proc. 25:394-397.

14. Chandler, Jr., R. F. 1939. Cation exchange properties of certain forest soils in the Adirondack section. J. Agri. Resh. 59:491-505.

15. Chapman, H. D. and F. P. Parker. 1961. Methods of analysis for soils, plants and water. Uni. of Calif. Division of Agri. Sci.

16. Chisman, H. H. and F. X. Schumacher. 1940. On the tree area ratios and certain of its application. J. For. 38:311-317.

17. Coile, T. S. 1935. Relation of site index for shortleaf pine to certain physical properties of the soil. J. For. 33:726-730.

18. _____________., 1938. Forest classification: Classification of forest sites with special reference to ground vegetation. J. For. 36:1062-1066.

19. _____________., 1948. Relation of soil characteristics to site index of loblolly and shortleaf pines in the lower Piedmont region of North Carolian. Duke University Sch. of For. Bull. 13:78pp.

20. _____________., 1952. Soil and growth of forests. Adv. in Agron. 4:329-398.

21. Coile, T. S. and F. X. Schumacher. 1953. Site index of young stands of loblolly and shortleaf pine in the Piedmont plateau region. J. For. 51:432-435.

22. _____________., and F. X. Schumacher. 1953. Relation of soil properties to site index of loblolly and shortleaf pines in the Piedmont region of the Carolinas, Georgia and Alabama. J. For. 51:739-744.

23. Cloeman, R. and M. L. Jackson. 1945. Mineral composition of the clay fraction of several Coastal Plain soils of southeastern U.S.A. Soil Sci. Soc. Ame. Proc. 10:381-391.

24. Cloeman, N. T. and A. Mehlich. 1957. The chemistry of soil pH. U.S.D.A. Year Book of Agriculture. 73-79.

25. Cox, G. S. et.al. 1960. Ponderosa pine productivity in relation to soil and land from the western Montana. Soil Sci. Soc. Amer. Proc. 24:139-142.

26 Copeland, O. L., Jr. 1958. Soil site index studies of western white pine in the northern rocky mountain region. Soil Sci. Soc. Amer. Proc.

27. Crocker, R. L. 1952. Soil genesis and the pedogenic factors. Quart. Rev. Biol. 27:139-168.

28. Crocket, J. J. 1966. The vegetation of Oklahoma. Unpublished hand out.

29. Davis, L. V. 1960. Geology and ground water resources of southern McCurtain County Oklahoma. Okla. Geological Survey Bull. 86:108pp.

30. Day, P. R. 1956. Report of the committee on physical analysis procedure. Soil Sci. Soc. Amer. Proc, 20:167-169.

31. Daubenmire, R. F. 1952. Forest vegetation of Northern Idaho and adjacent Washington and its bearing on concepts of vegetation classification. Ecol. Monograph. 22;301-330.

32. ____________,. 1961. Vegetative indicators of rate of height growth in Ponderosa pine. For. Sci. 7:24-34.

33. Della Bianca, L. and D. F. Olson, Jr. 1961. Soil site studies in Piedmont hardwood and pine hardwood upland forests. For. Sci. 7:320-329.

34. Diebold, C. H. 1935. Some relationships between soil type and forest site quality. Ecol. 16:640-647.

35. Dingle, R. W. and P. Y. Burns. 1954. Relationship of shortleaf pine growth to soil properties. Miss. Agri. Expt. Sta. Resh. Bull. 541;3-9.

36. Doolittle, W. T. 1957. Site index of Scarlet and Black Oak in relation to Southern Applachian soil and topography. For. Sci. 3:114-124.

37. ____________,. 1958. Site index comparisions for several forest species in the Southern Applachians. Soil Sci. Soc. Amer. 22:455-458.

38. Dryness, C. T. and C. T. Youngberg. 1958. Soil vegetation relationships in the central Oregan Pumice region. First north Amer. forest soils conference. Michigan State Univ. Press, East Lansing. 57-66.

39. Dwyer, D. D. and P. W. Stantelmann. 1964. A comparison of the post oak, black jack oak communities on two major soil types in north central Oklahoma. Okla. Sta. Univ. Expt. Sta. Bull. 625:15pp.

40. Gaiser, R. N. 1951. Relation between topography, soil characteristics and the site index of white oak in south eastern Ohio. U.S.D.A. For. Ser. Cent. State for Tech. paper. 121:1-12.

41. Gaiser, R. N. and R. W. Merz. 1953. Growth of planted red and white pine in Ohio and Indiana. Cent. State. For. Expt. Sta. Tech. paper 138:14.

42. Groggins, J. F. 1951. Slash and loblolly pine plantations in Alabama's Piedmont region. Ala. Agri. Expt. Sta. Cir. 99:22.

43. Gray, F. and H. M. Galloway. 1959. Soils of Oklahoma. Okla. Stat. Uni. Misc. Publ. 56:65pp.

44. Gysel, L. W. and A. L. John. 1953. Oak sites in southern Michigan. Their classification and evaluation. Mich. State. Coll. Tech. Bull. 236:57pp.

45. Haig, I. T. 1929. Colloidal content and related soil factors as indicators of site quality. Yale. Uni. Sch. For. Bull. 24;33pp.

46. Haney, G. P. 1962. A revised shortleaf pine bibliography. U.S.D.A. For. Ser. S.E. For. Expt. Sta. Sta. Paper. 155:

47. Harper, H. J. 1940. Relation of climatic conditions, soil characteristics and tree development in the southern great plain region. Soil Sci. Soc. Amer. Proc. 5:327-335.

48. Heiberg, S. O. 1941. Silvicultural significance of Mull and Mor. Soil Sci. Soc. Amer. Proc. 6:405-408.

49. Heimberger, C. C. 1934. Forest type studies in the Adirondack region. Corn. Agri. Expt. Sta. Mem. 165:122pp.

50. Hicock, H. W. et.al. 1931. The relation of soil factors to the growth of red pine plantations in plantations. Corn. Agri. Expt. Sta. Bull. 330:73.

51. Hilgard, E. W. 1930. Soils. Macmillian Co. London. pp. 547-549.

52. Hills, G. A. 1952. The classification and evaluation of site for forestry. Ontario Dept. Lands and For. Res. Rept. 24:41.

53. Hodgkins, E. L. 1956. Testing soil site index tables in south western Alabama. J. For. 54:261-266.

54. ____________,. 1960. Estimating site index for longleaf pine through quantitative evaluation of associated vegetation. Proc. Soc. Ame. For. 28-32.

55. ____________,. 1959. Forest site classification in the south east: An evaluation 8th Annual Forest symposium, Southern forest soils. Louisiana State University, Baton Rouge, 34-48.

56. Jackson, D. S. 1962. Parameters of site for certain growth components of Slashpine. Duke. Univ. School For. Bull. 16.

57. Jenny, H. 1946. Arrangement of soil series and types according to functions of soil forming factors. Soil Sci. 61:375-391.

58. Johnson, E. W. 1965. A short cut method of estimating tree site index in longleaf pine. J. For. 63:195-200.

59. Kelly, A. P. 1922. Plant indicator of soil types. Soil Sci. 13:411-423.

60. Kittredge, J. Jr., 1938. The inter relations of habitat, growth rate and associated vegetation in the Aspen community of Minnosota and Wisconsin. Ecol. Monographs. 8:153-246.

61. Klemmedson, J. O. 1964. Top functions of soils and vegetation in a range landscape. Amer. Soc. Agron. Spl. Pub. No. 5:176-189.

62. Kozlowski, T. T. 1955. Tree growth, action and interactions of soil and other factors. J. For. 53:509-510.

63. Lassen, L. et.al. 1952. Some plant soil water relations in watershed management. U.S.D.A. Cir. 910.

64. Linteau A. 1953. Site classification. Pulp and Paper Mag. of Can. 54(7):147-155.

65. Locke, S. S. 1941. The use of soil site factors in predicting Timber yields. Soil Sci. Soc. Amer. Proc. 6:399-402.

66. Losche, C. K. 1967. Soil genesis and forest growth and steeply sloping landscapes in the Southern Applachain. Ph.D. Thesis. N. Carolina State University.

67. Lunt, H. A. 1932. Soil characteristics of New England forest soils. Conn. Agri. Expt. Sta. Bull. 342:743-836.

68. Lutz, H. J. and R. F. Chandler, Jr., 1946. Forest Soils. John Wiley & Sons, Inc., N. Y. pp. 514.

69. Mader, D. L. and D. Fowen. 1961. Relationship between soil properties and red pine growth in Massachusetts. Soil Sci. Amer. Proc. 25:62-65.

70. Major. 1951. A functional, factorial approach to plant ecology. Ecology 32:392-412.

71. McClurkin, D. C. 1953. Soil and climatic factors related to the growth of longleaf pine. U.S. For. Ser. South. For. Expt. Sta. Occa. paper 132:12.

72. McGee, C. E. 1961. Soil site index for Georgia slashpine. S. E. For. Expt. Sta. paper. 119:1-9.

73. Page, N. R. 1965. Procedures used by state soil testing labs in the southern region of the U.S. S. Coop. Series Bull. 102-49.

74. Pawluk, S. and H. F. Arneman. 1961. Some forest soil characteristics and their relationship to jack pine growth. For. Sci. 7:160-171.

75. Peele, T. C. and O. W. Beale. 1950. Relation of moisture equivalent to field capacity and moisture retained at 15 atm. to the wilting percentage. Agron. J. 42:604-607.

76. Pegg. R. E. 1957. Slash pine site index to soil, vegetation and climate in southeast Queen's land. Queen's land Dept. For. Beerwah. 19:1-52.

77. Ralston, C. W. 1951. Some factors related to the growth of longleaf pine in the Atlantic Coastal Plain. J. For. 49: 408-412.

78. Richards, L. A. 1948. Porus plate apparatus for measuring moisture retention and transmission by soil. Soil Sci. 66:105-110.

79. Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A. Handbook 60, U. S. Government Printing Office, Washington, D. C.

80. Roe, Eugene I. 1935. Forest soils - the basis of forest management. Lake States. For. Expt. Sta. pp. 9.

81. Romell, L. G. 1935. Ecological problems of the humus layer in the forest. Corn. Uni. Agri. Expt. Stat. Mem. 170:28pp.

82. Row, C. 1960. Soil site relations of old field slash pine plantations in Carolina stand Hills. J. For. 58:704-707.

83. Samson, A. W. 1939. Plant indicator concept and status. Bot. Rev. 5:155-206.

84. Shantz, H. S. 1938. Plants as soil indicator. Soils & Men. Year Book of Agri. 835-860.

85. Shipman, R. D. and R. J. Victor. 1954. Factors affecting height growth of planted yellow poplar in southwestern Michigan. Mich. Agri. Expt. Sta. Tech. Bull. 242:44.

86. Silker, T. H. 1965. Plant indicators communicate ecological relationship in Gulf Coastal Plain forests. Forest soil relationships in North America. Ore. Stat. Univ. Press. p. 532.

87. Simonson, R. W. 1949. Genesis and classification of Red-yellow podzolic soils. Soil Sci. Soc. Amer. Proc. 14:316-319.

88. Smith, G. 1967. Soil vegetation relationships of some Artemisia types in North Park, Colorado. Ph.D. Thesis Colorado State University.

89. Snedecor, G. W. 1956. Statistical Methods. 5th edition. Iowa state College Press, Ames, Iowa. pp. 530.

90. Soil Survey Staff. 1960. Soil classification. A comprehensive system. 7th approximation. Soil Cons. Serv. U.S.D.A. pp 265.

91. Spurr, S. H. 1952. Forest Inventory. The Ronald Press. N. Y. 476 pp.

92. Stoeckeler, J. H. 1960. Soil factors affecting the growth of Quaking Aspen forests in the lake states. Minn. Agri. Expt. Sta. Tech. Bull. 233:3-40.

93. Storie, R. E. and A. E. Weislander. 1948. Rating soils for timber sites. Soil Sci. Soc. Amer. Proc. 13:499-509,

94. Tarrant, R. F. 1949. Douglas-fir site quality and soil fertility. J. For. 47:716-720.

95. Trimble, G. R., Jr. and S. Weitzman. 1958. Site index studies of upland oaks in the northern Applachain. For. Sci. 4:162-176.

96. Turner, L. M. 1937. Growth of second. Growth pine on the Coastal Plain soils of Arkansas. Agri. Expt. Sta. Bull. 342:49pp.

97. Tryon, C. P. et. al. 1960. The measurement of soil quality for yellow poplar. J. For. 58:968-969.

98. Ulrich, A. 1948. Plant analysis, methods and interpretation of results, diagnostic techniques for soil and crops. Amer. Pot. Inst. Washington D. C. 157-189.

99. Veihmeyer, F. J. and A. J. Hendrickson. . Plant Physiology in Russia. Pl. Physiol. 3:353-359.

100. Walker, L. C. and H. F. Perkins. 1958. Forest soils and silviculture in Georgia. Univ. of Georgia. Report No. 4.

101. Weaver, J. E. and F. E. Clement. 1938. Plant Ecology. McGraw Hill New York. 462-468.

102. Westveld, R. H. 1933. The relation of certain soil characteristics to forest growth and composition in the northern hardwood forest of N. Michigan. Mich. Sta. Col. Agri. Expt. Sta. Tech. Bull. 135:52pp.

103. Whittaker, R. H. 1953. A consideration of climax theory, the climax as a population and pattern. Ecol. Monog. 23:41-78.

104. Wilson, W. D. 1968. Shortleaf pine site index. Soils and plant association on the Coastal Plain of southeastern Oklahoma. M. S. Thesis. Oklahoma State University.

105. Young, H. E. 1954. Forest soils. Site index studies in Maine. Soil Sci. Soc. Amer. Proc. 18:85-87.

106. Youngberg, C. T. and H. F. Scholz. 1949. Relation of soil fertility and rate of growth of mixed oak stands in the driftless area of southwestern Wisconsin. Soil Sci. Soc. Amer. Proc. 14:331-332.

107. Zahner, R. . Estimating loblolly pine sites in the Gulf Coastal Plain. J. For. 52:448-449.

108. ___________., 1958. Site quality relationships of pine forests in southern Arkansas and northern Louisiana. For. Sci. 4: 162-176.

109. ___________., and R. D. Hedrich. 1966. Moisture release characteristics of forested sand entisols in northern lower Michigan. Soil Sci. Soc. Amer. Proc. 30:646-649.

APPENDIX

TABLE XIV

PHYSICAL PROPERTIES

SOIL TYPE: BOWIE FINE SANDY LOAM

PLOT NO. 6

Lab No.	Horizon	Depth in Inches	Slope	Gravel %	Mechanical Analisis			Textural Classification	Moisture Release Characteristics			
					Sand %	Silt %	Clay %		1/3 atm	1 atm	15 atm	Available Moisture
66-S-367	A_1	0-4	3%	1.7	56	35	9	Sandy loam	10.75	8.49	4.26	6.49
66-S-368	A_2	4-12		2.9	59	32	9	Sandy loam	8.85	8.08	3.19	5.66
66-S-369	B_{21t}	12-40		1.5	58	31	11	Sandy loam	11.68	8.15	4.18	7.50
66-S-370	B_{22t}	40-50		2.7	55	32	13	Sandy loam	10.84	10.27	4.88	5.96
PLOT NO. 7												
66-S-371	A_1	0-4	3%	11.5	62	34	4	Sandy loam	9.47	7.36	4.24	5.23
66-S-372	A_2	4-13		9.2	59	35	6	Sandy loam	13.39	10.03	2.33	11.06
66-S-373	B_{21t}	13-27		7.1	55	16	29	Sandy loam	16.54	15.28	5.65	10.89
66-S-374	B_{22t}	27-36		8.5	50	21	29	Sandy clay loam	12.34	8.56	8.50	3.84
PLOT NO. 8												
66-S-375	A_1	0-4	3%	2.7	51	43	6	Sandy loam	15.32	10.03	5.65	9.67
66-S-376	A_2	4-16		2.7	50	40	10	Loam	27.12	15.21	3.39	23.73
66-S-377	B_{21t}	16-31		2.6	35	39	26	Loam	28.45	19.88	9.53	18.92
66-S-378	B_{22t}	31-39		2.9	36	35	29	Clay loam	31.87	23.50	9.88	21.99

TABLE XIV — Continued

PLOT NO. 11

Lab No.	Horizon	Depth in Inches	Slope %	Gravel %	Mechanical Analisis Sand %	Silt %	Clay %	Textural Classification	Moisture Release Characteristics 1/3 atm	1 atm	15 atm	Available Moisture
66-S-387	A1	0-5		5.4	62	28	10	Sandy loam	11.91	9.18	8.63	3.28
66-S-388	A2	5-8		4.0	72	21	7	Sandy loam	11.85	10.34	7.44	4.41
66-S-389	B21t	8-17	3%	15.7	64	26	10	Sandy loam	9.40	9.18	7.43	1.97
66-S 390	B_{22t}	17-31		6.2	51	16	33	Sandy clay loam	17.60	15.46	8.63	8.97
66-S-391	A'_2 and B_{22t}	31-42		0.3	61	19	20	Sandy clay loam	12.30	10.34	8.63	3.67
PLOT NO. 12												
66-S-392	A_1	0-6		1.4	42	36	22	Loam	9.14	8.63	7.70	1.44
66-S-393	A_2	6-14	3%	1.5	52	35	13	Loam	9.84	9.40	8.48	1.36
66-S-394	B_{21t}	14-36		1.7	50	33	17	Loam	18.58	12.80	12.47	6.11
66-S-395	B_{22t}	36-67		2.1	52	27	21	Sandy clay loam	20.15	12.92	14.27	5.88
PLOT NO. 13												
67-S-805	A_1	0-8		1.3	77	21	2	Sandy loam	9.79	5.70	2.45	7.34
67-S-806	A_2	8-15	3%	2.0	73	21	6	Sandy loam	12.07	7.73	3.14	8.93
67-S-807	B_{21t} & B_{22t}	15-52		3.3	61	21	18	Sandy loam	17.59	12.96	7.90	9.69

TABLE XV

PHYSICAL PROPERTIES

SOIL TYPE: GOLDSBORO LOAM

Lab. No.	Horizon	Depth	Slope %	Gravel %	Mechanical Analysis Sand %	Silt %	Clay %	Textural Classification	Moisture Release Characteristics 1/3 atm	1 atm	15 atm	Available Moisture
PLOT NO. 5												
66-S-358	A_1	0-2		4.1	58	33	9	Sandy loam	16.42	12.07	4.99	11.43
66-S-359	A_2	2-5		5.1	60	31	9	Sandy loam	13.57	10.58	3.84	9.73
66-S-360	B_1	5-16	1%	3.9	52	36	12	Loam	18.70	10.55	3.48	15.22
66-S-361	B_{21t}	16-28		3.8	42	35	23	Loam	30.41	17.93	7.66	22.75
66-S-362	B_{22t}	28-39		3.7	33	38	29	Clay loam	33.28	21.59	10.34	22.94
PLOT NO. 9												
66-S-379	A_1	0-3		1.3	30	59	11	Loam	33.04	18.66	4.47	28.57
66-S-380	A_2	3-13	1%	1.2	24	60	16	Silt loam	30.60	18.31	3.99	26.61
66-S-381	B_1	13-25		1.3	18	63	19	Silt loam	31.73	20.86	5.00	26.73
66-S-382	B_{21t}	25-41		0.9	20	65	15	Silt loam	30.61	23.80	5.87	24.74
PLOT NO. 14												
67-S-808	A_1	0-5		1.2	59	39	2	Sandy loam	17.97	9.09	4.00	13.97
67-S-809	A_2	5-12	1%	1.5	56	36	8	Sandy loam	16.37	9.04	3.93	12.44
67-S-810	B_{21t}	12-34		2.9	35	47	18	Loam	24.10	15.85	8.09	16.01
67-S-811	B_{22t}	34-64		3.7	26	40	34	Clay loam	25.30	17.70	10.10	15.20
67-S-812	B_{23t}	64-74		6.7	51	39	10	Loam	17.38	10.86	4.84	12.54

TABLE XVI

PHYSICAL PROPERTIES

SOIL TYPE: HERNDON LOAM
PLOT NO. 2

Lab No.	Horizon	Depth	Slope %	Gravel %	Mechanical Analysis Sand %	Mechanical Analysis Silt %	Mechanical Analysis Clay %	Textural Classification	Moisture Release Characteristics 1/3 atm	1 atm	15 atm	Available Moisture
66-S-350	A_1	0-2		42.19	41	48	11	Loam	29.82	20.69	11.86	17.96
66-S-351	A_2	2-5	12	34.96	48	38	14	Loam	23.82	20.30	6.27	17.55
66-S-352	B_1	5-14		22.78	41	43	16	Loam	19.67	15.24	5.50	14.17
66-S-353	B_{21t}	14-27		16.67	28	37	35	Clay loam	34.75	26.79	12.66	22.11
PLOT NO. 3												
66-S-354	A_1	0-4		11.94	55	35	10	Sandy loam	23.40	20.70	6.63	16.77
66-S-355	A_2	4-10	12	19.92	59	28	13	Sandy loam	17.80	15.22	3.53	14.27
66-S-356	B_{21t}	10-15		4.81	40	37	23	Loam	19.21	17.62	7.11	12.10
66-S-357	B_{22t}	15-30		0.86	24	27	49	Clay	28.20	26.93	16.30	11.90

SOIL TYPE: MYATT SILT LOAM
PLOT NO. 10

Lab No.	Horizon	Depth	Slope %	Gravel %	Sand %	Silt %	Clay %	Textural Classification	1/3 atm	1 atm	15 atm	Available Moisture
66-S-383	A_1	0-5		0.5	36	56	8	Silt loam	26.51	18.56	9.39	17.12
66-S-384	A_{2q}	5-16	1	0.4	37	51	12	Silt loam	25.83	17.04	11.08	14.75
66-S-385	B_{2tq}	16-33		0.9	28	53	19	Silt loam	20.15	11.48	13.61	6.54
66-S-386	B_{22tq}	33-36		1.0	24	51	25	Loam	20.63	20.18	14.29	6.34

TABLE XVII

CHEMICAL PROPERTIES

SOIL TYPE: BOWIE FINE SANDY LOAM

Lab Number	Hori-zon	Depth in Inches	pH Paste 1:1	Exchangeable Cations M.e./100gms.						C.E.C. M.e./100gms
				H	Ca	Mg	K	Na	Total	
PLOT NO. 6										
66-S-367	A_1	0-4	6.0	1.99	3.7	3.36	0.26	0.61	9.92	8.78
66-S-368	A_2	4-12	5.8	1.00	2.2	2.00	0.26	0.70	6.16	6.00
66-S-369	B_{21t}	12-40	5.3	3.49	2.3	2.00	0.31	0.22	8.32	5.28
66-S-370	B_{22t}	40-50	5.1	3.49	2.2	2.51	0.26	0.26	8.72	6.16
PLOT NO. 7										
66-S-371	A_1	0-4	5.2	3.98	3.3	0.84	0.26	0.22	8.60	8.14
66-S-372	A_2	4-13	5.1	0.75	2.8	0.34	0.31	0.35	4.55	3.58
66-S-373	B_{21t}	13-27	4.9	3.98	2.3	2.00	0.31	0.26	8.85	6.00
66-S-374	B_{22t}	27-36	4.8	4.23	2.8	3.01	0.61	0.22	10.87	9.21
PLOT NO. 8										
66-S-375	A_1	0-4	5.1	1.25	4.0	3.34	0.31	0.22	9.12	9.85
66-S-376	A_2	4-16	4.8	1.00	3.0	2.51	0.31	0.22	7.04	6.43
66-S-377	B_{21t}	16-31	4.5	1.00	4.0	5.01	0.21	0.35	10.57	11.57
66-S-378	B_{22t}	31-39	4.7	2.00	3.1	3.06	0.31	0.26	8.73	12.71
PLOT NO. 11										
66-S-387	A_1	0-5	5.9	0.75	3.1	2.00	0.10	0.22	6.17	5.57
66-S-388	A_2	5-8	5.7	1.25	3.1	1.79	0.10	0.17	6.41	4.63
66-S-389	B_{21t}	8-17	5.5	2.50	3.1	0.84	0.10	0.17	6.71	6.14
66-S-390	B_{22t}	17-31	4.9	6.23	2.5	4.18	0.31	0.17	3.39	16.35
66-S-391	A_{2t} B_{22t}	31-42	4.8	4.21	2.6	0.33	0.26	0.22	7.62	5.71
PLOT NO. 12										
66-S-392	A_1	0-6	4.7	3.98	2.6	3.34	0.10	0.26	10.28	10.85
66-S-393	A_2	6-14	4.8	1.25	0.4	1.79	0.15	0.26	3.85	3.84
66-S-394	B_{21t}	14-36	4.6	5.70	0.6	1.39	0.23	0.35	8.27	7.71
66-S-395	B_{22t}	36-67	4.3	6.94	0.5	1.00	0.13	0.39	8.96	9.28

TABLE XVII — Continued

PLOT NO. 13

Lab Number	Horizon	Depth in Inches	pH Paste 1:1	Exchangeable Cations M.e./100gms.						C.E.C. M.e./100gms
				H	Ca	Mg	K	Na	Total	
67-S-805	A_1	0-8	5.2	2.23	1.5	1.00	0.31	0.22	5.26	4.28
67-S-806	A_2	8-15	5.0	2.23	2.0	1.67	0.41	0.38	6.69	6.14
67-S-807	B_{21t} B_{22t}	15-52	4.9	4.48	1.0	1.25	0.51	0.43	7.67	8.43

TABLE XVIII

CHEMICAL PROPERTIES

SOIL TYPE: GOLDSBORO LOAM

PLOT NO. 5

Lab Number	Hori-zon	Depth in Inches	pH Paste 1:1	Exchangeable Cations M.e./100gms.						C.E.C. M.e./ 100gms
				H	Ca	Mg	K	Na	Total	
66-S-358	A_1	0-2	5.9	2.74	4.00	4.18	0.26	0.35	11.53	12.28
66-S-359	A_2	2-5	5.8	1.25	2.80	4.18	0.05	0.35	8.63	12.35
66-S-360	B_1	5-16	5.7	1.00	2.00	1.67	0.77	0.43	5.87	4.14
66-S-361	B_{21t}	16-28	5.2	2.99	4.50	2.51	0.31	0.26	10.57	10.85
66-S-362	B_{22t}	28-39	5.0	4.99	2.50	2.92	1.53	0.43	12.37	12.42
PLOT NO. 9										
66-S-379	A_1	0-3	4.8	4.48	3.1	3.01	0.41	0.22	11.22	11.57
66-S-380	A_2	3-13	4.8	3.98	2.8	1.50	0.21	0.26	8.75	6.43
66-S-381	B_1	13-25	4.8	4.98	2.3	1.50	0.61	0.22	9.61	7.14
66-S-382	B_{21t}	25-41	4.7	4.98	3.0	3.01	0.26	0.18	11.43	8.12
PLOT NO. 14										
67-S-808	A_1	0-5	5.3	4.46	2.00	1.20	0.51	0.43	8.60	6.64
67-S-809	A_2	5-12	5.2	2.73	1.50	1.00	0.51	0.43	6.17	5.57
67-S-810	B_{21t}	12-34	4.8	4.48	1.00	1.25	0.41	0.38	7.52	9.00
67-S-811	B_{22t}	34-64	4.9	5.98	1.50	1.20	0.62	0.38	9.68	11.71
67-S-812	B_{23t}	64-74	4.9	4.71	1.50	0.83	0.51	0.35	7.90	6.28

TABLE XIX

CHEMICAL PROPERTIES

SOIL TYPE: HERNDON LOAM

Lab Number	Hori-zon	Depth in Inches	pH Paste 1:1	Exchangeable Cations M.e./100gms.						C.E.C. M.e./ 100gms
				H	Ca	Mg	K	Na	Total	
PLOT NO. 2										
66-S-350	A_1	0-2	5.1	5.59	5.10	5.01	0.31	0.70	16.71	16.35
66-S-351	A_2	2-5	5.0	3.99	2.20	2.08	0.41	0.64	9.32	8.78
66-S-352	B_1	5-14	5.0	4.48	1.80	3.34	0.21	0.64	10.47	9.92
66-S-353	B_{21t}	14-27	4.6	4.59	2.20	3.36	0.10	0.70	10.95	12.35
PLOT NO. 3										
66-S-354	A_1	0-4	4.8	6.72	4.00	2.51	0.41	0.52	14.16	12.14
66-S-355	A_2	4-10	4.9	5.98	2.30	2.51	0.26	0.44	11.49	10.85
66-S-356	B_{21t}	10-15	4.8	5.85	1.00	1.67	1.28	0.43	10.23	9.92
66-S-357	B_{22t}	15-30	4.8	10.58	1.20	4.68	0.51	0.26	17.23	18.42
SOIL TYPE: MYATT SILT LOAM										
PLOT NO. 10										
66-S-383	A_1	0-5	4.6	3.49	4.0	2.51	0.21	0.17	10.38	10.26
66-S-384	A_{2q}	5-16	4.7	5.48	3.5	2.51	0.31	0.35	12.15	11.57
66-S-385	B_{2tq}	16-33	4.9	7.48	3.0	3.34	0.10	0.39	14.31	12.71
66-S-386	B_{22tq}	33-36	5.0	6.72	3.0	2.50	0.89	0.65	13.76	16.98

TABLE XX

CHEMICAL PROPERTIES

SOIL TYPE: BOWIE FINE SANDY LOAM

Lab Number	Horizon	Depth in Inches	pH Paste 1:1	pH KCl	Nitrogen %	Available Nutrients Lbs. Per Acre: Phosphorus	Available Nutrients Lbs. Per Acre: Potassium
PLOT NO. 6							
66-S-367	A_1	0-4	6.0	5.4	0.052	7.54	105
66-S-368	A_2	4-12	5.8	5.0	0.037	7.56	85
66-S-369	B_{21t}	12-40	5.3	4.1	0.013	5.65	100
66-S-370	B_{22t}	40-50	5.1	3.8	0.009	7.54	90
PLOT NO. 7							
66-S-371	A_1	0-4	5.2	4.7	0.103	9.63	130
66-S-372	A_2	4-13	5.1	4.2	0.021	3.77	70
66-S-373	B_{21t}	13-27	4.9	3.8	0.017	3.77	105
66-S-374	B_{22t}	27-36	4.8	3.7	0.021	3.77	165
PLOT NO. 8							
66-S-375	A_1	0-4	5.1	4.5	0.155	18.85	165
66-S-376	A_2	4-16	4.8	4.0	0.026	5.65	60
66-S-377	B_{21t}	16-31	4.5	3.7	0.013	3.77	165
66-S-378	B_{22t}	31-39	4.7	3.6	0.015	3.77	170
PLOT NO. 11							
66-S-387	A_1	0-5	5.9	4.9	0.065	5.66	100
66-S-388	A_2	5-8	5.7	4.6	0.021	7.54	110
66-S-389	B_{21t}	8-17	5.5	4.7	0.009	5.66	90
66-S-390	B_{22t}	17-31	4.9	3.9	0.021	5.66	205
66-S-391	A'_{2t} B_{22t}	31-42	4.8	3.9	0.009	5.66	90
PLOT NO 12							
66-S-392	A_1	0-6	4.7	3.8	0.051	7.54	100
66-S-393	A_2	6-14	4.8	3.8	0.013	5.66	75
66-S-394	B_{21t}	14-36	4.6	3.4	0.013	3.77	75
66-S-395	B_{22t}	36-67	4.3	3.5	0.011	1.89	70
PLOT NO. 13							
67-S-805	A_1	0-8	5.2	4.2	0.057	3.77	70
67-S-806	A_2	8-15	5.0	3.9	0.031	3.77	85
67-S-807	B_{21t} B_{22t}	15-52	4.9	3.6	0.040	1.88	90

TABLE XXI

CHEMICAL PROPERTIES

SOIL TYPE: GOLDSBORO LOAM

PLOT NO. 5

Lab Number	Horizon	Depth in Inches	pH Paste 1:1	pH KCl	Nitrogen %	Available Nutrients Lbs. Per Acre Phosphorus	Available Nutrients Lbs. Per Acre Potassium
66-S-358	A_1	0-2	5.9	5.3	0.073	7.54	90
66-S-359	A_2	2-5	5.8	5.1	0.043	7.54	65
66-S-360	B_1	5-16	5.7	4.6	0.026	3.77	60
66-S-361	B_{21t}	16-28	5.2	4.1	0.013	5.66	130
66-S-362	B_{22t}	28-39	5.0	3.8	0.017	1.89	175
PLOT NO. 9							
66-S-379	A_1	0-3	4.8	4.1	0.056	9.63	80
66-S-380	A_2	3-13	4.8	3.9	0.026	3.77	75
66-S-381	B_1	13-25	4.8	3.8	0.013	1.89	90
66-S-382	B_{21t}	25-41	4.7	3.8	0.021	1.89	90
PLOT NO. 14							
67-S-808	A_1	0-5	5.3	4.4	0.079	13.20	80
67-S-809	A_2	5-12	5.2	4.0	0.031	5.65	60
67-S-810	B_{21t}	12-34	4.8	3.5	0.026	3.77	120
67-S-811	B_{22t}	34-64	4.9	3.5	0.026	3.77	110
67-S-812	B_{23t}	64-74	4.9	3.6	0.022	5.66	70

TABLE XXII

CHEMICAL PROPERTIES

SOIL TYPE: HERNDON LOAM

PLOT NO. 2

Lab Number	Horizon	Depth in Inches	pH Paste 1:1	pH KCl	Nitrogen %	Available Nutrients Lbs. Per Acre Phosphorus	Available Nutrients Lbs. Per Acre Potassium
66-S-350	A_1	0-2	5.1	4.8	0.249	77.29	470
66-S-351	A_2	2-5	5.0	4.4	0.120	54.67	420
66-S-352	B_1	5-14	5.0	4.2	0.034	20.74	340
66-S-353	B_{21t}	14-27	4.6	3.8	0.052	3.77	225
PLOT NO. 3							
66-S-354	A_1	0-4	4.8	4.2	0.129	16.97	210
66-S-355	A_2	4-10	4.9	4.1	0.043	7.54	130
66-S-356	B_{21t}	10-15	4.8	4.0	0.021	3.77	225
66-S-357	B_{22t}	15-30	4.8	3.7	0.026	3.77	230
SOIL TYPE: MYATT SILT LOAM							
PLOT NO. 10							
66-S-383	A_1	0-5	4.6	3.9	0.073	7.54	100
66-S-384	A_{2g}	5-16	4.7	3.9	0.026	3.77	75
66-S-385	B_{2tg}	16-33	4.9	3.6	0.017	3.77	40
66-S-386	B_{22tg}	33-36	5.0	3.7	0.026	1.89	40

TABLE XXIII

DEPENDENT AND INDEPENDENT (SOIL CHARACTERISTICS) VARIABLES (23)
FOR STEPWISE MULTIPLE REGRESSION ANALYSIS
(1st and 2nd Analysis)

	Independent Variable	Horizon wise for Entire Profile	S. No.	Plot	Dependent Variable i.e. Site Index	Soil Type
x_1	Depth in inches	$A_1, A_2, B_{21t}, B_{22t}$	1	Plot No. 6(367)	106	Bowie fine sand loam
x_2	Slope Percentage		2	Plot No. 7(371)	84	Bowie fine sand loam
x_3	Gravel Percentage	$A_1, A_2, B_{21t}, B_{22t}$	3	Plot No. 8(375)	80	Bowie fine sand loam
x_4	Sand Percentage	$A_1, A_2, B_{21t}, B_{22t}$	4	Plot No. 11(387)	95	Bowie fine sand loam
x_5	Silt Percentage	$A_1, A_2, B_{21t}, B_{22t}$	5	Plot No. 12(392)	108	Bowie fine sand loam
x_6	Clay Percentage	$A_1, A_2, B_{21t}, B_{22t}$	6	Plot No. 13(805)	96	Bowie fine sand loam
x_7	Ex. H M.e./100gms.	$A_1, A_2, B_{21t}, B_{22t}$	7	Plot No. 5(358)	104	Goldsboro loam
x_8	Ex. Ca M.e./100gms.	$A_1, A_2, B_{21t}, B_{22t}$	8	Plot No. 9(379)	92	Goldsboro loam
x_9	Ex. Mg M.e./100gms.	$A_1, A_2, B_{21t}, B_{22t}$	9	Plot No. 14(808)	97	Goldsboro loam
x_{10}	Ex. K M.e./100gms.	$A_1, A_2, B_{21t}, B_{22t}$	10	Plot No. 2(350)	79	Herndon loam
x_{11}	Ex. Na M.e./100gms.	$A_1, A_2, B_{21t}, B_{22t}$	11	Plot No. 2(354)	87	Herndon loam
x_1	Depth in inches	$A_1, A_2, B_{21t}, B_{22t}$	12	Plot No. 10(383)	102	Maytt Silt loam
x_2	Slope Percentage					
x_3	Cation Exchange Capacity (C.E.C.) M.e/100gms.	$A_1, A_2, B_{21t}, B_{22t}$				

TABLE XXIII — Continued

	Independent Variables	Horizon wise for Entire Profile	S. No.	Plot	Development Variable i.e. Site Index	Soil Type
x_4	Moisture Percentage at 1/3 atm	$A_1, A_2, B_{21t}, B_{22t}$				
x_5	Moisture Percentage at 1 atm	$A_1, A_2, B_{21t}, B_{22t}$				
x_6	Moisture Percentage at 15 atm	$A_1, A_2, B_{21t}, B_{22t}$				
x_7	Available water	$A_1, A_2, B_{21t}, B_{22t}$				
x_8	Nitrogen Percentage	$A_1, A_2, B_{21t}, B_{22t}$				
x_9	Available Phosphorus	$A_1, A_2, B_{21t}, B_{22t}$				
x_{10}	Available Potassium	$A_1, A_2, B_{21t}, B_{22t}$				
x_{11}	pH Paste (1:1)	$A_1, A_2, B_{21t}, B_{22t}$				
x_{12}	pH KCl	$A_1, A_2, B_{21t}, B_{22t}$				

TABLE XXIV

DEPENDENT AND INDEPENDENT (SOIL CHARACTERISTICS) VARIABLES (36)
FOR STEPWISE MULTIPLE REGRESSION

S. No.	Independent Variables	SOIL TYPE: BOWIE FINE SANDY LOAM					
		Plot 6(367)	Plot 7(371)	Plot 8(375)	Plot 11(387)	Plot 12(392)	Plot 13(805)
		Site Index 106	Site Index 84	Site Index 80	Site Index 95	Site Index 108	Site Index 96
x_1	Soil Series	3	4	4	3	4	3
x_2	Parent Material	2	2	2	2	2	2
x_3	Depth of A horizon	12"	13"	16"	8"	14"	15"
x_4	Depth of (A+B) horizon	50"	36"	39"	42"	67"	52"
x_5	Texture of Top Soil	1	1	1	1	2	1
x_6	Sand% in AxDepth of A	684	793	816	536	658	1125
x_7	Silt% in AxDepth of A	408	455	672	192	560	315
x_8	Clay% in AxDepth of A	108	65	128	72	182	60
x_9	Nitrogen % in AxDepth of A	0.540	0.806	1.456	0.344	0.448	0.660
x_{10}	(Silt+Clay)% of B) / (Field Capacity -B) x Depth of A	46.80	42.9	35.2	24.8	72.8	42.0
x_{11}	Silt% in BxDepth of A	384	234	576	160	420	315
x_{12}	Clay% in BxDepth of A	144	377	448	168	266	270
x_1	Gravel % in A horizon	2.3	10.4	2.7	4.7	1.5	1.7

TABLE XXIV — Continued

S. No.	Independent Variables	Plot 6(367) Site Index 106	Plot 7(371) Site Index 84	Plot 8(375) Site Index 80	Plot 11(387) Site Index 95	Plot 12(392) Site Index 108	Plot 13(805) Site Index 96
x_2	Sand % in A Horizon	57	61	51	67	47	75
x_3	Clay % in A Horizon	9	5	8	9	13	4
x_4	(Silt+Clay)% in A Horizon	43	40	50	33	53	25
x_5	pH of A Horizon	5.2	5.2	4.9	5.8	4.8	5.1
x_6	Nitrogen % in A Horizon	0.045	0.062	0.091	0.043	0.032	0.044
x_7	Nitrogen % Ave/each Horizon	0.028	0.041	0.052	0.025	0.022	0.043
x_8	Available p in A Horizon	7.6	6.7	12.3	6.6	6.6	3.8
x_9	Available K in A Horizon	95	100	113	105	88	78
x_{10}	C.E.C. of A Horizon	7.4	5.9	8.1	5.1	7.4	5.2
x_{11}	Exchangeable (Ca+Mg) in A Horizon	5.6	4.5	3.2	2.5	2.0	1.5
x_{12}	Exchangeable H. in A Horizon	1.5	2.2	1.1	1.0	2.6	2.2
x_1	Gravel % in B Horizon	2.1	7.8	2.8	7.4	1.9	3.3
x_2	Sand % in B Horizon	57.0	53	36	59	51	61
x_3	Clay % in B Horizon	12.0	29	28	21	19	18

TABLE XXIV — Continued

S. No.	Independent Variables	Plot 6(367) Site Index 106	Plot 7(371) Site Index 84	Plot 8(375) Site Index 80	Plot 11(387) Site Index 95	Plot 12(392) Site Index 108	Plot 13(805) Site Index 96
x_4	(Silt+Clay) % in B Horizon	44.0	47	64	41	49	39
x_5	Available p in B Horizon	6.6	3.8	3.8	5.7	2.8	1.9
x_6	Available K in B Horizon	135.0	135	168	128	73	90
x_7	C.E.C. in B Horizon	5.7	7.6	12.1	9.4	8.5	8.4
x_8	Exchangeable (Ca+Mg) in B Horizon	2.5	5.1	2.5	2.3	0.9	1.1
x_9	Exchangeable H in B Horizon	3.5	4.1	1.5	4.3	6.3	4.5
x_{10}	$\frac{\text{(Silt+Clay)\%}}{\text{Field Capacity}}$ in B Horizon	3.9	3.3	2.2	3.1	5.2	2.8
x_{11}	$\frac{\text{(Silt+Clay)\% B}}{\text{Depth of B}}$ in B Horizon	1.2	2.1	2.8	1.2	0.9	1.3
x_{12}	$\frac{\text{(Silt+Clay)\% of B}}{\text{Depth of A}}$ in B Horizon	3.7	3.7	4.1	5.1	3.5	3.3

TABLE XXIV — Continued

S. NO.	Independent Variables	SOIL TYPE: GOLDSBORO LOAM			SOIL TYPE: HERNDON LOAM		SOIL TYPE: MAYTT SILT LOAM
		Plot 5(358)	Plot 9(379)	Plot 14(808)	Plot 2(350)	Plot 3(354)	Plot 10(383
		S.I. 104	S.I. 92	S.I. 97	S.I. 79	S.I. 87	S.I. 102
x_1	Soil Series	2	2	3	1	1	5
x_2	Parent Material	1	1	1	3	3	1
x_3	Depth of A Horizon	5"	13"	12"	5"	10"	16"
x_4	Depth of (A+B) Horizon	39"	41"	74"	27"	30"	39"
x_5	Texture of Top Soil	1	2	1	2	1	3
x_6	Sand % in AxDepth of A	295	351	696	225	570	592
x_7	Silt % in AxDepth of A	160	767	456	215	325	864
x_8	Clay % in AxDepth of A	45	182	60	63	120	160
x_9	Nitrogen in A x Depth of A	0.265	0.533	0.660	0.920	0.860	0.784
x_{10}	Silt+Clay) % of B / Field Capacity of B x Depth of A	9.5	33.8	33.6	11.5	29.9	57.6
x_{11}	Silt % in BxDepth of A	135	832	504	195	320	832
x_{12}	Clay % in BxDepth of A	155	221	252	130	360	352
x_1	Gravel % in A Horizon	4.6	1.3	1.4	38.6	15.4	0.5
x_2	Sand % in A Horizon	59	27	58	45	57	37
x_3	Clay % in A Horizon	9	14	5	13	12	10

TABLE XXIV — Continued

S. No.	Independent Variables	SOIL TYPE: GOLDSBORO LOAM			SOIL TYPE: HERNDON LOAM		SOIL TYPE: MAYTT SILT LOAM
		Plot 5(358)	Plot 9(379)	Plot 14(808)	Plot 2(350)	Plot 3(354)	Plot 10(383)
		S.I. 104	S.I. 92	S.I. 97	S.I. 79	S.I. 87	S.I. 102
x_4	(Silt+Clay) % in A Horizon	41	73	43	55	43	64
x_5	pH of A Horizon	5.9	4.8	5.3	5.1	4.9	4.7
x_6	Nitrogen % in A Horizon	0.053	0.041	0.055	0.184	0.086	0.049
x_7	Nitrogen % in (A+B) Horizon	0.034	0.029	0.037	0.111	0.055	0.036
x_8	Available p in A Horizon	7.5	6.7	9.4	66.0	12.3	5.7
x_9	Available K in A Horizon	77	9.0	6.1	445	287	88
x_{10}	C.E.C. of A Horizon	12.3	9.0	6.1	12.6	11.5	10.9
x_{11}	Exch. (Ca+Mg) in A Horizon	7.6	2.6	1.4	7.2	5.7	3.2
x_{12}	Exch. H. in A Horizon	2.0	4.2	3.6	4.8	6.4	4.5
x_1	Gravel % in B Horizon	3.8	1.1	4.4	19.7	2.8	1.0
x_2	Sand % in B Horizon	42	19	37	35	32	26
x_3	Clay % in B Horizon	31	17	21	26	36	22

TABLE XXIV — Continued

S. No.	Independent Variables	SOIL TYPE: GOLDSBORO LOAM Plot 5(358)	Plot 9(379)	Plot 14(808)	SOIL TYPE: HERNDON LOAM Plot 2(350)	Plot 3(354)	SOIL TYPE: MAYTT SILT LOAM Plot 10(383)
x_4	(Silt+Clay) % in B Horizon	58	74	63	65	68	74
x_5	Available p in B Horizon	3.7	1.9	4.4	12.3	3.8	3.8
x_6	Available K in B Horizon	122	90	100	282	227	40
x_7	C.E.C. in B Horizon	9.1	7.6	9.0	11.1	14.2	14.9
x_8	Exchange (Ca+Mg) in B Horizon	5.4	2.5	1.2	5.4	3.8	3.0
x_9	Exchange H in B Horizon	3.0	5.0	5.1	4.5	8.2	5.0
x_{10}	$\frac{\text{(Silt+Clay)}}{\text{Field Capacity}}$ in B Horizon	1.9	2.6	2.8	2.3	2.9	3.6
x_{11}	$\frac{\text{(Silt+Clay) \% B}}{\text{Depth of B}}$ in B Horizon	1.5	2.9	1.0	3.0	3.4	3.7
x_{12}	$\frac{\text{(Silt+Clay) \% of B}}{\text{Depth of A}}$ in B Horizon	10.2	6.2	5.3	13.0	6.8	4.6

TABLE XXV

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF A_1 HORIZON

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable At Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard error of Y
1	0.61416	Gravel Percentage (x_3)	Clay Percentage	Gravel Percentage *(x_3)	*6.0564	-0.29469	0.29914	8.2456
2	0.72822	Clay Percentage (x_6)	Ex. Sodium M.e./100gms		2.9339	0.91796	0.36081	7.5480
3	0.79252	Ex. Sodium M.e./100g (x_{11})	Slope Percentage		2.1033	38.39916	15.24071	7.1239
4	0.85176	Slope Percentage (x_2)	Depth in Inches		2.4840	1.88098	0.90346	6.5429
5	0.89086	Depth in Inches (x_1)			1.9809	1.98108	1.40755	6.1276

Variables Tested	Tabulated F Level
Depth in inches (x_1)	$F_{.05}(1,7) = 5.59$
Slope percentage (x_2)	$F_{.01}(1,7) = 12.2$
Gravel percentage (x_3)	
Sand percentage (x_4)	
Silt percentage (x_5)	
Clay percentage (x_6)	
Ex. hydrogen (x_7)	
Ex. calcium (x_8)	
Ex. magnesium (x_9)	
Ex. potassium (x_{10})	
Ex. sodium (x_{11})	

$$Y = b_0+b_1x_1+b_2x_2+b_3x_3+b_6x_6+b_{11}x_{11}$$

$$Y = 73.68139+1.98108(x_1)-1.88098(x_2)-.29469(x_3)+0.91796(x_6)+38.39916(x_{11})$$

*Significant at 5 percent level.

TABLE XXV — Continued

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF A_2 HORIZON

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.6077	Gravel Percentage (x_3)	Depth in Inches	Gravel Percentage *(x_3)	*5.8422	-1.28942	0.23846	8.3011
2	0.72809	Depth in Inches (x_1)	Ex. sodium		3.0904	-1.55167	0.80759	7.5495
3	0.81721	Ex. sodium (x_{11})	Clay Percentage		3.3165	31.81813	12.38922	6.7326
4	0.88878	Clay Percentage (x_6)	Sand Percentage		4.0690	2.34406	1.09222	5.7237
5	0.91185	Sand Percentage (x_4)			1.4786	0.34390	0.28282	5.5375

Variables Tested	Tabulated F Level
Depth in inches (x_1)	$F_{.}$ (1,7) = 5.59
Slope percentage (x_2)	$F_{.}$ (1,7) = 12.2
Gravel percentage (x_3)	
Sand percentage (x_4)	
Silt percentage (x_5)	
Clay percentage (x_6)	
Ex. hydrogen (x_7)	
Ex. calcium (x_8)	
Ex. magnesium (x_9)	
Ex. potassium (x_{10})	
Ex. sodium (x_{11})	

$$Y = b_0+b_1x_1+b_3x_3+b_4x_4+b_6x_6+b_{11}x_{11}$$

$$Y = 60.23566-1.55167(x_1)-1.28942(x_3)+0.34390(x_4)+2.34406(x_6)+31.81813(x_{11})$$

*Significant at the 5 percent level.

TABLE XXV — Continued

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF B_{21t} HORIZON								
Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.61305	Clay Percentage (x_6)	Gravel		6.0213	-1.39424	0.00844	8.2546
2	0.90274	Gravel Percentage (x_3)	Ex. Hydrogen	Gravel Percentage*	21.3549*	-0.43938	0.03476	4.7379
3	0.92420	Ex. Hydrogen (x_7)	Sand Percentage		2.1506	2.67381	0.04759	4.4613
4	0.95343	Sand Percentage (x_4)	Slope		4.2232	0.40994	0.00418	3.7666
5	0.96437	Slope Percentage (x_2)	Depth in Inches		1.7981	-2.05264	0.05668	3.5686
6	0.97211	Depth in in.(x_1)	Ex. Sodium		1.3621	-0.45608	0.00396	3.4656
7	0.98401	Ex. Sodium (x_{11})	Ex. Potassium		2.9341	-22.86496	1.31402	2.9428
8	0.98936	Ex. Potassium (x_{10})	Calcium		1.4996	5.70808	0.57011	2.7747
9	0.99864	Ex. Calcium (x_8)	Ex. Magnesium		13.6120	-7.62112	0.18753	1.2163
10	1.00000	Ex Magnesium(x_9)		Ex. Magnesium**	797.9062**	7.32184	0.25921	0.0609

$$Y = 113.97211-0.45608(x_1)-2.05264(x_2)-0.43938(x_3)+0.40994(x_4)-1.39424(x_6)+2.67381(x_7)-7.6211(x_8)+7.32184(x_9)+5.70808(x_{10})-22.86496(x_{11})$$

*Significant at the 5 percent level.
**Significant at the 1 percent level.

TABLE XXV — Continued

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF B_{22t} HORIZON

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.57082	Ex. Magnesium	Gravel Percentage		4.3498	-2.6035	2.57986	9.0277
2	0.71636	Gravel Percentage	Sand Percentage		3.0786	-1.53696	0.65227	8.1368
3	0.78786	Sand Percentage	Ex. Sodium		1.9849	0.40826	0.22072	7.6779
4	0.83104	Ex. Sodium			1.3557	21.91827	18.82437	7.4900

$$Y = 85.65539-1.53696(x_3)+0.40826(x_4)-2.60353(x_9)+21.91827(x_{11})$$

Analysis of B_{21t} Horizon

Variables Tested	Tabulated F Level
Depth in inches (x_1)	$F_{.05}(1,2) = 18.5$
Slope percentage (x_2)	$F_{.01}(1,2) = 98.5$
Gravel percentage (x_3)	
Sand percentage (x_4)	
Silt percentage (x_5)	
Clay percentage (x_6)	
Ex. hydrogen (x_7)	
Ex. calcium (x_8)	
Ex. magnesium (x_9)	
Ex. potassium (x_{10})	
Ex. sodium (x_{11})	

Analysis of B_{22t} Horizon

Variables Tested	Tabulated F Level
Depth in inches (x_1)	$F_{.05}(1,7) = 5.59$
Slope percentage (x_2)	$F_{.01}(1,7) = 12.2$
Gravel percentage (x_3)	
Sand percentage (x_4)	
Silt percentage (x_5)	
Clay percentage (x_6)	
Ex. hydrogen (x_7)	
Ex. calcium (x_8)	
Ex. magnesium (x_9)	
Ex. potassium (x_{10})	
Ex. sodium (x_{11})	

TABLE XXVI

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF A_1 HORIZON

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.79373	Nitrogen percentage (x_8)	Available phosphorus	Nitrogen percentage**	17.0271**	-261.83995	71.52029	6.3554
2	0.86196	Available phosphrous (x_9)	Moisture at 15 atm		3.9562	0.32375	0.22434	5.5835
3	0.88370	Moisture at 15 atm (x_6)			1.3853	0.92778	0.78825	5.4677

$$Y = 108.34742+0.92778(x_6)-261.83995(x_8)+0.32375(x_9)$$

**Significant at the 1 percent level.

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF A_2 HORIZON

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.63617	Available water (x_7)	Slope percentage	Available water*	6.7988*	-0.89775	0.23679	8.0613
2	0.80197	Slope percentage (x_2)	C.E.C.	Slope percentage*	6.0135*	-1.46224	0.45027	6.5791
3	0.87446	C.E.C. (x_3)			4.1312	1.23748	0.60883	5.6667

$$Y = 102.14504-1.46224(x_2)+1.23748(x_3)-0.89775(x_7)$$

*Significant at 5 percent level.

TABLE XXVI — Continued

SUMMARY OF STEP WISE REGRESSION ANALYSIS OF B_{21t} HORIZON

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.72933	Available potassium (x_{10})	Moisture % at 1 atm	Available potassium**	11.3640**	-0.11919	0.4603	7.1483
2	0.84106	Moisture % at 1 atm	Moisture % at 1/3 atm	Moisture % at 1/3atm*	5.3966*	-3.10408	0.95269	5.9576
3	0.88020	Moisture % at 1/3 atm	Slope percentage		2.3925	1.52392	0.63098	5.5442
4	0.91893	Slope percentage			3.1356	1.85235	1.04608	4.9256

$$Y = 115.95569+1.85235(x_2)+1.52392(x_4)-3.10408(x_5)-0.11919(x_{10})$$

*Significant at the 5 percent level.
**Significant at the 1 percent level.

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF B_{22t} HORIZON

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.73710	Available potassium	-	Available potassium**	10.7072	-0.11870	0.03628	7.4302

$$Y = 110.4561-0.11870(x_{10})$$

TABLE XXVI — Continued

Variables Tested	Tabulated F Level
Analysis of A_1 Horizon Depth in inches (x_1) Slope percentage (x_2) C.E.C. (x_3) Moisture percentage at 1/3 atm (x_4) Moisture percentage at 1 atm (x_5) Moisture percentage at 15 atm (x_6) Available water (x_7) Nitrogen percentage (x_8) Available phosphorus (x_9) Available potassium (x_{10}) pH paste 1:1 (x_{11}) pH KCl (x_{12})	A_1 Horizon $F_{.05}(1,9) = 5.12$ $F_{.01}(1,9) = 10.6$
Analysis of A_2 Horizon Depth in inches (x_1) Slope percentage (x_2) C.E.C. (x_3) Moisture percentage at 1/3 atm (x_4) Moisture percentage at 1 atm (x_5) Moisture percentage at 15 atm (x_6) Available water (x_7) Nitrogen percentage (x_8) Available phosphorus (x_9) Available potassium (x_{10}) pH paste 1:1 (x_{11}) pH KCl (x_{12})	A_2 Horizon $F_{.05}(1,9) = 5.12$ $F_{.01}(1,9) = 10.6$
Analysis of B_{21t} Horizon Depth in inches (x_1) Slope percentage (x_2) C.E.C. (x_3) Moisture percentage at 1/3 atm (x_4) Moisture percentage at 1 atm (x_5) Moisture percentage at 15 atm (x_6) Available water (x_7) Nitrogen percentage (x_8) Available phosphorus (x_9) Available potassium (x_{10}) pH paste 1:1 (x_{11}) pH KCl (x_{12})	B_{21t} Horizon $F_{.05}(1,8) = 5.32$ $F_{.01}(1,8) = 11.30$
Analysis of B_{22t} Horizon Depth in inches (x_1) Slope percentage (x_2) C.E.C. (x_3) Moisture percentage at 1/3 atm (x_4) Moisture percentage at 1 atm (x_5) Moisture percentage at 15 atm (x_6) Available water (x_7) Nitrogen percentage (x_8) Available phosphorus (x_9) Available potassium (x_{10}) pH paste 1:1 (x_{11}) pH KCl (x_{12})	B_{22t} Horizon $F_{.05}(1,11) = 4.84$ $F_{.01}(1,11) = 9.65$

TABLE XXVII

SUMMARY OF STEPWISE REGRESSION ANALYSIS

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.55912	Slope Percentage (x_2)	Ex. calcium	Slope Percentage**	21.8302**	-1.44887	0.29114	-7.9972
2	0.61819	Ex. calcium*(x_8)		Ex. calcium*	5.2897	-2.39078	1.0395	-7.6621

$$Y = 105.83845-1.44887(x_2)-2.39078(x_8)$$

*Significant at the 5 percent level.
**Significant at the 1 percent level.

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.59503	Avail. potassium	Avail. water	Avail. potassium	26.3104**	-0.82979	0.44212	7.7524
2	0.64697	Avail. water	Slope percentage	Avail. water	5.2149*	-0.38993	0.14766	7.4329
3	0.67818	Slope percentage			3.5225	-0.02989	0.01938	7.2411

$$Y = 106.16403-0.82979(x_2)-0.38993(x_7)-0.02989(x_{10})$$

*Significant at the 5 percent level.
**Significant at the 1 percent level.

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.59503	Avail. potassium	Avail. water	Avail. potassium**	26.3104**	-0.02989	-0.01938	7.7524
2	0.64697	Avail. water	Slope percentage	Avail. water*	5.2149*	-0.38993	0.14766	7.4329

TABLE XXVII — Continued

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
3	0.67818	Slope Percentage			3.5225	-0.02989	0.01938	7.2411

$$Y = 106.16403 - 0.82979(x_1) - 0.38993(x_4) - 0.02989(x_5)$$

*Significant at 5 percent level.
**Significant at 1 percent level.

Variables Tested		Tabulated F Level
Depth in inches (x_1)	Depth in inches (x_1)	$F_{.05}(1,48) = 4.05$
Slope percentage (x_2)	Slope percentage (x_2)	
Gravel percentage (x_3)	C.E.C. (x_3)	$F_{.01}(1,48) = 7.22$
Sand percentage (x_4)	Moisture % at 1/3 atm (x_4)	
Silt percentage (x_5)	Moisture % at 1 atm (x_5)	
Clay percentage (x_6)	Moisture % at 15 atm (x_6)	
Ex. hydrogen (x_7)	Available water (x_7)	$F_{.05}(1,47) = 4.05$
Ex. calcium (x_8)	Nitrogen percentage (x_8)	
Ex. magnesium (x_9)	Available phosphorus (x_9)	$F_{.01}(1,47) = 7.23$
Ex. potassium (x_{10})	Available potassium (x_{10})	
Ex. sodium (x_{11})	pH paste 1:1 (x_{11})	
	pH KCl (x_{12})	
		$F_{.05}(1,47) = 4.05$
	Slope percentage (x_1)	
	Ex. calcium (x_2)	$F_{.01}(1,47) = 7.23$
	Slope percentage (x_3)	
	Available water (x_4)	
	Available potassium (x_5)	

TABLE XXVIII

SUMMARY OF STEPWISE REGRESSION ANALYSIS

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficent	Standard Error of Y
1	0.70897	Nitrogen % in A x Depth of A	(Silt+clay) of B / Field Capac X of Depth of A	Nitrogen % in A x Depth of A**	10.1064**	-33.76621	8.00325	7.3685
2	0.85823	(Silt+clay)%ofB / Field Capac.ofB X Depth of A		(Silt+clay) % of B / Field Capac. of B X Depth ofA*	7.9914*	0.27003	0.09552	5.6528

$$Y = 105.80823 - 33.76621(x_9) + 0.27003(x_{10})$$

*Significant at the 5 percent level.
**Significant at the 1 percent level.

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficent	Standard Error of Y
1	0.72071	Nitrogen % in A Horizon	Available p in A Horizon	Nitrogen % in A Horizon**	10.8083**	0.23678	0.12631	7.24321
	0.84578	Avail. phos. in A Horizon	C.E.C.of A Horizon	Avail. phos. in A Horizon*	6.1940*	-606.63063	109.62221	5.8761

TABLE XXVIII — Continued

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
	0.89996	C.E.C. of A Horizon	Sand % in A Horizon		3.9818	0.95238	0.25681	5.0927
	0.93459	Sand % in A Horizon	–		3.5143	1.99701	0.68074	4.4423

$$Y = 92.31079+1.99701(x_2)+0.23678(x_6)-606.63063(x_8)+0.95238(x_{10})$$

*Significant at the 5 percent level.
**Significant at the 1 percent level.

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.70448	Avail. potassium in B Horizon	(Silt+clay) % in B Horizon / Depth of B Horizon	Avail. potassium in B Horizon*	9.8529*	-0.08763	0.03308	7.4154
2	0.77647	(Silt+clay)% of B Horizon / Depth of B Horizon			2.4163	-3.37824	2.17329	6.9402

$$Y = 112.81541-0.08763(x_6)-3.37824(x_{11})$$

*Significant at 5 percent level
**Significant at 1 percent level

TABLE XXVIII — Continued

Order or Step	R^2 at Each Step	Variable Included at Each Step	Order of Variable at Next Step	Significant Variables	F Level	Coefficient	Error of Coefficient	Standard Error of Y
1	0.72071	Avail.phosphorus in A Horizon	C.E.C. of A Horizon	Avail. phosphorus in A Horizon*	10.8083*	-437.86739	138.49092	7.243211
2	0.84578	C.E.C. of A Horizon	Sand % in A Horizon	C.E.C. of A Horizon*	6.1940*	0.65072	0.30604	5.8761
3	0.89996	Sand % in A Horizon	(Silt+clay) % B / Depth of B		3.9818	2.70938	0.61612	5.0927
4	0.93751	(Silt+clay) % B / Depth of B	(Silt+clay) %B / Field Capac. of B (Depth of A)		3.9894	-3.17156	2.33446	4.3452
5	0.96004	(Silt+clay)% B (Depth of B) / Field capac. of B	Nitrogen % in A Horizon		3.2738	0.17751	0.08068	3.7751
6	0.97094	Nitrogen % in A Horizon			1.8368	0.20162	0.14876	3.5365

$$Y = 81.03079+0.17751(x_2)+0.20162(x_3)-437.86739(x_4)+0.65072(x_5)+2.70938(x_6)-3.17156(x_8)$$

*Significant at the 5 percent level.

TABLE XXVIII — Continued

Variables Tested		Tabulated F Level
Soil series (x_1)	Gravel % in B horizon (x_1)	$F_{.05}(1,10) = 4.96$
Parent material (x_2)	Sand % in B horizon (x_2)	
Depth of A horizon (x_3)	Clay % in B horizon (x_3)	$F_{.01}(1,10) = 10.0$
Depth of (A+B) horizon (x_4)	(Silt+Clay) in B horizon (x_4)	
Texture of top soil (x_5)	Available phosphorus in B horizon (x_5)	
Sand % in A x Depth of A (x_6)	Available potassium in B horizon (x_6)	$F_{.05}(1,9) = 5.12$
Silt % in A x Depth of A (x_7)	C.E.C. in B horizon (x_7)	
Clay % in A x Depth of A (x_8)	Ex. (Ca+Mg) in B horizon (x_8)	$F_{.01}(1,9) = 10.16$
Nitrogen % in A x Depth of A (x_9)	Ex. Hydrogen in B horizon (x_9)	
$\frac{\text{(Silt+Clay) \% of B}}{\text{Field Capacity of B}}$ x Depth of A (x_{10})	$\frac{\text{(Silt+Clay) \%}}{\text{Field Capacity}}$ in B horizon (x_{10})	$F_{.05}(1,10) = 4.96$
Silt % in B x Depth of A (x_{11})	$\frac{\text{(Silt+Clay) \% of B}}{\text{Depth of B}}$ in B horizon (x_{11})	
Clay % in B x Depth of A (x_{12})		$F_{.01}(1,10) = 10.0$
	$\frac{\text{(Silt+Clay) \% of B}}{\text{Depth of A}}$ in B horizon (x_{12})	
Gravel % in A horizon (x_1)		
Sand % in A horizon (x_2)		$F_{.05}(1,6) = 5.99$
Clay % in A horizon (x_3)	Nitrogen % in A x Depth of A (x_1)	
(Silt+Clay) % in A horizon (x_4)		$F_{.01}(1,6) = 13.70$
pH of A horizon (x_5)	$\frac{\text{(Silt+Clay) \% of B}}{\text{Field capacity of B}}$ x Depth of A (x_2)	
Nitrogen % in A horizon (x_6)	Sand % in A horizon (x_3)	
Nitrogen % in (A+B) horizon (x_7)	Silt % in A horizon (x_4)	
Available phosphorus in A horizon (x_8)	Available phosphorus in A horizon (x_5)	
Available potassium in A horizon (x_9)	C.E.C. of A horizon (x_6)	
C.E.C. of A horizon (x_{10})	Available potassium in B horizon (x_7)	
Exchange (Ca+Mg) in A horizon (x_{11})	$\frac{\text{(Silt+Clay) \% of B horizon}}{\text{Depth of B}}$ (x_8)	
Exchange Hydrogen in A horizon (x_{12})		

TABLE XXIX

FREQUENCY (PER ACRE) OF TREE SPECIES IN SELECTED PLOTS

S. No.	Species Code	Tree Species (Common Name)	Botanical Name	Plot No.6 (367)	Plot No.7 (371)	Plot No.8 (375)	Plot No.11 (387)	Plot No.12 (392)	Plot No.13 (805)
				Soil Type: Bowie Fine Sandy Loam					
1	01	Shortleaf pine	(*Pinus echinata*)	130	440	170	100	20	170
2	02	Loblolly pine	(*Pinus taeda*)	-	420	-	10	110	-
3	30	White oak	(*Quercus alba*)	90	40	70	90	110	210
4	29	S Red oak	(*Quercus falcata*)	140	180	3	210	70	120
5	37	Black oak	(*Quercus velutina*)	10	-	-	40	10	10
6	28	Post oak	(*Quercus stellata*)	20	150	10	30	30	-
7	39	Willow oak	(*Quercus phellos*)	10	-	-	-	-	30
8	38	Water oak	(*Quercus nigra*)	-	-	-	50	-	-
9	18	Dogwood	(*Cornus florida*)	360	-	60	130	40	240
10	20	Black gum	(*Nyssa sylvatica*)	10	40	-	10	70	170
11	26	Red maple	(*Acer rubrum*)	50	360	10	50	50	40
12	42	Black hickory	(*Carya texana*)	20	-	20	140	10	20
13	23	Mockernut hickory	(*Carya tomentosa*)	10	40	210	-	30	-
14	46	Bitternut hickory	(*Carya cordiformis*)	-	-	-	-	40	10
15	13	Bluebeech	(*Carpinus caroliniana*)	-	10	-	-	-	-
16	19	Winged elm	(*Ulmus alata*)	10	280	60	110	60	10
17	32	Redbud	(*Cercis canadensis*)	-	-	-	-	-	-
18	21	Sweet gum	(*Liquid ambar styraciflua*)	120	330	50	480	550	210
19	51	Wild plum	(*Prunus spp*)	-	-	20	20	-	-
20	49	Tree huckle berry	(*Vaccinium arboreum*)	-	-	50	-	10	-
21	11	Ash	(*Fraxinus texensis*)	-	-	50	-	-	-

TABLE XXIX — Continued

S. No.	Species Code	Tree Species (Common Name)	Botanical Name	Plot No.6 (367)	Plot No.7 (371)	Plot No.8 (375)	Plot No.11 (387)	Plot No.12 (392)	Plot No.13 (805)
				Soil Type: Bowie Fine Sandy Loam					
22	43	Hophornbeam	(Ostrya virginiana)	210	-	-	-	-	-
23	57	Red mulberry	(Morus rubra)	60	-	30	10	-	-
24	44	American elm	(Ulmus americana)	-	20	-	-	-	-
25	31	Persimmon	(Diospyros virginiana)	-	10	-	-	-	-
26	48	Deerberry	(Vaccinium stamineum	-	80	10	-	-	-
27	36	Sumac	(Rhus glabra)	-	-	-	-	70	10
28	24	Holly	(Ilex opaca)	-	10	-	-	-	20
				Soil Type: Goldsboro Loam			Soil Type: Herndon Loam		Soil Type: Myatt Silt Loam
				Plot No.5 (358)	Plot No.9 (379)	Plot No14 (808)	Plot No. 2 (350)	Plot No. 3 (354)	Plot No.10 (384)
1	01	Shortleaf pine	(Pinus echinata)	80	130	120	510	110	130
2	02	Loblolly pine	(Pinus taeda)	-	-	10	-	-	110
3	30	White oak	(Quercus alba	640	730	170	400	90	70
4	29	S. Red oak	(Quercus falcata)	100	180	80	70	20	30
5	37	Black oak	(Quercus velutina)	-	-	10	30	10	20
6	28	Post oak	(Quercus stellata)	-	20	50	-	10	50
7	39	Willow oak	(Quercus phellos)	-	10	-	-	-	30
8	38	Water Oak	(Quercus nigra)	-	-	-	-	-	50
9	18	Dogwood	(Cornus florida)	370	50	100	110	290	30
10	20	Black gum	(Nyssa sylvatica)	20	230	160	120	70	40
11	26	Red maple	(Acer rubrum)	10	10	70	40	-	20

TABLE XXIX — Continued

S. No.	Species Code	Tree Species (Common Name)	Botanical Name	Plot No.5 (358)	Plot No.9 (379)	Plot No14 (808)	Plot No. 2 (350)	Plot No. 3 (354)	Plot No.10 (384)
				Soil Type: Goldsboro Loam			Soil Type: Herndon Loam		Soil Type: Myatt Silt Loam
12	42	Black hickory	(*Carya texana*)	62	-	-	-	-	-
13	23	Mockernut hickory	(*Carya tomentosa*)	50	-	10	100	10	-
14	46	Bitternut hickory	(*Carya cordiformis*)	-	-	-	-	-	10
15	13	Bluebeech	(*Carpinus caroliniana*)	-	-	-	10	-	-
16	19	Winged elm	(*Ulmus alata*)	70	-	50	10	-	410
17	32	Redbud	(*Cercis canadensis*	-	-	-	20	-	-
18	21	Sweet gum	(*Liquidambar styraciflua*)	60	580	430	-	10	40
19	51	Wild plum	(*Prunus spp*)	20	-	-	-	10	10
20	49	Tree huckle berry	(*Vaccinium arboreum*)	-	-	-	-	10	-
21	11	Ash	(*Fraxinus texensis*)	40	20	-	-	-	30
22	43	Hophornbeam	(*Ostrya virginiana*)	10	-	-	-	-	-
23	57	Red mulberry	(*Morus rubra*)	30	-	10	-	-	-
24	44	American elm	(*Ulmus americana*)	-	-	-	-	-	-
25	31	Persimmon	(*Diospyros virginiana*)	-	-	-	-	-	-
26	48	Deerberry	(*Vaccinium stamineum*)	-	-	-	-	-	-
27	36	Sumac	(*Rhus glabra*)	-	-	10	-	-	10
28	24	Holly	(*Ilex opaca*)	30	-	-	-	-	-

TABLE XXX

FREQUENCY (PER ACRE) OF TREE SPECIES IN SELECTED SOIL TYPES
(TOTAL PLOTS OF EACH SOIL TYPE)

S. No.	Species Code	Tree Species (Common Name)	Botanical Name	Soil Types					
				Bowie Fine Sandy Loam (Six Plots	Goldsboro Loam (three plots)	Herndon Loam (two plots)	Myatt Silt Loam (one plot)	Total (twelve plots)	Number in the order of frequency
1	01	Shortleaf pine	(Pinus echinata)	1030	330	620	130	2110	3
2	02	Loblolly pine	(Pinus taeda)	540	10	0	110	660	9
3	30	White oak	(Quercus alba)	610	1540	490	70	2710	2
4	29	S. Red oak	(Quercus falcata)	723	360	90	30	1203	5
5	37	Black oak	(Quercus velutina)	70	10	40	20	140	14
6	28	Post oak	(Quercus stellata)	240	70	10	50	370	11
7	39	Willow oak	(Quercus phellos)	40	10	0	30	80	21
8	38	Water oak	(Quercus nigra)	50	0	0	50	100	17
9	18	Dogwood	(Cornus florida)	830	520	400	30	1780	4
10	20	Black gum	(Nyssa sylvatica)	300	410	190	40	940	7
11	26	Red maple	(Acer rubrum)	500	90	40	20	710	8
12	42	Black hickory	(Carya texana)	210	62	0	0	272	12
13	23	Mockernut hickory	(Carya tomentosa)	290	60	110	0	460	10
14	46	Bitternut hickory	(Carya cordiformis)	50	0	0	10	60	24
15	13	Bluebeech	(Carpinus caroliniana)	10	0	0	10	20	26
16	19	Winged elm	(Ulmus alata)	530	120	10	410	1070	6
17	32	Redbud	(Cercis canadensis)	0	0	20	0	20	27
18	21	Sweet gum	(Liquidambar styraciflua	1740	1070	10	40	2860	1

TABLE XXX — Continued

S. No.	Species Code	Tree Species (Common Name)	Botanical Name	Soil Types: Bowie Fine Sandy Loam (AxPlots)	Goldsboro Loam (three plots)	Herndon Loam (two plots)	Myatt Silt Loam (one plot)	Total (twelve plots)	Number in the order of frequency
19	51	Wild plum	(Prunus spp)	40	20	10	10	80	22
20	49	Tree huckle berry	(Vaccinium arboreum)	60	0	10	0	70	23
21	11	Ash	(Fraxinus texensis)	50	60	0	30	140	19
22	43	Hophornbeam	(Ostrya virginiana)	210	10	0	0	220	13
23	57	Red mulberry	(Morus rubra)	100	40	0	0	140	16
24	44	American elm	(Ulmus americana)	20	0	0	0	20	28
25	31	Persimmon	(Diospyros virginiana)	10	0	0	0	10	29
26	48	Deerberry	(Vaccinium stamineum)	90	0	0	0	90	20
27	36	Sumac	(Rhus glabra)	80	10	0	10	100	19
28	24	Holly	(Ilex opaca)	30	30	0	0	60	25

TABLE XXXI

REGENERATION FREQUENCY (PER ACRE) OF TREE SPECIES IN SELECTED PLOTS

S. No.	Species Code	Tree Species (Common Name)	Botanical Name	Soil Type: Bowie Fine Sandy Loam						
				Plot No. 6 (367)	Plot No. 7 (371)	Plot No. 8 (375)	Plot No. 11 (387)	Plot No. 12 (392)	Plot No. 13 (805)	Total
1	01	Shortleaf pine	(*Pinus echinata*)	-	2125	-	125	250	-	2500
2	02	Loblolly pine	(*Pinus taeda*)	-	1750	-	-	-	-	1750
3	28	Post oak	(*Quercus stellata*)	-	3125	-	1750	625	-	5500
4	29	S. Red oak	(*Quercus falcata*)	-	125	750	875	125	-	1875
5	30	White oak	(*Quercus alba*)	750	875	125	375	-	1500	3625
6	37	Black oak	(*Quercus velutina*)	125	250	-	125	-	-	500
7	38	Water oak	(*Quercus nigra*)	250	625	125	125	-	-	1125
8	39	Willow oak	(*Quercus phellos*)	125	-	-	-	-	-	125
9	40	Shummards oak	(*Quercus shummardii*	-	-	375	-	-	-	375
10	42	Black hickory	(*Carya texana*)	250	-	500	375	500	250	1875
11	46	Bitternut hickory	(*Carya cordiformis*)	-	-	-	-	250	375	625
12	23	Mockernut hickory	(*Carya tomentosa*)	-	-	1500	-	-	-	1500
13	11	Ash	(*Fraxinus texensis*)	-	-	125	-	-	-	125
14	13	Bluebeech	(*Carpinus caroliniana*)	-	375	-	-	-	-	375
15	18	Dogwood	(*Cornus florida*)	750	125	6000	2375	1125	4750	15125
16	19	Winged elm	(*Ulmus alata*)	-	1500	1000	125	625	-	813
17	20	Black gum	(*Nyssa sylvatica*)	-	250	-	-	750	125	1125
18	21	Sweet gum	(*Liquidambar styracifolia*)	-	1125	250	-	-	-	1370
19	24	Holly	(*Ilex opaca*)	375	-	-	-	-	-	625
20	26	Red maple	(*Acer rubrum*)	750	5000	250	750	1125	1250	9125

TABLE XXXI — Continued

S. No.	Species Code	Tree Species (Common Name)	Botanical Name	Soil Type: Bowie Fine Sandy Loam Plot No. 6 (367)	Plot No. 7 (371)	Plot No. 8 (375)	Plot No. 11 (387)	Plot No. 12 (392)	Plot No. 13 (805)	Total
21	36	Sumac	(<u>Rhus glabra</u>)	-	-	-	250	-	-	250
22	43	Hophornbeam	(<u>Ostrya virginiana</u>)	375	-	-	-	-	-	375
23	44	American elm	(<u>Ulmus americana</u>)	-	250	-	-	-	-	250
24	47	Deciduous holly	(<u>Ilex decidua</u>)	375	-	250	-	-	-	625
25	48	Vacc spp	(<u>Vaccinium staminum</u>)	750	1375	-	250	625	1625	4625
26	50	Red haw	(<u>Crataegus L spp</u>)	375	125	-	-	-	-	500
27	51	Wild plum	(<u>Prunus spp</u>)	-	-	250	250	-	-	500
28	56	Black haw	(<u>Viburnum rufidulum</u>)	-	-	-	-	-	-	0
29	57	Red mulberry	(<u>Morus rubra</u>)	-	-	125	-	-	-	125
30	62	Azalea	(<u>Rhododendron L spp</u>)	-	-	125	-	-	-	125
31	16	Cedar	(<u>Juniperus virginiana</u>)	-	-	-	-	-	-	0

S. No.	Species Code	Tree Species (Common Name)	Soil Types: Goldsboro Loam Plot No. 5 (358)	Plot No. 9 (379)	Plot No. 14 (808)	Total	Herndon Loam Plot No. 2 (350)	Plot No. 3(354)	Total	Myatt Silt Loam Plot No. 10 (383)	Grand Total of all the Plots
1	01	Shortleaf pine	-	-	1375	1375	-	-	0	-	3875
2	02	Loblolly pine	-	-	-	0	-	-	0	2125	3875
3	28	Post oak	-	-	-	0	-	-	0	250	5750
4	29	S. Red oak	-	250	750	1000	125	-	125	250	3125
5	30	White oak	2500	500	1500	4500	125	-	125	-	8250
6	37	Black oak	-	-	-	0	-	-	0	-	500
7	38	Water oak	1625	-	250	1875	-	-	0	1250	4250

TABLE XXXI — Continued

S No.	Species Code	Tree Species (Common Name)	Soil Types: Goldsboro Loam Plot No. 5 (358)	Plot No. 9 (379)	Plot No. 14 (808)	Total	Herndon Loam Plot No. 2 (350)	Plot No. 3 (354)	Total	Myatt Silt Loam Plot No. 10 (383)	Grand Total of all the Plots
8	39	Willow oak	-	-	125	125	-	-	0	-	250
9	40	Shummards oak	-	-	-	0	-	-	0	-	375
10	42	Black hickory	-	250	500	750	-	-	0	-	2625
11	46	Bitternut hickory	-	-	-	0	-	-	0	-	625
12	23	Mockernut hickory	125	-	-	125	-	-	0	-	1625
13	11	Ash	125	-	125	250	-	-	0	250	625
14	13	Bluebeech	-	-	-	0	375	-	375	-	750
15	18	Dogwood	125	1125	1750	3000	1250	5125	6375	500	29500
16	19	Winged elm	-	-	625	625	-	-	0	2625	3063
17	20	Black gum	-	2375	-	2375	375	625	1000	1125	5625
18	21	Sweet gum	625	1375	-	2000	625	1875	2500	625	6495
19	24	Holly	-	-	250	250	-	-	0	-	625
20	26	Red Maple	250	-	1000	1250	-	-	0	-	500
21	36	Sumac	-	-	250	250	-	-	0	-	500
22	43	Hophornbeam	-	-	125	125	-	-	0	-	375
23	44	American elm	125	-	-	125	-	-	0	-	875
24	47	Deciduous holly	-	250	-	250	-	-	0	-	625
25	48	Vacc spp	1750	1750	9625	13125	2000	8125	10125	500	28375
26	50	Red haw	-	-	125	125	-	-	0	-	625
27	51	Wild plum	-	-	-	0	-	125	125	-	1625
28	56	Black haw	-	-	-	0	125	-	125	-	250
29	57	Red mulberry	125	-	-	125	-	-	0	-	125
30	62	Azalea	-	-	-	0	-	-	0	-	1112
31	16	Cedar	-	-	-	0	-	-	0	-	0

TABLE XXXII

TREE SPECIES IN PLOTS (AVERAGE FOR EACH SOIL TYPE)

S. No.	Species Code	Tree Species (Common Name)	Frequency Soil Type				Regeneration Soil Type			
			Bowie	Goldsboro	Herndon	Myatt	Bowie	Goldsboro	Herndon	Myatt
1	01	Shortleaf pine	172	110	310	130	417	458	0	0
2	02	Loblolly pine	90	3	0	110	292	0	0	2125
3	30	White oak	102	513	245	70	604	1500	63	0
4	29	S. Red oak	121	120	45	30	313	250	63	250
5	37	Black oak	12	3	20	20	83	0	0	0
6	28	Post oak	40	23	5	50	917	0	0	250
7	39	Willow oak	7	3	0	30	21	42	0	0
8	38	Water oak	8	0	0	50	188	625	0	1250
9	18	Dogwood	138	177	200	30	252	1000	3188	500
10	20	Black gum	50	137	95	40	188	792	500	1125
11	26	Red maple	93	30	20	20	1521	417	0	0
12	42	Black hickory	35	21	0	0	313	250	0	0
13	23	Mockernut hickory	48	20	55	0	250	42	0	0
14	46	Bitternut hickory	8	0	0	10	104	0	0	0
15	13	Bluebeech	2	0	5	0	63	0	187	0
16	19	Winged elm	88	40	5	410	542	208	0	2625
17	32	Red bud	0	0	10	0	–	–	–	–
18	21	Sweet gum	290	357	5	40	228	666	1250	625
19	51	Wild plum	7	3	5	10	83	0	63	0
20	49	Tree huckleberry	10	0	5	0	–	–	–	–
21	11	Ash	8	20	0	30	21	83	0	250
22	43	Hophornbeam	35	3	0	0	63	42	0	0
23	57	Red mulberry	17	13	0	0	21	42	0	0
24	44	American elm	3	0	0	0	92	42	0	0
25	31	Persimmon	2	0	0	0	–	–	–	–
26	48	Deerberry	15	0	0	0	771	4375	5063	500

TABLE XXXII — Continued

S. No.	Species Code	Tree Species (Common Name)	Frequency Soil Type				Regeneration Soil Type			
			Bowie	Goldsboro	Herndon	Myatt	Bowie	Goldsboro	Herndon	Myatt
27	36	Sumac	13	3	0	10	42	83	0	0
28	24	Holly	5	10	0	0	63	83	0	0
29	40	Shummards oak	-	-	-	-	63	0	0	0
30	47	Deciduous holly	-	-	-	-	104	83	0	0
31	50	Red haw	-	-	-	-	83	42	0	0
32	56	Black haw	-	-	-	-	0	0	62	0
33	62	Azalea	-	-	-	-	61	0	0	0
34	16	Cedar	-	-	-	-	0	0	183	0

VITA 3

Satyanarayana Paka

Candidate for the Degree of

Doctor of Philosophy

Thesis: RELATION OF SOIL PROPERTIES TO SITE INDEX OF SHORTLEAF PINE AND DISTRIBUTION OF TREE SPECIES IN THE COASTAL PLAIN SOILS OF SOUTHEAST OKLAHOMA

Major Field: Soil Science

Biographical:

Personal data: Born in Warangal, Andhrapradesh, India, February 18, 1935, the son of Sri Malliah and Lakshmamma.

Education: Graduated from A.V. High School, Warangal, (A.P.), India, in 1950, received the Bachelor of Science degree from Osmania University, Hyderabad, India, in 1955 with a major in Agriculture; received the Master of Science degree from Osmania University, Hyderabad, India, in 1961 with a major in Agricultural Chemistry; completed requirements for the Doctor of Philosophy degree at Oklahoma State University, Stillwater, Oklahoma, U.S.A. in August, 1969 with a major in Soil Science.

Professional Experience: Research Assistant in the Department of Agriculture (A.P.), India, October 1956 to March 1962; Assistant Agricultural Chemist in the Department of Agriculture (A.P.), India, April 1962 to April 1963; Part-time Soil Testing Laboratory Technician, Agronomy Department, Oklahoma State University, January 1966 to November 1968.

Professional Organizations: Member of the American Society of Agronomy.