ELEVEN YEAR BIOLOGIC-ECONOMIC EVALUATION
OF UNDESIRABLE HARDWOOD SITES
CONVERTED TO PINE

By

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CHAPTER I

INTRODUCTION

The demand for wood products continues to exert pressure on the forest land manager to increase production from his forest land. A desire for an ever-increasing standard of living by society tends to increase these pressures. An increasing population and a decreasing land base puts pressure on the production of wood products from both directions. In response to this pressure, land not previously considered feasible for commercial timber production is looked at with more interest.

The Cross Timbers area, consisting of a total of about two and a quarter million acres and occupying some five percent of Oklahoma land surface, is such an area (Figure 1). Average annual rainfall is less than 42 inches in this area (Figure 1). Moreover, precipitation during the growing season months of May to October does not exceed 12.6 inches 30 percent of the time and 50 percent of the time does not exceed 20 inches (15). As much as 3.0 inches below normal per month occurs periodically at some stations within the study area during this season. This pattern can be critical to pine regeneration and growth since precipitation normally ranges from 3.09 to 3.84 inches per month from July through October. Pan evaporation records (16) indicate 5.5 to 12.1 inches of water can be lost per month during the May to October period. This results in water deficits for much of the period (15).

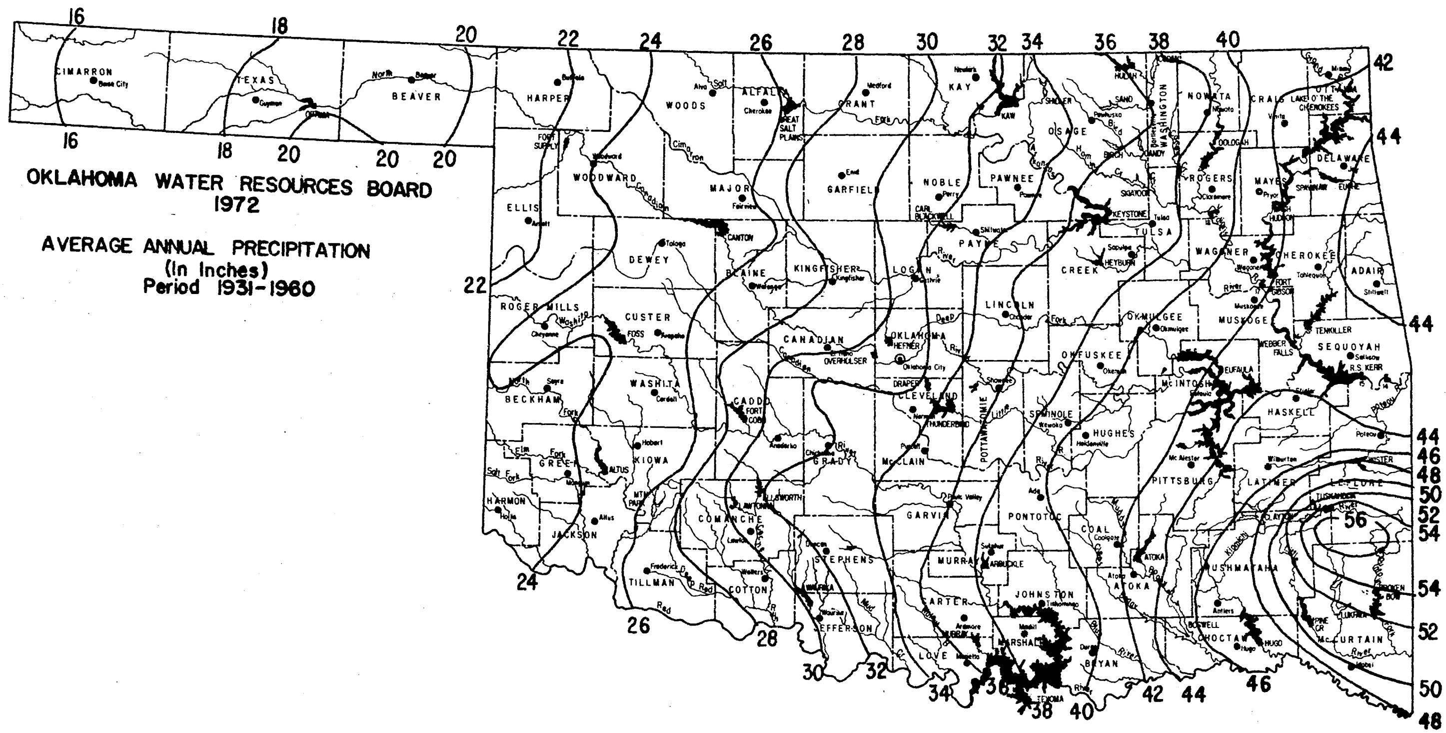


Figure 1. Area of Study, with Precipitation Patterns.

Native trees consist of low-quality post oak (Quercus stellata, Wang), winged elm (Ulmus alata, Michx.) and blackjack oak (Quercus marilandica, Muench.) over shallow rocky soils (Figure 2A). With deeper soils, hickory (Carya spp.) and occasionally red oak (Quercus falcata, Michx. and/or Quercus velutina) of poor quality may be found in limited areas (Figure 2B). Medium and tall grasses are found in the understory, with tall grasses abundant in openings that have not been overgrazed.

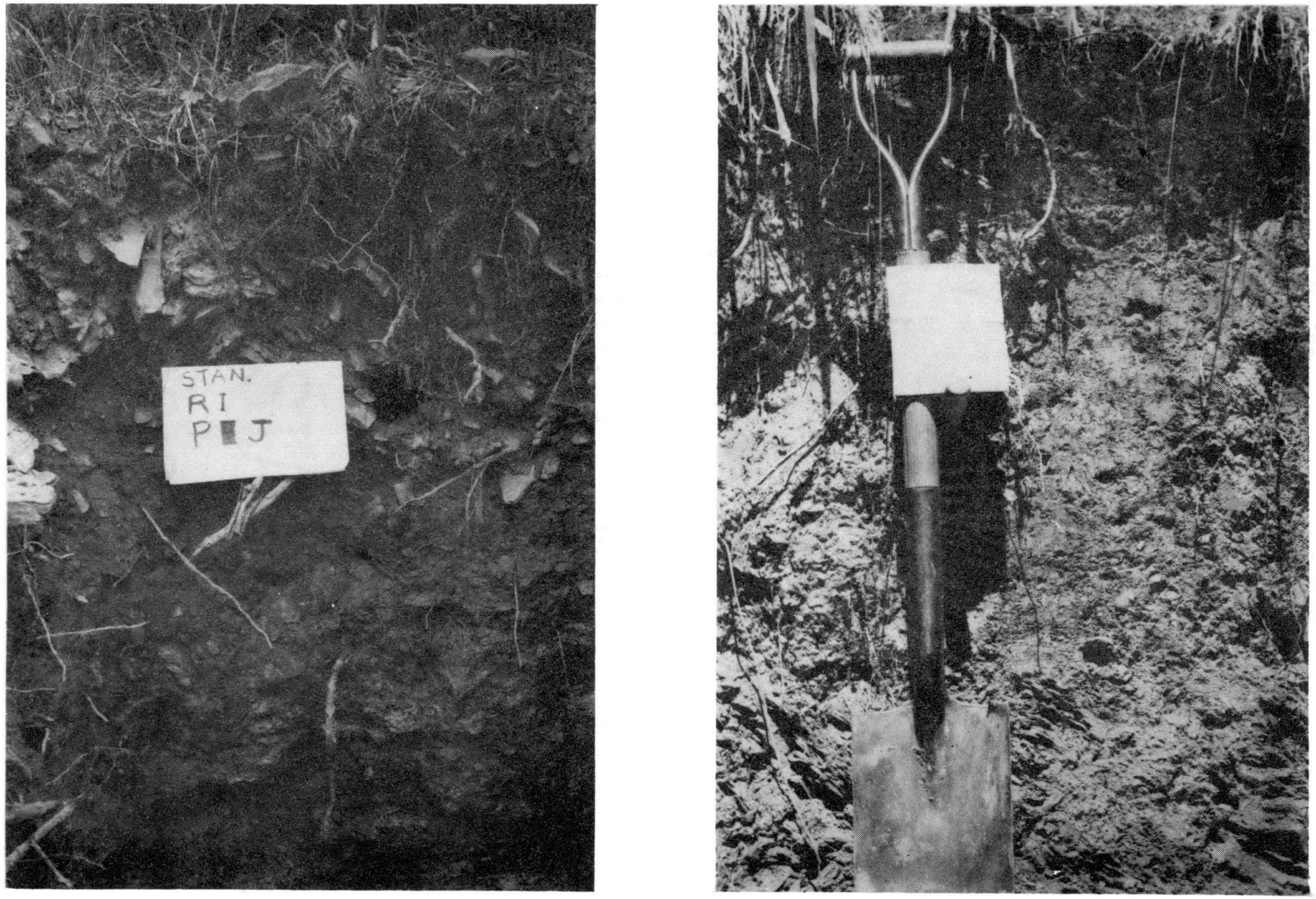
Bedrock in the study area is predominately Pennsylvanian age sandstone and shales common to the Ouachita Highland and Cross Timbers provinces. Alternating and tilting layers of these occurred frequently. Since the sandstone weathers toward a sandy texture soil and the shales toward a clayey texture, the alternating layers often confuse identification of the dominant bedrock before weathering. Within the sandstone, there was a relatively soft, easily weatherable sandstone and a hard, slowly weatherable sandstone found. Where relatively thick layers of the soft sandstone were present, weathering proceeded much more rapidly than where the hard sandstone dominated. Degree of weathering and influence on depth of A horizons and content of rocks is illustrated in Figure 3.

Due to physical limitations in the Cross Timbers area, there is some doubt as to the feasibility of converting the scrub-hardwood lands to tree species that can be managed for commercial wood fiber. If timber management is feasible, the increase in potential land base, resultant commercial activity and job opportunities could be large. It would be difficult to project the exact influence because of the large number of landowners with relatively small holdings. However, resolution of the land management potential would offer each of these

(A)

(B)

Figure 2. Native Tree Species on Sites Before Treatment: (A) Post Oak, Blackjack Oak, Hickory and (B) Post Oak, Blackjack Oak, Hickory and Red Oak.



(A) (B)

Figure 3. Predominant Soil Condition on Two Land Classes: (A) Shallow A Horizon, with High Rock Content, and (B) Moderately Deep A Horizon, with Moderate Rock Content.

landowners another management alternative not previously available to them. If the timber management alternative is not feasible, investment effort can be directed more toward conversion to range or other uses.

To help resolve the question of management potential, the Oklahoma Agricultural Experiment Station instituted a study in 1963 to determine if shortleaf pine could be introduced on scrub-hardwood lands and if the investment would be biologically and economically feasible. The objectives of the original study were:

1. To test the effect of climatic pattern, soil and seedbed condition on pine seed germination, survival and development in the Ouachita Highland resource area and check the effect on survival and growth of premium pine seedlings planted under comparable site conditions.

2. To compare arasan and endrin treated seed with non-treated seed to determine need for and effectiveness of bird and rodent repellent treatment.

3. To test the effect of scrub-hardwood overstory control on pine seed germination and survival.

4. To check range recovery under fencing control and subsequent composition changes and production as related to overstory hardwood control and pine development.

The study plots were related to two plant associations (sites), two climatic zones and two biotic conditions:

<u>Plant Associations</u>:

a. Relatively poor forestry chances in post oak-blackjack oak-hickory associations on rocky, shallow sandy loam soils above compact clays (Figure 3A).

b. Fair forestry chances in post oak-blackjack oak-hickory-red oak associations on similar geologic bedrock but deeper soil profiles (Figure 3B).

Climatic Zones:

a. Less than 42 inch total annual precipitation.

b. Over 44 inch total annual precipitation.

Biotic Condition:

a. Heavily-grazed native range.

b. Ungrazed native range.

Two fenced and unfenced blocks were established at three locations within each climatic zone. Pine direct seeding and the planting of premium grade pine seedlings were carried out in the 1963, 1964 and 1965 seasons to span the effect of annual climatic patterns.

This study attempted to examine and evaluate the plots planted in 1965 and report the results after 11 growing years. The major objectives of this thesis were:

1. To examine soil profiles at all locations to determine relationships, if any, between soils and tree response.

2. To correlate information on tree survival, height and form class with soils and the limiting factors in the low rainfall tension zone.

3. To determine, if possible, the lowest quality site(s) biologically and economically suited to growing and managing shortleaf pine.

CHAPTER II

LITERATURE REVIEW

Recognition of "good ground" and "stony ground" dates back to Biblical times. Almost 2000 years ago, Jesus used a comparison of the two types in a parable he used to teach his disciples (13).

Dokuchaev (4) first suggested that soils are the result of five factors affecting genesis: climate, biosphere, topography, parent materials and time. Marbut (12) brought these concepts to the attention of soil scientists in the United States.

Kellogg (10), who succeeded Marbut as Director of the United States Soil Survey, has, with his co-workers, continued the development of soil classification, building on the foundation laid by Dokuchaev and Glinka (Soil Survey Staff, 1951, p. 6). Kellogg recognized the move toward correlation between soils and timber management:

> Until recently forest management has been mainly management and protection of the trees . . . The adaptability of individual species of trees to kinds of soil and their growth rates as measured by forest site indices have received wide attention in recent years (page 1).

Kellogg further stressed the usefulness and need for additional effort:

> The results of these correlations between kinds of soil and forest site indices are very useful today . . . Yet I regard this work as merely a start toward the appreciation of the relations of soil to trees (page 1).

Kellogg emphasized a need for standards giving the characteristics of the ideal soils for each tree species. Retzer (17) gave guidelines for the future collection of interpretative data (page 114).

1. Soil taxonomic units represent the most effective way of stratifying significant physical and natural differences in a landscape.

2. The taxonomic soil unit rather than the vegetative type should be recognized as the primary object being investigated. Trees are measured merely as a means of evaluating the productive potential of a soil.

3. Collection of interpretative data should generally be limited to selected key or benchmark soils, each of which covers a portion of the range from low to high productivity.

4. It should be recognized that soils are at least as variable in composition as are timber types and that careful plot selection is essential to the usefulness of the data.

5. The productive potential of a soil should be reported as a range and if feasible, an average.

6. It is desirable to measure yields in some direct basic unit of weight or volume rather than as site-index.

7. The soil map shows where to look for a soil type but the soil on the research plot must be specifically identified in all instances.

Lemmon (11) pointed out the fact that evaluating the effects of different kinds of soil on seedling mortality has been based on scattered pieces of information resulting from research developed with other objectives in mind or from experience and observation of soil technicians and forest technicians, implying that better research data was desired.

Hills (8), after an elaborate discussion, cautioned:

> Soil profile classes provide a basis for forest site evaluation only when placed within the limits of specific physiographic sites, described in terms of the effect of significant variations in climate, relief and parent materials on vegetation development (page 210).

Rudolph (19) concludes:

> The forest manager not only adapts his choice of species and practices to soil conditions, but he must increasingly apply practices which will modify the soil and improve its productivity (page 170).

Following this apparent explosion of forest soils knowledge, McDermott and Fletcher (14) in 1959, recognized that a large portion of research in forest soil relationships had been done by non-foresters. Much information had to be adapted to forestry, to bridge the gap from supportive literature that was fragmented and unrelated except as it might fit into topics for forestry texts. McDermott and Fletcher (14) asked such basic questions as:

> Why does shortleaf pine, a southern species, reach its northwestern extremity in southern Missouri? Why does its range stop where it does? As it approaches its range extremities, why does it occur in disjunct patches (page 10)?

Comparison of a distribution map for shortleaf pine and a geological map indicated that shortleaf occurs where sandstone, sandy dolomite or granite porphyry are the underlying rocks. Pine was noted to be especially prominent as a component of the prevailing oak-hickory association where the Roubidoux sandstone formation is strongly dissected by rugged relief. The implication is that these sites are good enough for pine regeneration, but poor enough so as to effectively limit competition.

An exception was noted about 75 miles north of shortleaf's natural range. The environment seemed ideal but no natural stands had ever been found. Critical precipitation and temperature relationships occur there during the period of November through April and they surmise (14) that:

> It appears that winter precipitation and temperatures become increasingly critical (limiting) factors as the northwestern limits of the range of shortleaf pine are approached (page 11).

Fletcher and McDermott, citing their 1957 work (6), state that shortleaf pine is more stable on sites where it is more tolerant of limiting factors than its hardwood associates are. Pine occurs simply because it is better able to regenerate where hardwood associates are limited. Pine would grow faster on better sites, but so would the hardwoods. Pine seedlings can't compete with heavy stands of oak sprouts present. They note that the justification for the added cost of controlling oaks in the better sites should be questioned.

Hodgkins (9) recognized the usefulness of site classification in forest management but he cautioned against making the applications too broad. In the use of regression he demonstrated why one of the two following conditions should be met.

> 1. If the regression study area (or areas) is large and complex, the man who uses the prediction equation must be thoroughly familiar with both the regression study and the area to be typed.
>
> 2. The regression studies involved are for relatively uniform conditions of topography and soil formation.
>
> For the purpose of improving future silvicultural practice, forest managers should begin thinking and acting now in terms of total site instead of site index (pages 34-47).

Coile (2) charged that soil maps by the Soil Conservation Service of the United States Department of Agriculture do not have high utility.

> They are science and art for the sake of science and art; they are an exercise. They were not designed to be directly useful even in conventional agriculture (pages 77-85).

He gives examples of a soil series being too broad and cites his experience of adding six incnes to the standard 42 inch soil auger in order to sample more of the soil profile. For forest management, he feels that the soil profile should be examined 4 to 6 feet deep.

Farnsworth and Leaf (5), while working with sugar maple-soil relationships in New York, had similar problems. While initially working with "known" soils and measuring total tree height and age, several questions were raised concerning the adequacy of using published site index curves in classifying the site. The "within" soil series range in site index appeared to be too great, and the "among" range had even less meaning. Because of this, they went back and had the soils examined and described in more detail. They used destructive techniques of sampling their trees, by cutting the trees down and measuring height. They also took out a disc every ten feet for a laboratory count of growth rings. This eliminated questions as to the soil data and measurements techniques. Inconsistencies were found in soil classification; errors were found in total tree height and age. With the improved techniques, it was found that the hardwood species of sugar maple often exhibited "normal" growth part of its life and abnormal growth through other parts. They were only able to study what was found on the sites, and although samples were restricted to sites which had not been disturbed for 30 years, they had no control over them and could only surmise what had occurred.

Farnsworth and Leaf (5) listed some reasons for difficulty in correlation of soils with tree response. They believe the soil cannot be directly classified as to moisture, nutrient elements and aeration over the complex and varied rooting zone of the soil. The soil must be measured by such indirect measures as depth, horizon thickness, ground water level, bulk density, texture, organic matter, color, structure, pores, reaction, extractable nutrient elements and cation exchange capacity.

Foresters, in classifying sites, have used plant indicator associations, volumes produced, site index of trees on an area at a given age, and parent rock as well as soils. While Farnsworth and Leaf mention the problem of using indirect measurements to compare site factors with tree response, which may in itself have errors, they do mention one tool that is often useful.

> If the growth of a forest stand is controlled by one or a few of the site factors, and if these are known and can be measured, the task of classifying the site can be rather simple. Unfortunately, this is rarely the case. Climatic, biological and edaphic factors occur in complex combinations of independent and interdependent factors, in which instrumental measurement is either extremely difficult or impossible (page 280).

Two examples given are: (a) depth to bedrock or fragipan and (b) soil texture. Both of these properties can be compared directly to tree response within a given area.

Coile (1), in his study of soil-site relationships for shortleaf pine in North Carolina sites, covered the following factors:

1. Depth of the A Horizon.

2. Relation of silt-plus-clay to the moisture equivalent of the B Horizon.

3. Depth to the C Horizon.

4. Imbibitional water value of the soil, (differences between moisture and xylene equivalents of a soil).

5. Combination of these variables (Bulletin 13).

He found: (a) the depth of the A Horizon, (b) imbibitional water value, and (c) the combination of these variables, all to be significant in the soil-site relationships.

Zahner (23) modified Coile's procedure by substituting soil consistency for the imbibitional water value. He applied this in the Coastal

Plain area of Texas, Louisiana and Arkansas. This modification is more practical for field foresters to use.

Silker (20), in his study of soil-site-plant association relationships on soils of the Gulf Coastal Plain in Texas and southeastern Oklahoma, used hardwood climax plant associations to rank relative site quality. The system he developed to analyze the site uses plant indicators in both the understory and overstory. Plant indicators are used to predict site potential in terms of soil moisture availability and effect on the pine regeneration class, associate species competition and economic silvicultural treatment for certain land management classes. This wedge chart (Figure 4) concept is an attempt to illustrate the above relationships so as to be readily understood and used by the forest manager or layman (species abbreviations and corresponding names are listed in Table I).

The concept is based on the following premises:

a. Soil moisture is usually the most important factor controlling plant adaptation to site, where other minimums are met.

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

c. Groups of hardwoods are practical, natural, statistical expressions of total site factors affecting physiological minimums or maximums. Or, we might say that species frequency and commercial bole length and form are "mirror images" of what the total environment may express.

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

3. Hardwoods should be reliable indicators because: (1) many are climax plants; (2) they are less subject to rapid change than ground flora that are readily affected by fire, cutting and grazing; and (3) they usually reflect an age or minimum time expression of 50 to 150 + years (page 319).

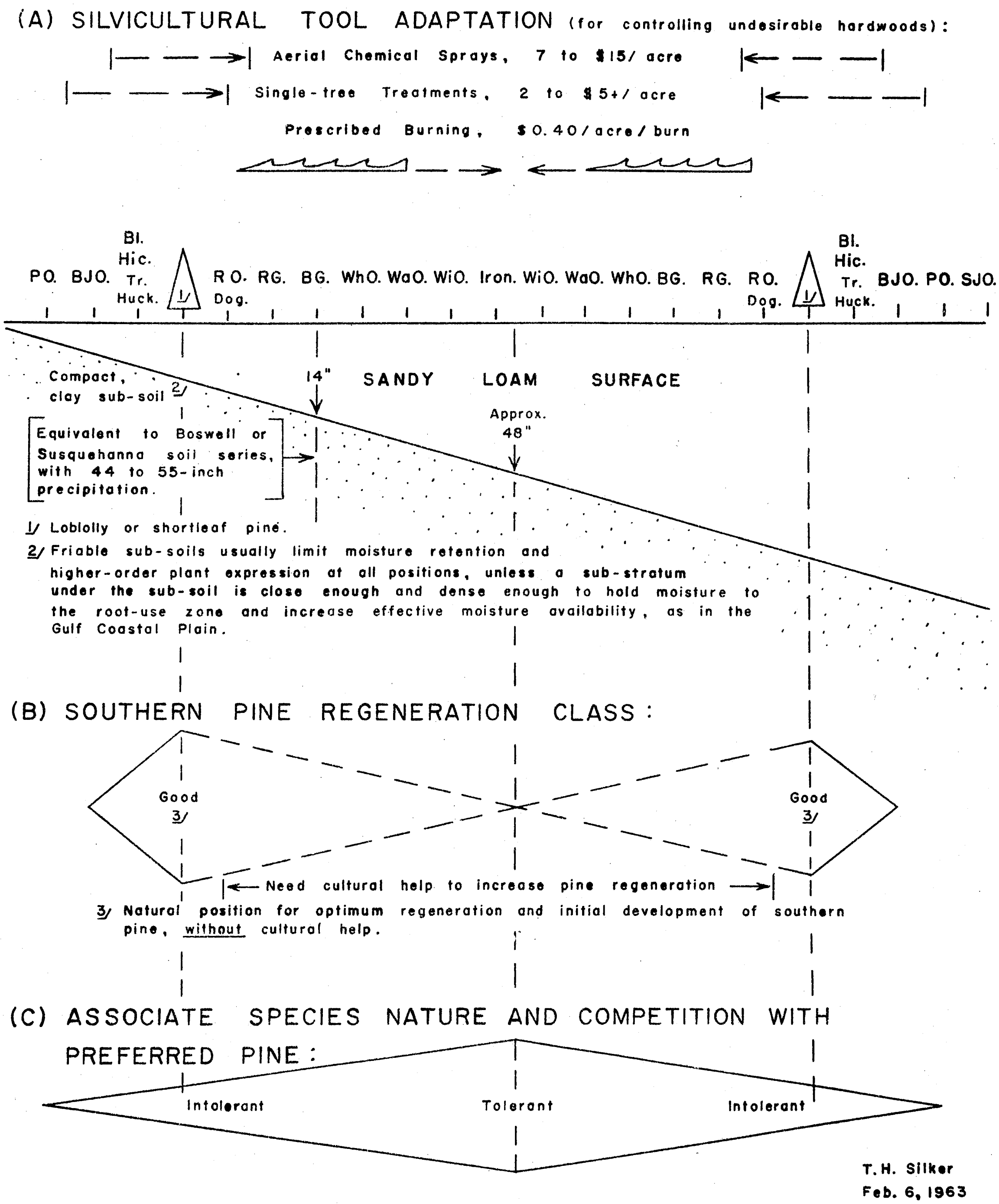


Figure 4. "Total Site Classification" by the Use of Plant Indicators and Position of Predominant and Common Hardwoods in Reflecting Soil Moisture Availability.

TABLE I

AN EXPLANATION OF SPECIES ABBREVIATIONS USED IN SILKER'S WEDGE CHART (FIGURE 4)

Abbreviation on Wedge Chart	Common Name	Generic Name
P.O.	Post Oak	Quercus stellata, Wang.
B.J.O.	Blackjack Oak	Quercus marilandica, Muench.
Bl. Hic.	Hickory	Carya spp.
Tr. Huck.	Tree Huckleberry	Vaccinium arboreum, Marsh.
	Pine	Pinus echinata, Mill. or P. taeda, L.
R.O.	Southern Red Oak	Quercus falcata, Michx.
Dog.	Flowering Dogwood	Cornus florida, L.
R.G.	Red or Sweetgum	Liquidambar styraciflua L.
B.G.	Black Gum	Nyssa sylvatica, Marsh.
Wh.O.	White Oak	Quercus alba, L.
Wa.O.	Water Oak	Quercus nigra, L.
Wi.O.	Willow Oak	Quercus phellos, L.
Iron.	Ironwood	Ostrya virginiana, (Mill.) K. Koch.
S.J.O.	Sandjack Oak	Quercus cinerea, L.

By using these plant indicator groups to evaluate the sites, the following may be indicated:

1. Minimal needs for each species.

2. Optimum site for each commercial species.

3. Relation of the commercial species to their associates, (i.e., competition with the commercial species).

4. Treatments that are biologically favorable for development of the commercial species, with economic inferences.

Thus, plant indicators should help assay bio-economic relationship or total classification of forest sites (page 328).

Wilson (22) used Silker's hardwood plant associations to study relationships between shortleaf pine site index, associated plants and soil. The four associations he studied are found in Table II. These show a relationship between plant association and pine site index in the Gulf Coastal Plain in southeastern Oklahoma. Wilson concludes that discrete moisture classes can be differentiated by use of specific plant groups and these groups in turn can be used to forecast growth response of shortleaf pine on the various sites.

TABLE II

HARDWOOD PLANT ASSOCIATIONS AND CORRESPONDING SITE INDEX FOR ASSOCIATE SHORTLEAF PINE ON SOILS OF THE COASTAL PLAIN IN OKLAHOMA 3/

Plant Associations	Shortleaf Pine Site Index
1. Post oak-blackjack oak-hickory-tree huckleberry	64
2. Post oak-blackjack oak-red oak	71
3. Red oak-sweet gum	79
4. Sweet gum-black gum-white oak	90

[3]Adapted from: W. Dale Wilson, "Shortleaf Pine Site Index--Soils and Plant Associations on the Coastal Plain of Southeastern Oklahoma," unpublished master's thesis, Oklahoma State University, 1968.

CHAPTER III

METHODS AND PROCEDURES

Field-Soils

Three soil pits were opened at each field location with a backhoe. Two soil profiles were studied at one of the replications and one at the other. Pits were located in fenced plots, to exclude cattle.

An exception to this was the POE property near Kiowa. Here all samples were taken from replication 1 because fire had damaged replication 2. A total of five pits were dug to insure the proper representation of soils due to an obvious soil change.

The pits were dug 60 inches deep or to bedrock. The soil profiles were then classified and described by soil scientists from the nearest Soil Conservation Service office. Bulk and small samples of soil were taken from each horizon on the uphill side of the pit after color and black-and-white photographs were taken.

Bulk samples 12 x 12 x 6 inches thick were collected from the thickest representative portion of the horizon to allow determination of rock percentage. A one-half pint sample was also taken to insure a representative horizon sample in the event the bulk sample became contaminated during process. This also provided materials for running duplicate pH and hydrometer tests.

Field-Pine Measurements

Measurements were taken on the 16 interior trees of each sub-plot at the end of the 11 year growing season. The original sub-plots were laid out in eight rows of eight trees each, spaced about six feet apart. There was an edge effect noted on many of the locations due to competition from nearby hardwoods. These 16 interior trees more adequately reflect growth responses under plantation conditions.

The first measurements were made using marked poles to determine heights. Diameter measurements were taken using a prismatic dendrometer, at five-foot intervals from stump height throughout the tree. Measurements were made from up-slope and the readings checked against those made with outside calipers. Each tree was also measured for diameter at breast height and at 17 feet 3 inches. Bark thickness was also measured at breast height.

The intent of these measurements was to get volume per tree data, Girard form class data and overall height. When this data was used it was discovered that while volume, height and diameter breast height were complete, there was not an adequate number of trees measured at 17 feet 3 inches to give sufficient form class information. This was due to the limitations of the prismatic dendrometer which would not measure any diameter smaller than 1.8 inches. Tree heights indicated there were adequate numbers of dominant and co-dominant trees present; therefore all dominant and co-dominant trees were again measured at 17 feet 3 inches by means of ladders and outside calipers. Bark thickness was also measured at 17 feet 3 inches to eliminate the need for any interpolations for bark thickness, as was the case when bark was measured breast height. Some smaller diameter trees would not support the ladder and it was necessary to estimate the top diameters. On these trees the ladder was placed against a nearby tree and the observer climbed as high as possible to be as near as possible to the 17 feet 3 inch mark on the pole. Estimates made in this manner were noted in field notes.

Laboratory

Soil samples were oven dried at 100° Centigrade to a constant weight. They were allowed to stabilize to constant weight at normal room temperature, with weights being recorded to the nearest .01 gram. The soil was then passed through a 2mm screen to remove all pebbles and rocks. Rocks were then washed with lukewarm water. Rocks with soil imbedded in pits and crevices were scrubbed with a soft nylon brush to remove all soil particles. Extreme care had to be used on some rocks because they were soft; i.e. both soft sandstones and soft shales.

Rocks were then oven dried at 100° Centigrade to a constant weight. They were then allowed to stabilize at room temperature and weights were recorded to the nearest .01 gram. Total rock weight was used to calculate the percentage of rock by weight in each horizon.

Particle size was determined by hydrometer test using the Day procedure (3). The soil was oven dried to constant temperature. Thirty grams were put into a 400 ml beaker and distilled water added to bring it to 150 ml. This was stirred to allow the water to take on the pH of the soil. After 24 hours the pH was read and recorded, using a Corning meter.

After the pH was read, 10 ml of two percent solution of $Na_2CO_3 \cdot NaHCO_3$ were added to each sample. Distilled water was added to bring the total volume to 200 ml. The sample was stirred and allowed to set 24 hours after addition of $Na_2CO_3 \cdot NaHCO_3$ and adjusted to provide a pH range of 9 to 10 to insure adequate particle dispersion.

Each sample was then placed on a sonic dispersion unit for 15 minutes. The sample was then put into clear tubes and distilled water added to bring total volume to 1,000 ml. The sample was then conditioned in a "constant temperature" room.

After thorough sample agitation, hydrometer readings were taken at intervals of 30 seconds, one minute, three minutes, one hour, four hours, eight hours and 26 hours. The 30 second hydrometer readings were the most difficult to obtain. Following agitation the hydrometer was often "bobbing" too much to get an accurate reading. When this happened, the observer agitated the solution and started over. Some samples of high clay content still had some "bobbing" movement after 30 seconds which could not be eliminated. These samples were read three times and the readings were averaged and recorded. The hydrometer was left in the sample and one and three minute readings were taken without it being disturbed. If the sample was jarred or the hydrometer was misread, the sample was agitated and the one and three minute readings were repeated. Following the three minute readings all samples in "sets" were agitated at one minute intervals to assure proper readings of each sample at the one hour and later readings.

Additional samples were picked at random to have a minimum of 25 percent of the samples duplicated. A few other samples were also re-run to check possible first run errors. In all, about 25 percent were re-run. Clay content varied by no more than eight percent in any duplicate run and was usually within three percent. The precision between initial and duplicate readings tends to build confidence in the procedures.

CHAPTER IV

RESULTS AND DISCUSSION

Soils Comparisons

Soils within the study area were found to be mostly Ultisols, with an Inceptisol found at one location. Within the area of < 42-inch rainfall, all soils were classed as Enders, Enders-like and Enders-Modal series. The A horizons were usually six inches or less thick. Exeptions to this six inch depth were found at two of the three locations. A portion of the Kiowa location had A_1 horizons as deep as 15 inches. This had been expected and extra pits were dug to adequately examine the site. Total depth of A horizon at the Stanfield location ran from 13 to 23 inches; this had not been anticipated, but may be accounted for by the fact that all pits were near intermittent streams. Rock content was high on the Stanfield location, ranging from a low of 19.2 percent for an A_1 horizon to 76 percent for an A_2 horizon. The weighted mean rock content for locations in the < 42-inch rainfall zone was 43.2 percent (Table III).

The shallow soils within the higher rainfall environment were also very rocky, with the percentage ranging from 36 percent to 74 percent and weighted mean of 60 percent. The depth of A horizon was lowest on an Inceptisol, which had only six inch total for A_1 and A_2 horizons. The mean depth of A horizons for all shallow-soil locations within the > 44-inch rainfall zone was 10.8 inches (Table III and Figure 3).

TABLE III

MAIN ENVIRONMENTAL FACTORS AND THEIR RELATIVE IMPACT ON SHORTLEAF PINE HEIGHT AND GIRARD FORM CLASS AND INFERRED LAND CLASS AND MANAGEMENT POTENTIAL

ENVIRONMENT	A1 - A2 HORIZONS		PINE STATUS 11 YR, AGE	
	DEPTH (INCHES)	% ROCK	HEIGHT (FT.)	GIRARD FORM CLASS
	AVERAGE			
< 42 inch Rainfall:				
PO-BJO-HIC	9.8	43.2	19.0	22
> 44 inch Rainfall:				
PO-BJO-HIC	10.8	60.0	21.1	30
PO-BJO-HIC-RO	12.2	18.9	23.3	41.5

The deeper soils within the > 44-inch rainfall area consisted of Ultisols of the Carnasaw and Zafra series. The total A horizon depths were more consistent and ranged from 10 to 15 inches. The percentage rock in A horizons ranged from less than 1 to 53.9 percent and showed a weighted average of 18.9 percent. This relatively low rock content is in strong contrast to the mean of 60 percent found in A horizons of shallow soils in this precipitation zone.

Pine Survival

The survival for planted shortleaf pine seedlings, through age 11, is 68.7 percent in poor soils in the < 42 inch rainfall zone, 72.4 percent in poor soil in the > 44 inch rainfall zone, and 61.9 percent on the good soil in the > 44 inch rainfall zone. Records of adjacent direct seeded areas show a germination of 1,400 to 13,000 seeds per acre, from the one pound per acre seeding rate for shortleaf pine (approximately 43,000 seed) for the 1965 seeding year, (a greater than average precipitation year). The pine direct seeding on poor sites with low rainfall had a survival through the fifth year of about one percent; under the better rainfall pattern all sites showed 10 percent - 15 percent survival.

Pine Diameter Breast Height

One of the most commonly used measurements by foresters is Diameter Breast Height (D.B.H. at 4.5 feet above ground), because of its convenience and universal acceptance. Figure 5 shows the D.B.H. results by location, in conjunction with the means for the three different environments. There is so little difference in D.B.H. between environments,

AVERAGE TREE DBH 1/ BY ENVIRONMENT

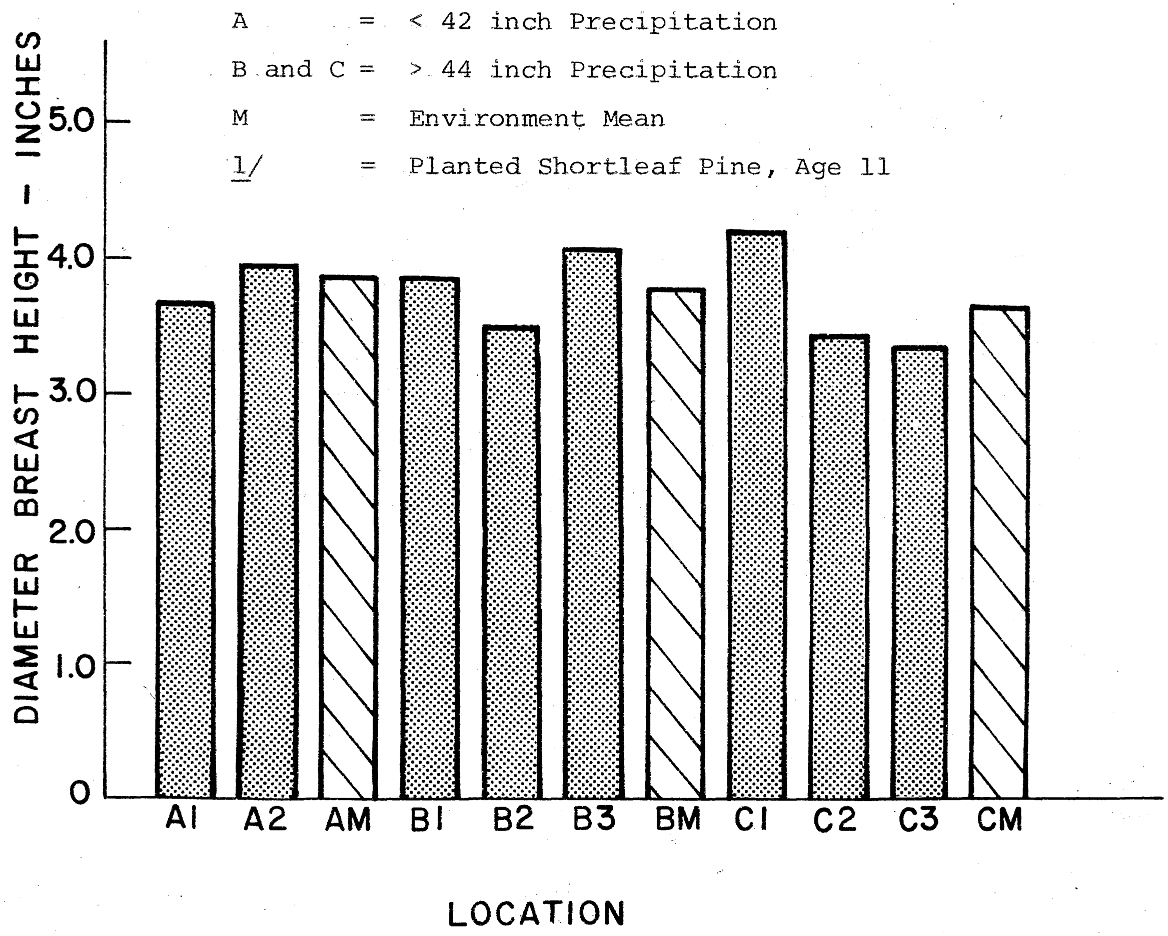


Figure 5. DBH Histogram, by Location and Environment Means.

.06 inches between low rainfall versus high rainfall and .15 inches between the soil patterns, that it was surmised that D.B.H. is not a strong indicator of environmental conditions. Initial results indicated that where there were D.B.H. differences, the larger D.B.H. occurred on the poorest sites.

Pine Volume Comparisons

The marketable portion of each tree is the solid wood inside the bark of the bole. The results of solid wood volume computations are found in Figure 6. The volume per tree is very similar for all locations. There is only a slight increase in mean cubic foot volume per tree for planted pine when progressing from the < 44 inch rainfall zone to deeper, less rocky soils in the > 44 inch rainfall zone. While these volumes reflect what was there at the time of measurement they fail to show any significant relationship to site quality differences at this age.

Pine Height Comparisons

Tree height is used to determine site index, using tree height obtained at various ages. The most common age for southern use has been 50 years, but private companies are beginning to use 25 years. While the pines on the study area were only 11 years old, it was felt that site quality might be reflected even at this early stage if tree heights were compared. This comparison is shown in Figure 7 and Table III. There is a 2.1 foot difference in planted shortleaf pine height between rainfall zones and a 2.2 foot difference in pine height between soil patterns. This difference might not be readily seen on the ground unless the observer was looking for it or took precise measurements. It should

AVERAGE TREE VOLUME 1/ BY ENVIRONMENT

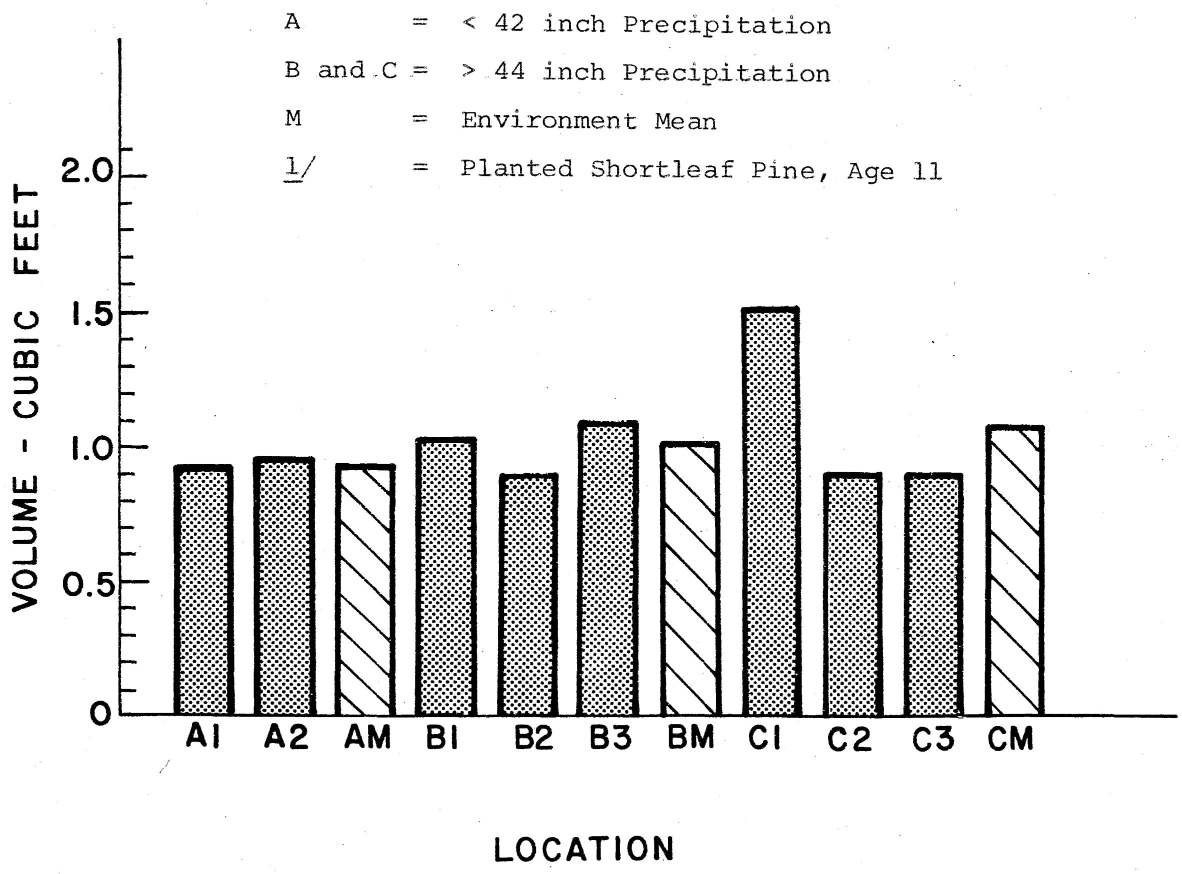


Figure 6. Volume Histogram, by Location and Environment Means.

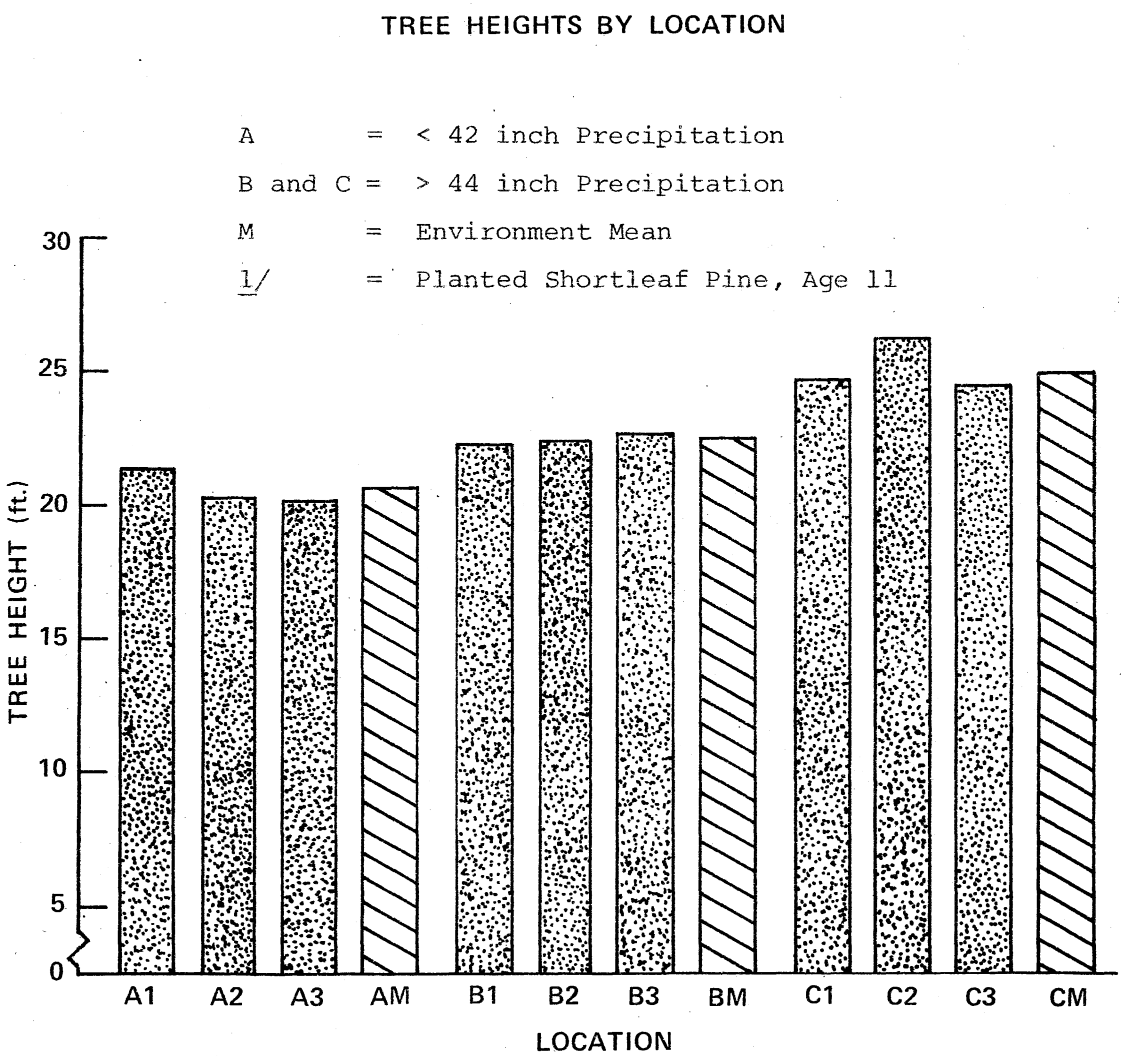


Figure 7. Tree Heights Histogram, by Location and Environment Means.

become more apparent as the trees grow older. The land manager in making his evaluation as early as possible could detect these differences and make his decisions accordingly. Diameters should increase throughout the tree, and especially in the upper bole, as the trees increase in height. Bole taper should decrease as the trees mature. The decreasing taper should reflect an increase in volume, as the better quality sites have taller trees for given diameters (Figure 8A and B).

Relative tree height and bole taper are better illustrated and related to site quality in Figure 8A and B. These 11 year planted pine are on contiguous sites in the < 42 inch rainfall zone. On sites formerly supporting native stands of post oak-blackjack oak the pine averaged 18.9 feet. On sites formerly supporting post oak-blackjack oak-hickory associations the pine averaged 23.1 feet.

Records of tree heights for the first 11 years were used to plot regression curves by use of computer, using the overall mean for each environment. It was thought projections might assist the land manager in making early decisions about management investments on certain land classes. The formula for each line and equations for the line of best fit were calculated and each line was projected through age 25 (Figure 9). The line of best fit is a second degree polynomial. The formulas are as follows, where x = teee height and i = years

Group 1 $x = -.7359 + 1.9157i - .0163i^2$

Group 2 $x = -.8133 + 1.7851i + .0190i^2$

Group 3 $x = -.2527 + 1.5230i + .0544i^2$

The negative coefficiant of i^2 in Group 1 indicates the rate of increase in the tree height per year was decreasing from year to year.

(A)

(B)

Figure 8. Planted Shortleaf Pine Height Difference of 4.2 Feet, Age 11, Between: (A) Site with Native Post Oak-Blackjack Oak Association and (B) Site with Native Post Oak, Blackjack Oak, Hickory Association.

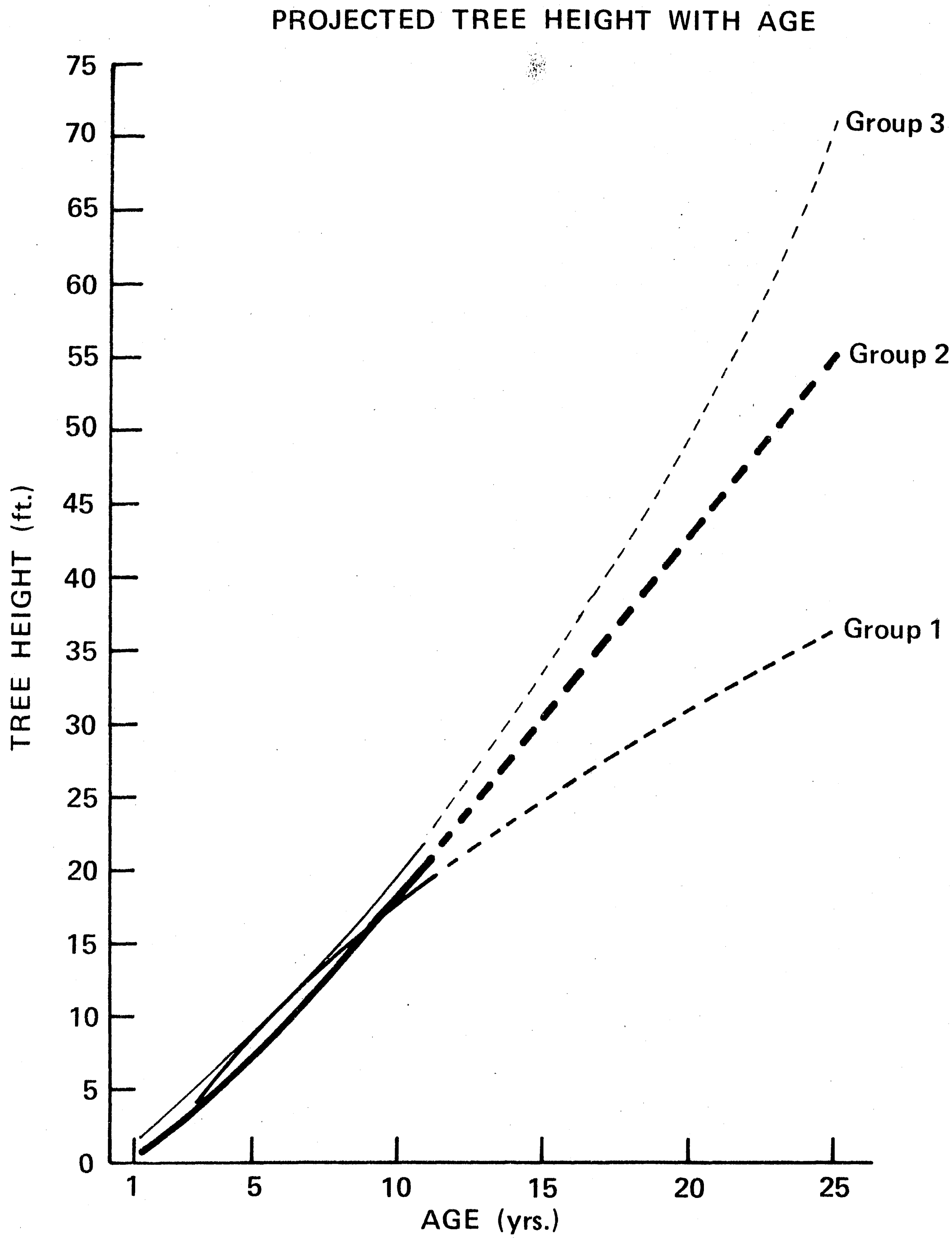


Figure 9. Tree Height Projections, by Environment.

The group lines are based on some of the most active height growth years in the life of the tree. The slopes projected by formula for the last few years are likely over-stated. While height growth will continue, the percent increase for Groups 2 and 3 will likely diminish. The expected heights in Figure 9 are considered reliable no further than about age 20. The relative curves, however, certainly show difference between sites.

The projection of tree height to age 20 should be suggestive and usable by the land manager in separating land management classes and pine management objectives. Additional periodic height and volume measurements should document real performance potential.

Girard Form Class

Girard Form class is commonly used to express the relative bole taper and quality of standing trees. It is computed by relating the following measurements obtained only from dominant and co-dominant trees:

$$\frac{\text{Diameter Inside Bark @ 17' 3"}}{\text{Diameter Outside Bark, Breast High x 100}}$$

This gives a number less than 100 for each tree, from which a location mean can be obtained and compared with other locations. Results from the study area appear in Figure 10 and Table III. Since form class is a comparison of relative diameter at the end of the first log (17' 3") it reflects the relative quality and expected volume of the tree from site to site.

All form classes for studied trees are low because they are based on measurements made on very young trees, some of which were barely

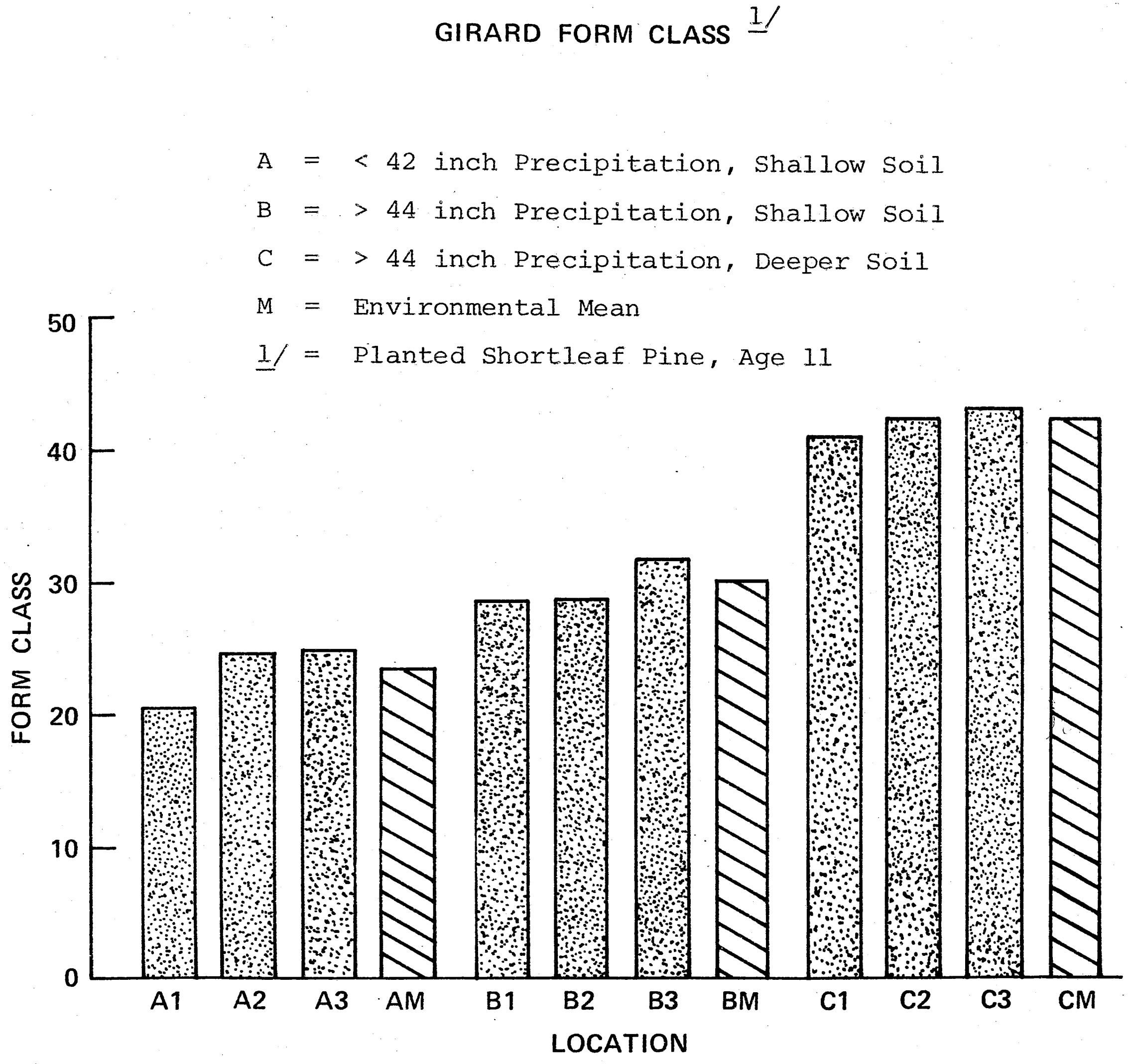


Figure 10. Girard Form Class Histogram, by Location and Environment Means.

tall enough for the 17 feet 3 inch diameters to be taken. Girard Form class is normally not determined for trees of this size; however, the difference in form class by environments is still valid as they are relative one to another.

The higher form classes on the better sites indicate a longer merchantable stem in contrast to the lower form classes on poorer sites, where the dominant and co-dominant trees barely will make the one log. These comparisons show that shortleaf pine form class does improve with the better site; i.e., form class 22 for poor soil and 42 inch rainfall, 30 for poor soil and 44 inch rainfall and 41.5 for better soil and 44 inch rainfall.

Data suggest that only differences in planted pine height and Girard form class appear meaningful and related to replication x environment x location x fencing interaction. The factor considered to substantially affect the mean of these two parameters is environment: (a) effect of rainfall zone and (b) effect of soil (depth of A horizon and percent rock content).

CHAPTER V

SUMMARY AND CONCLUSIONS

The findings of this study indicate: (a) there is a strong correlation between soils and planted shortleaf pine tree response; (b) there is a correlation between rainfall and tree response in the "critical" zone of less than 42 inch rainfall and greater than 44 inch zone; (c) judicial use of soils information and plant indicators can aid in site evaluation and enhance management investment.

The fact that pine trees were available for measurements on nearly all sites which had not been damaged indicates that pine can grow on all sites examined, if the trees are planted. Trees that had been established by direct seeding were found on most sites, but not enough were found in the designated sample area to effectively evaluate them. On the post oak-blackjack oak sites with low rainfall, the establishment of pine by direct seeding would be somewhat risky. A rainfall pattern sufficient to establish pine in the normally less than 42 inch precipitation zone occurs about once every three years. Even if seeding was carried out in a favorable year, the danger of drought within the next five years or so is high. Mortality due to low rainfall distribution may be extreme. When costs for direct seeding for three consecutive years, including carrying cost, are considered, it would probably be more economical than hand planting in the stony soil.

If pine occurs naturally, it could be used as a seeding source, and aerial spraying of the hardwoods to improve the seeding chance would be feasible; cost for such site treatment would also be relatively low. The seed source would be there when a good year of precipitation occurred, and would also be there to reseed areas lost to drought. Naturally occurring pines have limited distribution in the area of less than 42 inch rainfall and a seed tree or shelterwood regeneration plan may be limited to areas regenerated to pine previously. Efforts to find a marketable use for low quality hardwood on these sites is being exerted by Drs. Tom Hennessey and Greg Jones of Oklahoma State University Forestry Department. Reduction of associate hardwood competition is necessary to reporduce the intolerant pine. Such hardwood reduction would increase the "net effective moisture" available to pine and enhance their survival and growth. Any reduction in conversion cost, such as sale of hardwoods, would certainly enhance the forestry management potential.

Management of pine in areas of low rainfall (less than 42 inches) and limited soils is further restricted by the growth characteristics of the pine grown on the sites. The form class (Figure 10) of pine on post oak-blackjack oak-hickory sites is low compared to better sites, indicating the bole length will probably not be sufficient to get much sawtimber per acre. The logs would have extreme taper and low quality because of frequency and size of limbs along the upper bole. The carrying cost for a sawlog rotation would probably be prohibitive.

A pulpwood rotation should be more promising for the poorer quality sites. The diameter breast height and volume per tree of "solid wood" on young trees on such sites compares favorably even with the better sites with higher rainfall. The better sites, however, should soon begin showing considerably more volume per tree and per acre, due to their height and form-class advantage. The shorter pulpwood rotation could make maximum use of the diameter growth since volume of "solid wood" is the main management objective and bole quality is not a critical item because solid wood is converted into chips. The second rotation might also be more lucrative if management alternatives such as shelterwood or seed tree systems were used to regenerate the pine. These systems usually require less investment to control associate hardwood competition and provide the open seedbed demanded by pine. Lower total interest charges on management treatment costs would also be in harmony with the low growth and pine form potential of poorer sites.

The poor soils within the higher rainfall zone show limited mortality due to drought. The form class is somewhat better than on the poor soils with low rainfall. The length of merchantable stem would still be somewhat limiting when we compare it with nearby sites with deeper soils.

The land manager responsible for poor sites and good sites within the 44 inch rainfall zone may want to produce both sawlogs and pulp. Data suggest he could manage the deeper soils mainly for sawlogs. The shallow soils could be concentrated in pulp or veneer core stock, with sawlogs occurring in limited quantities.

While the above are possible management opportunities available to the land manager, he must be able to evaluate the various sites within a given rainfall pattern to determine his management chances. Table III shows the main environmental factors and their relative impact on shortleaf pine height and Girard form class and inferred land class and management potential. The mean depth of the A horizons on the poor sites in the 44 inch precipitation zone was 10.8 inches where post oak, blackjack oak and hickory occurred naturally. On better sites where post oak, blackjack oak, hickory and red oak occurred naturally, the mean depth of the A horizons was 12.2 inches. The average percentage rock by weight found in A horizons was 60 percent for the poor sites and 18.9 percent on the better sites (Table III).

Of the two soil characteristics, depth of A horizons and the percentage rock, the percentage rock is probably easier for the inexperienced soil examiner to evaluate. While only 1.4 inch difference in depth of A horizon might make a difference in tree response, how does he determine any real site differences between 10.8 and 12.2 inches? Does the greater A horizon thickness lie above the poor rocky soil or lie over a good, less-rocky soil? Does he manage for sawtimber and risk not getting it or settle for a pulp rotation and possibly lose growth the site is capable of producing? The percentage of rock is perhaps a better clue. Many soils with an average of 60 percent rock in the A_1-A_2 horizons looked as if the only soil was caught between rock fragments. Rock fragments were also prominent on the soil surface. The sites with 50 percent or more rock by weight would certainly be easily evaluated. The percentage rock also provides a cross reference to expected A horizon depth. When either the depth of A horizons or percentage rock is marginal between the two sites, the other factor should be looked at more closely.

The native plant association, in acting in response to soil condition, may confirm or cause doubt about the evaluation reached.

Ideally, red oak would be found on the better sites. If the site has been cut over, heavily burned, or shows other signs of significant disturbance the final evaluation often has to be based on soil examinations. Even on the most disturbed site hardwood resprout growth, however small, may indicate plant association and site quality before disturbance.

The correlation between rainfall pattern, soils and tree growth response should aid in: (a) soil-site evaluation; (b) land manangement class identification; (c) fair and equitable land tax determination and assessment; (d) long-range planning for future timber needs, especially the part that the Cross Timbers area is expected to contribute; and (e) confirmation of plant indicators as reliable, responsive tools in site evaluation.

Further work is called for on this project to get the actual tree volumes and quality of usable stem to better project the volume per acre and the return that could be expected for a given harvest period or rotation. While a projection of data beyond age 11 gives an expected yield for a longer rotation, this is by no means an actual reflection of what will really happen. Additional study could also be used to point out adjustments that need to be made in future projections or perhaps suggest another approach. It is desirable to evaluate any given stand as soon as possible for economic reasons but an actual check on the projections made would be beneficial.

Pine needles from various sites were collected and analyzed by the flame spectrophotometer technique (18) to determine major cation content. This had been suggested by needle color differences from site to site. Iron was one element that showed marked differences from site to site, having the greatest number of parts per million in pine needles obtained from the poorer quality sites. Perhaps meaningful needle color differences could be ranked by use of a Munsel color chart which assigns numbers to hue value and chroma. Key index colors might be used to segregate sub-marginal and marginal land management classes from more favorable sites. Off-color needles have always suggested some sort of tension in tree growth but this could be of more use if a systematic study was made to assign and correlate values that could be consistantly duplicated.

There exists the possibility of using satellite photographs to identify management potential. This would have greatest application on areas established in pine, as color differences due to thrift would be expected. The cost would be low enough to justify periodic evaluations to show results of a drought, hunt for insect infestations or just to see the biotic response to management practices in any given area.

In summary, the eleventh-year status of pine and soils evaluations in two climatic zones suggest the following: (a) both pine height and form-class appear directly related to depth of surficial soil horizons above compact sub-soils and/or percent of rock material in the upper solum; (b) native plant associations have considerable value for predicting both height and form-class development of pine on certain land classes; (c) even the poorest sites tested appear biologically suited to pine establishment; however, development assays suggest only sites supporting a native association of post oak-blackjack oak-hickory or better on Carnasaw or similar soils may be economically feasible to convert to pine managed on short rotations; (d) direct-seeding appears the best means to afforest pine on extremely rocky sites unsuited to machine, or even hand-planting; and (e) native plant associations indicate an allowable and equitable base for land tax assessment, based on land productivity potential.

With the increasing pressure for the forest land manager to more effectively manage his decreasing land base, the need for more effective site evaluation will continue to increase. Any information that aids in this quest should be sought.

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APPENDIXES

TABLE IV

SOIL PROFILE DATA, KIOWA, OKLAHOMA--POE, REP. I-OPEN, PLOT E
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Sandstone and Shale

SOIL CLASSIFICATION: Fine over loamy, mixed, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-3	10 YR 4/3	5.8	Sandy loam	60.81	35.74	3.44	51.46
A2	3-6	10 YR 6/3	5.3	Sandy loam (field class)	M	M	M	M
$B21_t$	6-13	5 YR 5/4		Silty clay (field class)	M	M	M	16.59
$B22_t$	13-20	5 YR 5/4	5.8	Silt loam	23.56	53.74	22.70	M

M = Missing Information

TABLE V

SOIL PROFILE DATA, KIOWA, OKLAHOMA--POE, REP. I-OPEN, PLOT J-1
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Gray Shale

SOIL CLASSIFICATION: Fine, mixed, thermic Albaquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-5	10 YR 3/1	6.0	Sandy loam	48.93	47.31	3.76	M
A2	5-9	10 YR 6/3	5.0	Sandy loam (field class)	M	M	M	M
$B21_t$	9-15	2.5 Y 4/6	4.8	Clay	25.63	25.86	48.51	M
$B22_t$	15-26	2.5 Y 4/4	6.0	Clay	15.67	28.20	56.12	M
B3	26-40	5 Y 4/2	7.0	Clay (field)	M	M	M	M

M = Missing Information

TABLE VI

SOIL PROFILE DATA, KIOWA, OKLAHOMA--POE, REP. I-OPEN, PLOT J-2
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Grey Shale

SOIL CLASSIFICATION: Fine, mixed, thermic, Albaquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 3/1	5.7	Sandy loam	56.57	32.86	10.57	14.00
A2	4-8	10 YR 6/3	5.1	Loam	50.62	39.72	9.66	8.21
$B21_t$	8-20	2.5 Y 4/6	5.4	Clay	28.32	29.65	42.04	7.65
$B22_t$	20-30	2.5 Y 4/4	5.4	Clay	19.35	34.90	45.75	3.61
B3	30-44	5 Y 4/2	6.7	Clay	18.58	21.95	59.47	.59

TABLE VII

SOIL PROFILE DATA, KIOWA, OKLAHOMA--POE, REP. I-FENCED, PLOT E
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Shale

SOIL CLASSIFICATION: Fine, mixed, thermic Aquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION % SAND	SILT	CLAY	ROCK %
A	0-4	10 YR 3/1	6.5	Sandy loam	64.65	27.74	7.61	12.51
$B2_t$	4-14	10 YR 6/6	5.5	Loam	44.62	28.45	26.93	3.62
B3	14-23	5 Y 5/2	5.6	Loam	31.05	42.94	26.01	1.78
C	23-38	5 Y 4/2	M	Soft Shale (field class)	M	M	M	M

M = Missing Information

TABLE VIII

SOIL PROFILE DATA, KIOWA, OKLAHOMA--POE, REP. I-FENCED, PLOT J
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Grey Shale

SOIL CLASSIFICATION: Fine, mixed, thermic Albaquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-6	10 YR 4/3	5.9	Sandy loam	64.92	30.91	4.17	7.57
A2	6-15	10 YR 6/4	5.7	Sandy loam	61.75	28.04	10.21	8.50
$B21_t$	15-23	2.5 YR 4/6	5.1	Clay	30.52	27.92	41.56	8.15
$B22_t$	23-31	10 YR 5/6	5.8	Silt loam	18.50	62.49	19.01	1.57
C	31-42	5 Y 4/2	M	Soft grey shale (field class)	M	M	M	M

M = Missing Information

TABLE IX

SOIL PROFILE DATA, BLOCKER, OKLAHOMA--STANFIELD, REP. I-FENCED, PLOT E
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Hard Sandstone

SOIL CLASSIFICATION: Clayey-skeletal, mixed, thermic Aquic Hapludults
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-2	10 YR 4/2	6.7	Sandy loam	68.61	27.99	3.40	19.23
A2	2-23	10 YR 6/4	5.9	Sandy loam	70.65	23.21	6.14	67.66
$B21_t$	23-33	2.5 YR 4/6	4.8	Clay loam	39.32	27.07	33.60	29.27
$B22_t$	33-47	10 YR 4/6	4.7	Clay	16.16	38.83	45.01	40.88

TABLE X

SOIL PROFILE DATA, BLOCKER, OKLAHOMA--STANFIELD, REP. I-FENCED, PLOT J
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Sandstone and Grey Shale

SOIL CLASSIFICATION: Clayey-skeletal, mixed, thermic Aquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION % SAND	SILT	CLAY	ROCK %
A1	0-4	10 YR 3/2	6.7	Sandy loam	69.07	27.49	3.44	51.92
A2	4-17	10 YR 6/4	5.4	Sandy loam	52.81	38.54	8.65	56.36
$B2_t$	17-33	2.5 YR 4/6	5.2	Clay	9.00	26.13	64.87	60.70

TABLE XI

SOIL PROFILE DATA, BLOCKER, OKLAHOMA--STANFIELD, REP. II-FENCED, PLOT J
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Sandstone and Grey Shale

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, thermic Aquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 4/3	5.5	Sandy loam	61.80	33.20	5.00	53.30
A2	4-13	10 YR 6/4	6.1	Sandy loam	54.27	41.16	4.57	75.99
$B21_t$	13-33	2.5 YR 4/6	4.8	Loam	46.12	40.63	13.24	54.79
$B22_t$	33-40	2.5 YR 4/6	5.7	Loam	44.93	39.19	15.88	5.14

TABLE XII

SOIL PROFILE DATA, MCALESTER, OKLAHOMA--GABARINO, REP. I-FENCED, PLOT E
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Sandstone

SOIL CLASSIFICATION: Fine, mixed, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION % SAND	SILT	CLAY	ROCK %
A1	0-4	10 YR 3/2	6.1	Sandy loam	55.70	36.70	7.60	4.88
$B21_t$	4-20	2.5 YR 3/6	5.3	Clay	21.34	25.38	53.27	1.60
$B22_t$	20-40	2.5 YR 3/6	5.3	Clay loam	31.12	41.89	27.00	1.20

TABLE XIII

SOIL PROFILE DATA, MCALESTER, OKLAHOMA--GABARINO, REP. I-FENCED, PLOT J
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Sandstone

SOIL CLASSIFICATION: Fine, mixed, thermic Albaquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-2	10 YR 3/2	6.1	Sandy loam	61.19	37.21	1.60	8.48
A2	2-6	10 YR 6/3	6.2	Loam	47.07	42.70	10.23	13.01
$B21_t$	6-36	2.5 YR 4/6	4.4	Loam	47.66	36.71	15.64	2.17
$B22_t$	36-54	2.5 YR 4/6	5.8	Sandy clay loam	51.09	24.93	23.98	1.44

TABLE XIV

SOIL PROFILE DATA, MCALESTER, OKLAHOMA--GABARINO, REP. II-FENCED, PLOT J
(GROUP 1)

COUNTY: Pittsburg
UNDERLYING BEDROCK: Sandstone

SOIL CLASSIFICATION: Fine over loamy, mixed, thermic Aquic Hapludults
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-5	10 YR 3/2	6.4	Sandy loam	61.84	35.65	2.51	19.90
B1	5-13	10 YR 4/3	5.2	Sandy loam	56.21	30.66	13.13	25.11
$B21_t$	13-25	5 YR 5/4	4.6	Clay loam	24.19	39.41	36.40	5.99
$B22_t$	25+	2.5 YR 4/6	4.7	Clay loam	22.50	38.22	39.28	6.38

TABLE XV

SOIL PROFILE DATA, ANTLERS, OKLAHOMA--STONE, REP. I-FENCED, PLOT J
(GROUP 2)

COUNTY: Pushmataha
UNDERLYING BEDROCK: Hard Sandstone

SOIL CLASSIFICATION: Clayey-skeletal, mixed thermic Albaquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-3	10 YR 4/2	6.1	Sandy loam	60.33	36.82	2.84	84.41
A2	3-11	10 YR 6/4	6.2	Sandy loam	67.40	25.76	6.83	87.64
$B21_t$	11-29	2.5 YR 4/6 w/7.5 YR 5/6 mottles	5.5	Clay	19.82	38.70	41.48	M
$B22_t$	29-46	5 Y 5/2 (mottles)	5.4	Silty clay	14.40	41.86	43.74	51.34

M = Missing Information

TABLE XVI

SOIL PROFILE DATA, ANTLERS, OKLAHOMA--STONE, REP. II-FENCED, PLOT E
(GROUP 2)

COUNTY: Pushmataha
UNDERLYING BEDROCK: Hard Sandstone

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, thermic Aquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 4/2	5.1	Loamy sand	75.55	23.33	1.12	55.32
A2	4-13	10 YR 6/4	5.8	Sandy loam	67.49	27.92	4.59	59.10
$B21_t$	13-28	2.5 YR 4/6 (mottles)	4.6	Clay loam	37.09	35.26	27.65	43.33
$B22_t$	28-38	2.5 YR 4/6 (mottles)	4.6	Clay	11.26	27.48	61.26	44.29

TABLE XVII

SOIL PROFILE DATA, ANTLERS, OKLAHOMA--STONE, REP. II-FENCED, PLOT J
(GROUP 2)

COUNTY: Pushmataha
UNDERLYING BEDROCK: Hard Sandstone

SOIL CLASSIFICATION: Clayey-skeletal, mixed, thermic Albaquultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 4/2	5.5	Sandy loam	71.70	21.62	6.68	71.12
A2	4-12	10 YR 6/4	5.5	Sandy loam	73.52	19.69	6.79	73.91
$B21_t$	12-24	2.5 YR 4/6	5.3	Clay	24.53	20.75	54.72	47.49
$B22_t$	24-40	2.5 YR 4/6	4.9	Loamy	43.15	31.07	25.78	8.43

TABLE XVIII

SOIL PROFILE DATA, LITTLE RIVER, REP. II-FENCED, PLOT J
(GROUP 2)

COUNTY: McCurtain
UNDERLYING BEDROCK: Sandstone

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-5	10 YR 4/2	6.6	Sandy loam	62.31	33.20	4.49	45.90
A2	5-12	10 YR 5/4	6.8	Sandy loam	65.62	31.32	3.06	73.81
B1	12-18	7.5 YR 5/6	5.7	Sandy loam	54.88	33.68	11.44	27.64
$B2_t$	18-30	5 YR 5/8	5.3	Loam	47.31	33.42	19.27	71.66

TABLE XIX

SOIL PROFILE DATA, LITTLE RIVER, REP. II-FENCED, PLOT E
(GROUP 2)

COUNTY: McCurtain
UNDERLYING BEDROCK: Sandstone

SOIL CLASSIFICATION: Coarse-loamy, siliceous, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-5	10 YR 4/2	6.3	Sandy loam	61.23	34.73	4.03	47.98
A2	5-14		6.1	Sandy loam	59.00	38.19	2.81	53.30
B1	14-23		6.5	Sandy loam	59.96	28.87	11.17	21.58
$B2_t$	23-34		5.5	Sandy loam	56.60	30.88	12.52	12.13

TABLE XX

SOIL PROFILE DATA, MERRY CROSS ROADS, REP. I-FENCED, PLOT E
(GROUP 2)

COUNTY: McCurtain
UNDERLYING BEDROCK: Hard, Thin Shale

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, mixed, thermic Lithic Dystrochrepts
SOIL SERIES: Pickens

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION % SAND	SILT	CLAY	ROCK %
A1	0-4	10 YR 3/2	6.3	Sandy loam	65.13	32.50	2.37	43.49
A2	4-9	10 YR 4/3	5.4	Sandy loam	61.70	31.97	6.33	40.64
B2	9-15	7.5 YR 5/6	5.6	Loam	39.12	46.83	14.05	23.32

TABLE XXI

SOIL PROFILE DATA, MERRY CROSS ROADS, REP. I-FENCED, PLOT J
(GROUP 2)

COUNTY: McCurtain
UNDERLYING BEDROCK: Hard, Thin Shale

SOIL CLASSIFICATION: Loamy-skeletal, mixed, siliceous, thermic Lithic Dystrochrepts
SOIL SERIES: Pickens

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 3/2	5.9	Sandy loam	48.14	45.65	6.22	50.15
A2	4-9	10 YR 4/3	5.6	Sandy loam	47.76	47.23	5.02	46.93
B2	9-20	5 YR 5/8	5.4	Silt loam	30.19	54.33	15.48	10.95
R/C	20-28	M	5.0	Clay loam (C)	36.96	34.45	28.59	88.33

M = Missing Information

TABLE XXII

SOIL PROFILE DATA, MERRY CROSS ROADS, REP. II-FENCED, PLOT J
(GROUP 2)

COUNTY: McCurtain
UNDERLYING BEDROCK: Hard, Thin Shale

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, mixed, thermic Lithic Dystrochrepts
SOIL SERIES: Pickens

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-3	10 YR 3/2	6.2	Sandy loam	58.69	36.43	4.88	35.93
A2	3-6	10 YR 4/3	6.1	Silt loam	42.13	51.54	6.33	64.42
B2	3-13	7.5 YR 5/6	5.8	Loam	46.97	39.29	13.74	75.31

TABLE XXIII

SOIL PROFILE DATA, JONES RANCH ROAD, REP. I-FENCED, PLOT E
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Shale and Limestone ?

SOIL CLASSIFICATION: Fine, mixed thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-6	10 YR 3/2	6.0	Sandy loam	58.32	35.65	6.03	5.16
A2	6-15	10 YR 5/4	5.9	Sandy loam	59.29	34.08	6.63	.92
$B21_t$	15-22	Red	5.5	Clay loam	42.93	28.02	29.05	.55
$B22_t$	22-32	Red	5.1	Sandy loam	53.75	27.54	18.71	1.04
$B23_t$	32-48	Red and Brown	5.2	Sandy clay loam	68.35	27.66	4.00	1.39

TABLE XXIV

SOIL PROFILE DATA, JONES RANCH ROAD, REP. I-FENCED, PLOT J
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Shale and Limestone ?

SOIL CLASSIFICATION: Fine-loamy, siliceous, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 4/2	5.9	Sandy loam	59.84	34.69	5.47	8.85
A2	4-15	7.5 YR 5/6	5.8	Sandy loam	59.86	33.21	6.92	11.65
$B21_t$	15-24	Yellow-Red	5.7	Loam	49.21	34.13	16.65	5.80
$B22_t$	24-36	Red	5.2	Loam	40.11	37.52	22.37	1.26
$B3_t$	36-46	Red and Brown	5.2	Loam	36.14	38.72	25.14	37.44

TABLE XXV

SOIL PROFILE DATA, JONES RANCH ROAD, REP. II-FENCED, PLOT J
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Shale and Limestone?

SOIL CLASSIFICATION: Fine-loamy siliceous, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 4/2	6.3	Sandy loam	55.32	41.35	3.33	5.88
A2	4-11	10 YR 5/3	6.2	Sandy loam	55.52	37.09	7.38	6.38
$B21_t$	11-17	7.5 YR 5/6	5.9	Loam	49.40	39.19	11.32	8.28
$B22_t$	17-34	Yellow-Red	5.6	Loam	47.86	31.39	20.75	21.20
$B3_t$	34-42	YR & R	5.2	Sandy loam	60.74	32.53	6.73	24.81
C	42-55		5.4	Sandy loam	66.26	26.96	6.78	57.83

TABLE XXVI

SOIL PROFILE DATA, ASHLEY CCC ROAD, REP. I-FENCED, PLOT E
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Shale and Sandstone

SOIL CLASSIFICATION: Fine-loamy, siliceous, thermic Typic Hapludults
SOIL SERIES: Sherwood

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 5/2	6.0	Sandy loam	65.03	28.04	6.88	33.74
A2	4-15	10 YR 5/4	6.0	Sandy loam	64.91	25.78	9.31	24.37
$B21_t$	15-22	10 YR 5/6	5.8	Sandy loam	59.08	28.44	12.48	18.68
$B22_t$	22-32	Y, R, & B	5.6	Sandy clay loam	52.98	26.91	20.11	19.50
C	32-40	M	5.6	Soft Shale	57.16	23.99	18.85	10.44

M = Missing Information

TABLE XXVII

SOIL PROFILE DATA, ASHLEY CCC ROAD, REP. I-FENCED, PLOT J
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Shale and Sandstone

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, thermic Typic Hapludults
SOIL SERIES: Zafra

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 4/2	6.3	Sandy loam	62.30	33.66	4.05	10.57
A2	4-10	10 YR 5/4	5.8	Sandy loam	57.45	33.23	9.32	33.04
$B21_t$	10-17	7.5 YR 5/6	5.3	Loam	47.10	34.52	18.38	9.31
$B22_t$	17-31	5 YR 5/6	5.7	Sandy loam	61.32	24.74	13.93	54.83
$B3_t$	31-40	M		Sandy loam				
C	40-46	Alternating shale and sandstone layers			69.88	14.20	15.92	24.11

M = Missing Information

TABLE XXVIII

SOIL PROFILE DATA, ASHLEY CCC ROAD, REP. II-FENCED, PLOT J
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Shale and Sandstone

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, thermic Typic Hapludults
SOIL SERIES: Zafra

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-6	10 YR 4/2	5.7	Sandy loam	64.16	29.74	6.10	28.44
A2	6-14	10 YR 5/6	5.5	Sandy loam	58.66	31.80	9.54	26.26
$B2_t$	14-22	7.5 YR 5/6	6.3	Sandy loam	59.26	25.18	15.55	M
$B3_t$	22-36	5 YR 5/6	5.5	Sandy loam	52.23	31.53	16.24	37.63
C	36-45	Soft red, yellow-brown shale laminated with soft sandstone		Sandy loam (layers)	64.66	17.98	17.36	52.81

M = Missing Information

TABLE XXIX

SOIL PROFILE DATA, BILLY BELL, REP. I-FENCED, PLOT J
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Shale

SOIL CLASSIFICATION: Fine-loamy, siliceous, thermic Typic Hapludults
SOIL SERIES: Sherwood

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 3/2	7.0	Sandy loam	51.61	42.04	6.34	9.29
A2	4-10	10 YR 5/4	6.7	Sandy loam	46.93	47.02	6.05	19.56
$B21_t$	10-14		6.0	Loam	31.32	47.32	21.36	10.91
$B22_t$	14-28		6.0	Loam	46.32	40.09	13.59	20.73
$B3_t$	28-42	5 YR 4/8	5.5	Loam	49.06	38.30	12.64	23.66
C/R	42 +		5.7	Fractured, laminated shale	53.48	35.23	11.29	34.00

TABLE XXX

SOIL PROFILE DATA, BILLY BELL, REP. II-FENCED, PLOT E
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Soft and Hard Sandstone

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-5	10 YR 3/2	6.9	Sandy loam	61.88	34.51	3.61	8.18
A2	5-12	10 YR 5/4	6.7	Sandy loam	65.35	29.28	5.37	43.81
B1	12-18	10 YR 5/8	6.5	Sandy loam	66.22	24.74	9.05	56.69
$B2_t$	18-26	7.5 YR 6/6	6.2	Sandy loam	59.15	28.14	12.71	51.09
B3	26-32	5 YR	6.3	Loamy sand	78.45	14.58	6.97	M

M = Missing Information

TABLE XXXI

SOIL PROFILE DATA, BILLY BELL, REP. II-FENCED, PLOT J
(GROUP 3)

COUNTY: McCurtain
UNDERLYING BEDROCK: Soft and Hard Sandstone

SOIL CLASSIFICATION: Loamy-skeletal, siliceous, thermic Ultic Hapludalfs
SOIL SERIES: None

HORIZON (FIELD CLASS)	(INCHES)	COLOR	pH	TEXTURE-HYDROMETER TEST	PARTICLE SIZE DISTRIBUTION %			ROCK %
					SAND	SILT	CLAY	
A1	0-4	10 YR 3/2	6.8	Loamy sand	73.56	25.95	.49	1.26
A2	4-10	10 YR 5/4	6.7	Loamy sand	74.89	23.56	1.55	53.85
B1	10-15	7.5 YR 5/6	6.5	Sandy loam	65.75	25.81	8.44	48.70
$B2_t$	15-26	5 YR 5/8	6.4	Sandy loam	64.66	27.03	8.31	22.26
B3	26-31	YR	6.0	Sandy loam	72.45	20.27	7.29	26.97

VITA - 2

William Connie Mullen

Candidate for the Degree of

Master of Science

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Professional Experience: Grew up on a farm and worked for a feed store during two summers. Served six months active duty at Fort Jackson, South Carolina, with the Oklahoma National Guard. Worked two summers for Ozark National Forest as forestry aide and one summer on the Ochocco National Forest, Pineville, Oregon, as fire control guard. Worked one year for Southern Pine Association; worked six years for Strat-O-Span Buildings, Inc. as manager of Eastern (Pennsylvania) Division; served as graduate research assistant and as teaching assistant, Department of Forestry, Oklahoma State University.

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