SPECIES COMPOSITION AND SPATIAL DISTRIBUTION OF VEGETATIVE COMMUNITIES ON THE COOKSON HILLS STATE GAME REFUGE

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PREFACE

This study examines the species composition of plant communities on the Cookson Hills State Game Refuge, and the relationships of the plant communities to geology, soils, and topography. The primary objective is to evaluate the usefulness of geological strata, soil series, and topography for predicting the occurrence of plant community types and the relative abundance and performance of plant species. A polyclimax model is assumed, and Jenny's (1941) model for a soil is modified to serve as a model to predict the occurrence of plant community types.

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CHAPTER I

INTRODUCTION

The white-tailed deer (Odocoileus virginianus) is a major wildlife resource in Oklahoma both historically and presently. Duck and Fletcher (1944) reported a substantial trade in deer hides occurring in Oklahoma in the mid 19th century. Deer were important to the pioneers for subsistence and as a source of income from sales of meat and hides. By the early 1900's the formerly abundant deer herds in Oklahoma were exterminated by the early settlers. Protection by complete closure of deer hunting seasons, establishment of a national game reserve in the Wichita National Forest (now called the Wichita Mountains National Wildlife Refuge), and creation of a state game refuge in McCurtain County helped remnant deer herds in Oklahoma increase in number. A system of game refuges was established in eastern Oklahoma in the 1940's by the Oklahoma Game and Fish Commission. A trapping and transplanting program helped restore the herds, and deer are now sufficiently abundant to support an annual hunting season (Aldrich 1953, Curtis 1952, Duck and Fletcher 1944, Wint 1951). Deer hunting in Oklahoma resumed with a 5-day, bucks-only season in seven counties in 1933; in 1954 the deer season was opened state wide. In 1933 deer license sales earned $4,760 for the Oklahoma Game and Fish Commission, and 3,922 hunters bagged 235 deer. In 1957 deer license sales were $77,934.25, and 20,027 hunters bagged 1,291 deer (Curtis n.d.). Bond (1957) estimated that deer hunters in Oklahoma spent over $1.2 million for all expenses in that year. Total income from sale of deer licenses in Oklahoma from 1933 to 1967 was $2,509,198.25 (Curtis n.d.). In 1971 deer license sales earned $473,075 for the Oklahoma Department of Wildlife Conservation and 90,515 hunters bagged 7,025 deer (Oklahoma Department of Wildlife Conservation 1972). Oklahoma's deer herd has become an important recreational and economic resource. Deer management is of considerable interest socially, economically, and, because authority to regulate deer seasons resides in the legislature, politically.

Maximum harvest from a deer herd can be sustained when deer numbers are maintained at or slightly under the carrying capacity of their range and age structure of the herd is adjusted so that the maximum number of fawns survive to balance losses of adults to hunting and nonhunting mortality. Manipulation of hunting regulations and habitat improvement are the techniques most commonly used to manage deer herds. Population trends of deer herds and relationships of deer density to carrying capacity are the biological bases for management recommendations. Except for experimental anterless deer hunts in 1971, 1972, 1973, and 1974, Oklahoma has customarily opened deer hunting for bucks only as a management practice to increase deer numbers in the state.

Density of deer numbers is difficult to determine; estimates are made by censusing. Population trends can be estimated from censusing deer and key plants that indicate degree of deer use, deer-season harvest figures, and age structure in the harvested deer. Change in sex ratios from before to after deer hunting season and harvest data may also be used to estimate deer density. Data for incidence of pregnancy and fetuses per doe have generally not been available to Oklahoma deer biologists and they have had to use less direct methods to estimate natality. Magnitude of loss to nonhunting mortality from poaching, predation, accidents, and interactions of parasites, disease, and malnutrition are undetermined in Oklahoma.

The relationship of deer numbers to the carrying capacity of the range may be estimated indirectly by studies of the condition of deer and their range. Stout (1973) used level of parasitism and amount of kidney fat as indices of condition of Oklahoma deer. There is little information in the literature about Oklahoma's deer range. Objective information about food habits and the quantity and quality of forage are needed to help determine condition and carrying capacity of deer ranges in Oklahoma. A method that is accurate, economical, and rapidly performed for describing, analyzing, and correlating elements of deer range is needed.

Studies of the distribution, habits, and movements of a deer population are more meaningful when correlated with characteristics of the habitat. Composition and distribution of food and cover are often the most important attributes of the habitat. Quantity and quality of browse influence the health and numbers of a deer herd. Seasonal distribution and availability of browse and cover, as well as seasonal variation in nutritional quality of food plants, influence both seasonal distribution and daily movements of deer.

Species composition, age class, shape or life form, and density of vegetation influence the abundance and availability of deer food and cover in a plant community. The amount of food and cover can vary greatly between community types. If community types can be correlated with such factors as soil series, available moisture, soil nutrients, position in relation to slope grade and aspect, and land use history, then management units can be more easily and precisely defined. Higher correlations between plant species and environmental factors can provide more detailed elucidation of plant-environment relationships. Clearer understanding of these relationships will permit more accurate prediction of the effect of management techniques designed to increase deer food or cover in a specific management unit. Management techniques can be tailored to meet specific needs and applied where they will most probably produce the desired results. By applying management techniques to increase food or cover where deficient, the carrying capacity of deer range can be increased.

Regional resource development and planning bodies need adequate information to make land-use decisions. The natural resources of the Ozark Highlands and their bordering region in northeast Oklahoma are primarily water, timber, fish and wildlife, gravel deposits, limestone, and scenic beauty. Industry is virtually absent because of a shortage of natural resources, capital, and adequate transportation. Much of the timber was exploited in the past, and the present resource is mostly unmanaged. Agricultural and grazing operations are often marginal or submarginal because soils are low in productivity and land holdings are in small uneconomical units.

The Department of Forestry at Oklahoma State University prepared a proposal in reference to a timber conversion research project for the Oklahoma Ozarks region in 1968. This proposal was in response to a request from the Resource Conservation and Development Committee of Adair, Cherokee, and Delaware Counties for assistance in making land-use decisions concerning conversion of certain forest types to grass or other crops (T. Silker, personal communication). This proposal presented assumptions and predictions based on data then available, and it proposed additional research and field evaluations. The findings of this study are applicable to such decision-making processes.

The forests of the Oklahoma Ozarks yield water, timber, wildlife, and recreation. Forest management research in this region is limited. Studies are needed to define land classes and their preferred and alternate resource-management options. Soils and forest types need to be identified and their potentiality for the following management systems determined: (1) hardwoods that may be managed for sustained yield and integrated use of timber production, watershed protection, wildlife production, and recreation; (2) conversion to pine or pine-hardwood with management objectives similar to those in (1) above; (3) conversion to grass; or (4) retain unmanaged native cover for watershed protection, wildlife production, and recreational use.

The economics of conversion to better commercial timber depends on cost of conversion, growth rate during rotation, and value of the crop at harvest. The Oklahoma Ozarks cannot equal the southern forest region in timber production, neither can this region economically match other areas having better soils in crop or pasture production. Even the better sites may be marginal for moderate investments in timber production. If other incomes can be generated to supplement timber production without reducing tree growth, capital value might increase considerably (T. Silker, personal communication). Recreational activity on these lands is a potential income-producing use. Tours to view spring flowers and fall leaf colors are conducted annually in the region. Tourism and camping activities are increasing, and leasing of areas for deer hunting is a growing source of income for landowners in this region.

Determination of the interrelationships of soils, slope grade, slope aspect, land use, fire, and type of vegetation can provide useful criteria for land classification and land-use decision making. Soils, grade and aspect of slope, and fire influence growth and vigor of plants. Varied responses of different plant species to a given set of environmental conditions influence the assemblages of plants present on a site at different stages of succession or between sites at equivalent successional stages. Different agricultural, grazing, or forestry practices modify the kind and degree of vegetative response to a site. Determining the influence of and interactions between these environmental factors will permit predictions of plant assemblages and species responses on a site. This information can be used to choose between alternative land uses and alternative management techniques for achieving the objectives.

The lone star tick (*Amblyomma americanum*) is abundant in the Ozark Ozarks and it is a serious biological and economic pest. This parasite is a disease vector for man, domestic animals, and wildlife. Bites of this tick are painful and annoying. Its presence causes economic loss by discouraging tourism and outdoor recreation activity and by reducing livestock gains. Bolte et al. (1970) reported fawn mortality rates up to 57 percent attributed to the lone star tick.

The tick is commonly found in wooded areas. Hair and Howell (1970: 4) state that:

> Environmental factors such as temperature, humidity, amount of overstory or understory vegetation, soil cover or humus, and the existence of large animal populations are important in

> tick survival and abundance. A definite correlation between host utilization of specific plant communities and tick abundance seems to exist.

There is correlation between different plant-community types and the survival and abundance of different developmental stages of the tick (Ragland and Lancaster 1971, Semter 1972). There also seems to be a tick-deer-vegetation interaction. Correlation between plant communities and physical and chemical factors of the environment and study of their use by deer can help give better insight to such a parasite-host-habitat interaction. Better understanding of these relationships can help in the selection of more effective control measures for the tick.

Correlations of vegetation with environmental variables can prove useful to soil scientists, foresters, geologists, and engineers. The occurrence, relative density, and vigor of plant species can serve as indicators of texture, available moisture, base saturation, or other soil variables. These soil characteristics can be clues to the nature of the parent material of the soil. Changes in vegetation can help determine soil boundaries and provide clues to geologic structure below the soil mantle such as faults or boundaries between different kinds of rock. The presence and performance of indicator species can aid the soil scientist in interpreting the suitability of soils for growing crops, pasture, or timber, or for various engineering applications.

Soils and forests on the Cookson Hills State Game Refuge represent much of the deer habitat of northeast Oklahoma. Soil series present on the refuge occur on 77.8 percent of the land area of Adair, Cherokee, and Delaware Counties. The area has been managed as a deer refuge since the early 1950's, and vegetation is mostly second-growth hardwood timber that has not been logged or grazed after the area became a refuge. Deer numbers have peaked at high levels and deer have had some impact in localized areas on the refuge. Determination of vegetation parameters in and near these areas of heavy deer use will be useful in determining preferred elements of deer habitat in the Oklahoma Ozarks region. The Cookson Hills State Game Refuge has some soils and vegetative types that are present also on the Spavinaw Hills Refuge in Delaware County and other soils and vegetative types that are found on the Cherokee Wildlife Refuge and Camp Gruber Game Management Area in Cherokee and Muskogee Counties. The Spavinaw Hills Refuge and the Cherokee-Gruber area have no soil series or vegetative types in common.

This investigation describes and analyzes plant communities on the Cookson Hills State Game Refuge. The objectives of this study are to: (1) determine the parameters of plant communities on the Cookson Hills Refuge; (2) correlate the occurrence of plant species with selected physical and chemical variables in the environment; (3) evaluate the suitability of soil series, slope grade, slope aspect, land-use history, and fire history as criteria for predicting the occurrence of plant associations and performance of plant species; (4) select plant species for use as indicators for the response of other plant species to a given set of environmental conditions; and (5) compare several techniques for sampling and analyzing vegetation.

CHAPTER II

LITERATURE REVIEW

Basic Concepts of Plant Ecology

Ecologists have long recognized that vegetation varies in time and space (Greig-Smith 1957, Kershaw 1964, Spurr 1964). Kerner's (1863) description of the vegetation of the Danube Valley is an excellent discussion of the seral relationships of plants and of the influence geology, soils, and topography have on species occurrence. Early in the twentieth century ecologists began forming theories of plant succession and climax vegetation to account for the variation of vegetation (Whittaker 1953, Kershaw 1964). Disagreements over these theories resulted from opposing concepts about the nature of vegetation as expressed by the "complex organism" of Clements and the "individualistic" view of Gleason (Greig-Smith 1957, Kershaw 1964, McIntosh 1967).

In the monoclimax theory (Clements 1916), plant communities are regarded as super organisms in which the associated species interact beneficially to enhance their survival and thus the survival of the association. The associations are seen as distinct entities that may be classified. Clements (1916) theorized that only one type of plant association can be the climax vegetation in a region and that climate is the factor that determines which association becomes the climax. Given a sufficiently long period of time for bedrock to fully weather, and land form to become uniform over a region, a common soil will develop and climatic climax vegetation will also be uniformly present over the region.

Clements (1916) formalized successional theory by distinguishing between primary and secondary succession and by elaborating series of developmental stages through which vegetation proceeds from initially different habitat and vegetation types to culminate in a common climatic climax. Succession in the Clementian view is the death of an association and its replacement by an association that more nearly resembles the climax association. Replacement of one type by another is relatively rapid in early stages of succession and proceeds more slowly as the climax state is approached. When undisturbed by fire, logging, or other external factors, the climax state is characterized by replacement of an association, (at death), by an identical association.

An alternative to the monoclimax theory is the polyclimax theory (Kershaw 1964, Spurr 1964, Whittaker 1953). In the polyclimax theory, all stable plant communities are accepted as climaxes rather than exceptions to be defined, explained, and related to a climatic climax (Kershaw 1964, Spurr 1964).

In the individualistic concept of vegetation (Gleason 1926), assemblages of plants are seen as chance aggregations of plants able to populate a site and survive there. Vegetation is regarded as continuously variable in a continuously variable environment; associations are not recognized as distinct entities and are therefore not classifiable. Vegetation is also seen as varying continuously in time (Gleason 1926) and succession is an evolutionary process in which species are gradually replaced by other species as vegetation modifies the habitat. The climax is a relatively stable state in which vegetation fluctuates about a mean of number and kind of species and individuals.

Gleason's individualistic concept modified the polyclimax theory (Kershaw 1964, Spurr 1964) and is the forerunner of the continuum concept (McIntosh 1957). The continuum concept was developed by Cottam (1949) and by Curtis and McIntosh (1951). In the continuum concept species vary continuously in some measure of performance along an environmental gradient. Different species assume dominance at different points along the gradient (Brown and Curtis 1952). The continuum approach is not used to classify vegetation, but rather is used to illustrate the interrelationships between species as they are influenced by environmental gradients (Kershaw 1964).

An excellent summation on the current status of species associations, climax, and succession is given by McIntosh (1967). Succession is a directional change in which the initial rate of vegetational change is rapid and becomes slower as the climax state is approached (Kershaw 1964). Succession is characterized by an increase in complexity of species structure of vegetation and usually by a decrease in the association of species (Greig-Smith 1957). Odum (1971) gives a function of succession as an accumulation of biomass through excess photosynthetic fixation of energy over loss from the system by respiration. In the climax state, photosynthetic fixation of energy and loss of energy through respiration approach equilibrium. Communities tend to become more stable as the climax is approached through increasing structural and functional complexity (Odum 1971).

Environmental Factors that Influence Vegetation

Major environmental factors that influence plants are light, moisture, and temperature. Climate, as the expression of these factors, was regarded by Clements (1916) as the dominant factor in controlling vegetation. Soil and physiography also modify the three major factors (Humphrey 1962, Knight 1965, Spurr 1964). Soils vary in the amount of moisture available to plants through variation in depth and texture. Color of a soil will influence its temperature. Temperature of a soil has a direct effect on plants through influencing metabolic rates and an indirect effect by influencing the rate of evaporation of soil moisture. Physiography influences the amount of light falling on a unit area through relation of the surface of the soil to the angle of solar radiation. Slopes that face the sun receive more sunlight than slopes facing the opposite direction. Slopes receiving more light will be warmer. Slopes will lose more precipitation as runoff than will level areas; low-lying sites will receive moisture as runoff or subsoil percolation from upland sites. Other factors affecting plants include geology, soil chemistry, disturbance from fire and wind; biotic factors of competition for light, moisture, and space from other plants; and grazing or trampling by animals (Humphrey 1962, Knight 1965, Spurr 1964).

Correlation between types of vegetation and types of soil has been found by some investigators (Allred and Mitchell 1955, Anderson and Talbot 1965, Barkham and Norris, 1970, Grigal and Arneman 1970, Marchand 1973, McLean 1970, Read 1952). Soil moisture is considered to be the most important soil factor influenceing vegetation according to Patten (1963), Silker (1965), and Raynal and Bazzaz (1973). Rice (1965) in Oklahoma and Daubenmire (1970) in Washington did not find close correlation between vegetation types and types of soils. In Oklahoma, positional effects (stream bottoms) or gradual changes between soils may mask any effects from differences in the soils. Broadfoot (1969) was unable to find correlation between site index and any soil variable observable in the field for most of the tree species he examined.

Physiography has been found to be a significant factor by some workers. Cantlon (1953), Cooperrider (1962), and Dick-Péddie and Moir (1970) found that slope aspect influenced species occurrence. Elevation also influences vegetation (Borman et al. 1970, Dick-Peddie and Moir 1970, McLean 1970). Dick-Peddie and Moir (1970) also found that the steepness of slopes was a significant factor.

Read (1952) and Patten (1963) found that geology can influence species frequencies.

Fire as a disturbance factor is an important influence on vegetation (Ohman and Ream 1971). Ohman and Ream (1971) stated that the length of a post-fire interval was the deciding factor in determining community type in the Boundary Waters Canoe Area in northern Minnesota. Disturbance by forest management has been found to increase productivity of forbs and shrubs following clear-cut harvesting (Della-Bianca and Johnson 1965, Murphy and Ehrenreich 1965) and timber-stand improvement cuts (Baskett et al. 1957, Crawford 1971). Removal of the overstory reduces competition and ground-cover vegetation. Siccama et al. (1970) found that productivity of shrubs was inversely related to productivity of the overstory and that the increase was from more vigorous growth rather than from increase in numbers of shrubs.

Ozark Highlands Vegetation Studies

Greig-Smith (1957:19) lists three categories into which objectives may be classed in making quantitative estimates: (1) an estimate of the overall composition of the vegetation within certain boundaries for comparison with other areas or with the same area at another time, (2) the investigation of variation within the area, or (3) correlation of vegetative differences with differences in one or more habitat factors. A fourth category is (4) to estimate the productivity of vegetation for utilization or management purposes (Harlow and Whelen 1969).

Arend (1950) studied the relationship of fire and soils in red cedar in the Ozarks and found that fire largely confined the cedar to shallow limestone soils or rough land where fires do not burn readily. Read (1952) studied the occurrence of tree species on soils derived from four different parent materials. Dominant trees on sandstone and chert soils were different from the dominant trees on limestone and cherty limestone soils. Kucera and Martin (1957) studied the relationship of limestone soils to vegetation of the cedar glades in southwest Missouri. Steyermark (1959) estimated composition of presettlement Ozark forests in Missouri and Arkansas from Federal Land Survey records and journals of early travelers to compare them with present-day forests in the same region. Rice and Penfound (1959) studied the upland forests of Oklahoma to determine composition and variation of stands across the state and to relate differences in vegetation to changes along a climatic gradient. Risser and Rice (1971) measured diversity of tree species in Oklahoma's upland forests.

The few published papers on deer range in eastern Oklahoma and the Ozark Highlands region have been inventories of a resource (wildlife, foods, timber), studies of productivity, or studies of management techniques. Lindsey (1951) estimated composition and productivity of vegetation at eight localities in McCurtain County, Oklahoma. Carlile (1958) compared species composition and density of vegetation between three refuges and 16 areas near the refuges in northeast Oklahoma. Dunkison (1955) surveyed deer range in the Missouri Ozarks. Segelquist and Pennington (1968) surveyed productivity of browse in southeast Oklahoma. Murphy and Crawford (1970) studied composition, variation, and productivity of eight forest types in the Missouri Ozarks. Other studies have reported the effects of timber harvest (Murphy and Ehrenreich 1965, Crawford and Harrison 1971), timber stand improvement cuttings (Murphy and Ehrenreich 1965, Baskett et al. 1957, Crawford 1971) and wildlife food plantings (Segelquist 1974).

Vegetative Study Methods

Criteria that may be used quantitatively to estimate vegetation are (1) floristic composition, (2) abundance of species, (3) performance or productivity of species, (4) growth and life form, (5) physiognomy, (6) pattern or type of distribution of individuals, and (7) constants derived from other criteria (Greig-Smith 1957:121). Methods of vegetation study are detailed by Cain and Castro (1959) and by Phillips (1959).

All studies cited above employed floristic composition and various measures of abundance. Murphy and Crawford (1970) and Segelquist and Green (1968) also measured production in the Ozarks. Frequency, density, and basal area are commonly used to express abundance of species. Buell and Cantlon (1950) recommend estimates of cover as of greater value in expressing community structure and tree-shrub-herb relationships as opposed to density, frequency, or basal area. Productivity is often measured in terms of weight measures of vegetation on plots. This method was used by Segelquist and Green (1968) and by Murphy and Crawford (1970). This method is subject to great error both from variation in vegetation (Hope-Simpson 1940) and bias by the observer (Smith 1944). A measure of performance used with trees is the site index which is the mean height of individuals of a tree species at a certain age (Spurr 1964). Site index is based on quantitative measurement of height and age of trees and should be less subject to error than weight estimates. Broadfoot (1969) pointed out the difficulties in obtaining ages of trees for site index.

Proper design for statistical analysis to estimate variation and probability can increase predictive value of investigative findings (Steel and Torrie 1960). Placement of sampling units is an important consideration. Lindsey (1951) and Carlile (1958) apparently selected their sampling locations by subjective means; their data cannot be analyzed to estimate variance. Rice and Penfound (1959) and Murphy and Crawford (1970) used systematic sampling. Segelquist and Green (1968) randomized their sampling. Bourdeau (1953) found little difference in accuracy between systematic and random sampling. However, he concluded that stratified random sampling was preferred because there was little loss in accuracy combined with better estimation of sampling error over both systematic and unrestricted random sampling.

The shape of sampling units also affects the efficiency of sampling. Borman (1953) found that rectangular plots were more efficient than square or circular plots. Variance could be used to find the most efficient size and shape of plot in addition to helping determine the number of plots needed for a required degree of accuracy. Canfield (1941) introduced the line interception method to increase the accuracy of cover estimates for range vegetation. Other workers have applied the line intercepts to shrubs (Bauer 1943, Heady et al. 1959, Kinsinger et al. 1960) and trees (Buell and Cantlon 1950, Lindsey 1955). Bauer (1943) found that the line required less time than did quadrats, it gave better accuracy with estimates of coverage, and the two methods were of about equal accuracy for measuring abundance and frequency. Lindsey (1955) concluded that the line was rapid and unbiased for cover estimates, but impractical for density estimation. He recommended using strips to estimate density and basal area. Strong (1966) devised a method for estimating density using lines by multiplying the sum of the reciprocals of crown diameters by a constant and by the length of the line.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

The Cookson Hills State Game Refuge (hereafter called the refuge) was authorized by the Oklahoma Fish and Game Commission in 1946, and in 1951 began operations as the final unit of a group of deer refuges established in northeastern Oklahoma that were managed by the Oklahoma Fish and Game Department (Anonymous 1946, 1954). The refuge covers 21.8 square miles of rugged hills clothed with oak-hickory and oak-pine timber on the southwest flank of the Ozark Plateau. In topography, soils, and vegetation, the refuge represents much of the available deer habitat in northeast Oklahoma and adjacent Arkansas and Missouri.

Location

The refuge is located in southwest Adair County and southeast Cherokee County, Oklahoma. It is 13 miles southeast of Tahlequah, 8.5 miles southwest of Stillwell, 1 mile west of Bunch, and 3 miles east of Cookson. The south boundary of the refuge is situated three-fourths of a mile north of the Sequoyah County line (Fig. 1).

Total area of the refuge is 13,935 acres. The acreage is distributed as follows: 7,760 acres in the east half of T14N, R23E, Cherokee County; 5,055 acres in the west third of T14N, R24E, Adair County; and 1,120 acres in the southwest corner of T15N, R24E, Adair County (Fig. 2).

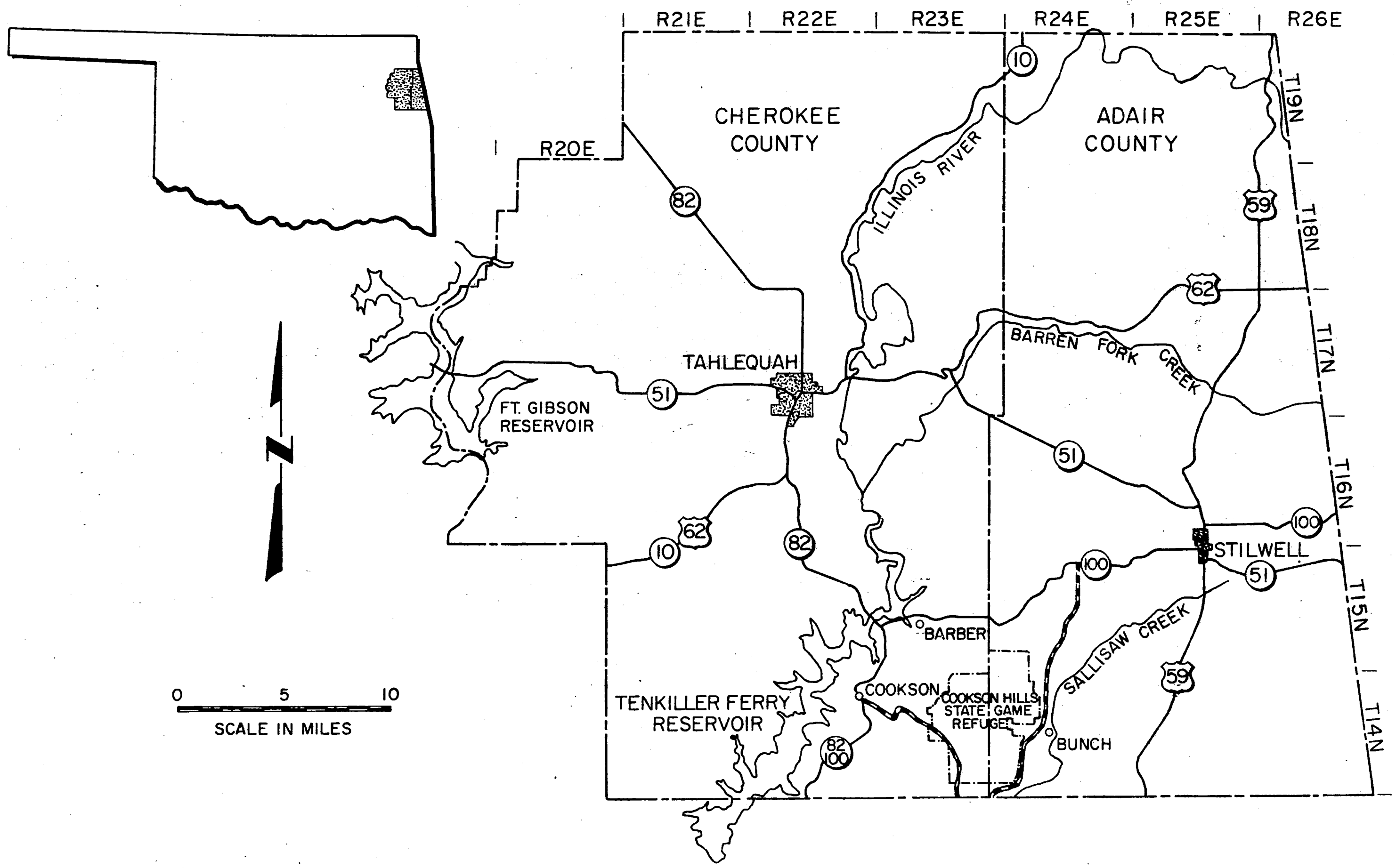


Figure 1. Map of Adair and Cherokee Counties, Oklahoma, showing location of the Cookson Hills State Game Refuge

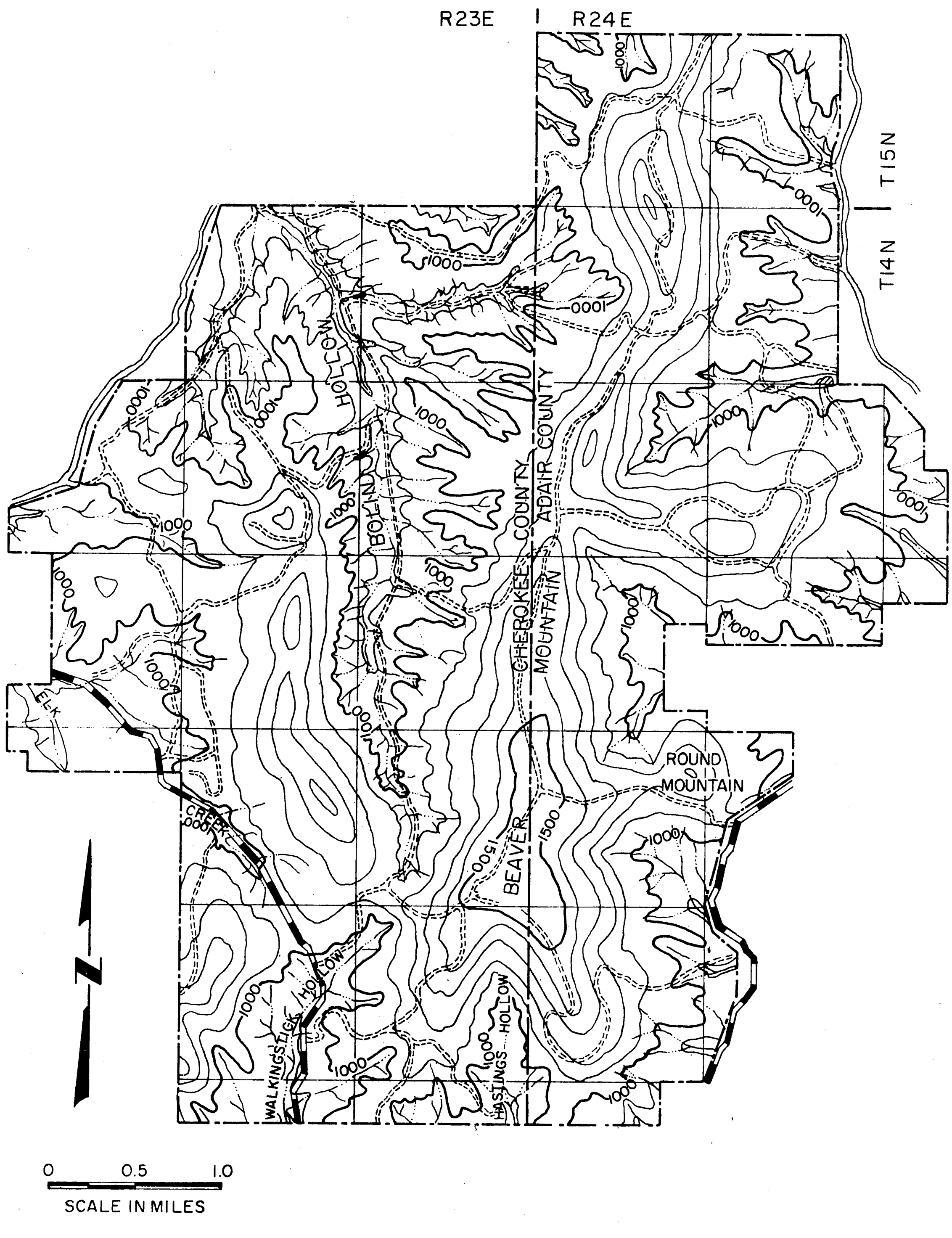


Fig. 2. Topographic map of the Cookson Hills Refuge

Topography

The refuge is located in the Cookson Hills which are on the southwest edge of the Ozark physiographic region. The Cookson Hills are a westward extension of the Boston Mountains extending from western Arkansas into eastern Oklahoma. The region is characterized by:

> . . . a series of northeast tending faults separates the area into prominent fault blocks with steep escarpment faces and gentle dip slopes capped by the resistant sandstones of the Atoka. Stream dissection has cut deep valleys through the ridges while major drainage lines are developed in the softer shales and limestone valleys paralleling the faulting (Huffman 1958:11).

The refuge is on an elevated fault block bounded by faults to the northwest and southeast. Downthrows are displaced 200 ft at the northwest fault and 700 ft at the southeast fault (Huffman 1958). Drainage on the east and south sides of the refuge is into Sallisaw Creek, a tributary of the Arkansas River. Two tributaries of the Illinois River, Dry Creek and Elk Creek, drain the north, central, and west areas of the refuge. The axes of the two main ridges on the refuge lie in north-south lines whereas secondary ridges on the flanks generally lie east to west. Maximum relief on the refuge is approximately 800 ft. The lowest points, in Walkingstick Hollow at the south boundary and in Bolin Hollow at the north boundary, are approximately 750 ft above mean sea level. The highest point is 1,550 ft in elevation and is situated at the south end of Beaver Mountain (Fig. 2). Slopes range from less than 3 percent to more than 50 percent in steepness.

Geology

The following discussion is based on <u>The Geology of the Flanks of</u>

the Ozark Uplift (Huffman 1958). Rock exposed on the refuge ranges in age from Silurian to Pennsylvanian (Fig. 3). Upper slopes are covered with colluvium. Alluvium of Pleistocene and Recent age forms terraces and covers stream bottoms in the valleys.

Surface Geology

The surface geology of the refuge is shown in Fig. 4. Because of their limited extent, and because they were seen only in stream beds, the St. Joe and Chattanooga formations are mapped with the St. Clair. The Reeds Spring and Keokuk formations are mapped as one unit. Because the contacts are usually covered and difficult to detect along benches, the Moorefield, Hindsville, and Fayetteville formations are mapped into a single unit. The Pitkin, Hale, Bloyd, and Atoka formations are mapped as separate units.

Stratigraphy

Silurian System. Exposures of St. Clair limestone occur in Walkingstick Hollow, Hastings Hollow, and Bolin Hollow. Thickest exposure (12 to 15 ft) are in Bolin Hollow in Sections 1 and 2, T14N, R23E. On the refuge, the St. Clair is a light-grey-to-bluish colored, medium-to-coarsely-crystalline, massive limestone (Fig. 5).

Devonian System. The St. Clair is overlain unconformably by the Chattanooga formation. The Sylamore sandstone member of the Chattanooga is exposed in Hastings Hollow. Exposures of the Chattanooga black shale are present in Walkingstick Hollow, Hastings Hollow, and Bolin Hollow. Thickness of the black shale observed was 1 to 3 ft. The Chattanooga

SYSTEM	SERIES	FORMATION	ROCK	FEET	CHARACTERISTICS
PENNSYLVANIAN	ATOKAN	ATOKA		0-205	INTERBEDDED SANDSTONES, SILTSTONES, AND SHALES
PENNSYLVANIAN	MORROWAN	BLOYD		154-160	VARIABLE LIMESTONE INTERBEDDED WITH SHALES, SANDSTONE, AND SILTSTONES
PENNSYLVANIAN	MORROWAN	HALE		58-98	BLUE-GREY TO BROWN, FINE-TO-MEDIUM CRYSTALLINE, FOSSILIFEROUS LIMESTONE CALCARIOUS SANDSTONE GRADING UPWARD INTO SANDY LIMESTONE
MISSISSIPPIAN	CHESTERIAN	PITKIN		19	GREY TO BLUE-GREY, FINELY CRYSTALLINE-TO-LITHOGRAPHIC LIMESTONE
MISSISSIPPIAN	CHESTERIAN	FAYETTEVILLE		24-28	INTERBEDDED BLUISH-GREY LIMESTONE AND BLACK SHALE BLACK, FISSILE SHALE
MISSISSIPPIAN	CHESTERIAN	HINDSVILLE		9-32	GREY, MEDIUM CRYSTALLINE, THICK-BEDDED, FOSSILIFEROUS LIMESTONE WITH STRONG BITUMINOUS ODOR
MISSISSIPPIAN	OSAGEAN	KEOKUK		96-135	MASSIVE WHITE-TO-BUFF AND GREY-MOTTLED FOSSILIFEROUS CHERT INTERBEDDED WITH STRINGERS AND MASSES OF BLUE-GREY, DENSE, FINE-GRAINED LIMESTONE
MISSISSIPPIAN	OSAGEAN	REEDS SP.		49	DARK-GREY TO BLUE-GREY CHERT ALTERNATING WITH THIN-BEDDED FINE-GRAINED, DENSE LIMESTONE
MISSISSIPPIAN	KINDERHOOKIAN	ST. JOE		5	INTERBEDDED GREY GLAUCONITIC LIMESTONE AND GREEN, GLAUCONITIC SHALE
DEV.	KINDERHOOKIAN	CHATTANOOGA		1-3	BLACK, FISSILE, PYRITIC, CARBONACEOUS, AND BITUMINOUS SHALE
SIL.	NIAGRAN	ST. CLAIR		UN-KNOWN	LIGHT-GREY TO BLUISH, MEDIUM-TO-COARSE-CRYSTALLINE, MASSIVE LIMESTONE

Fig. 3. Stratigraphic column section for the Cookson Hills Refuge

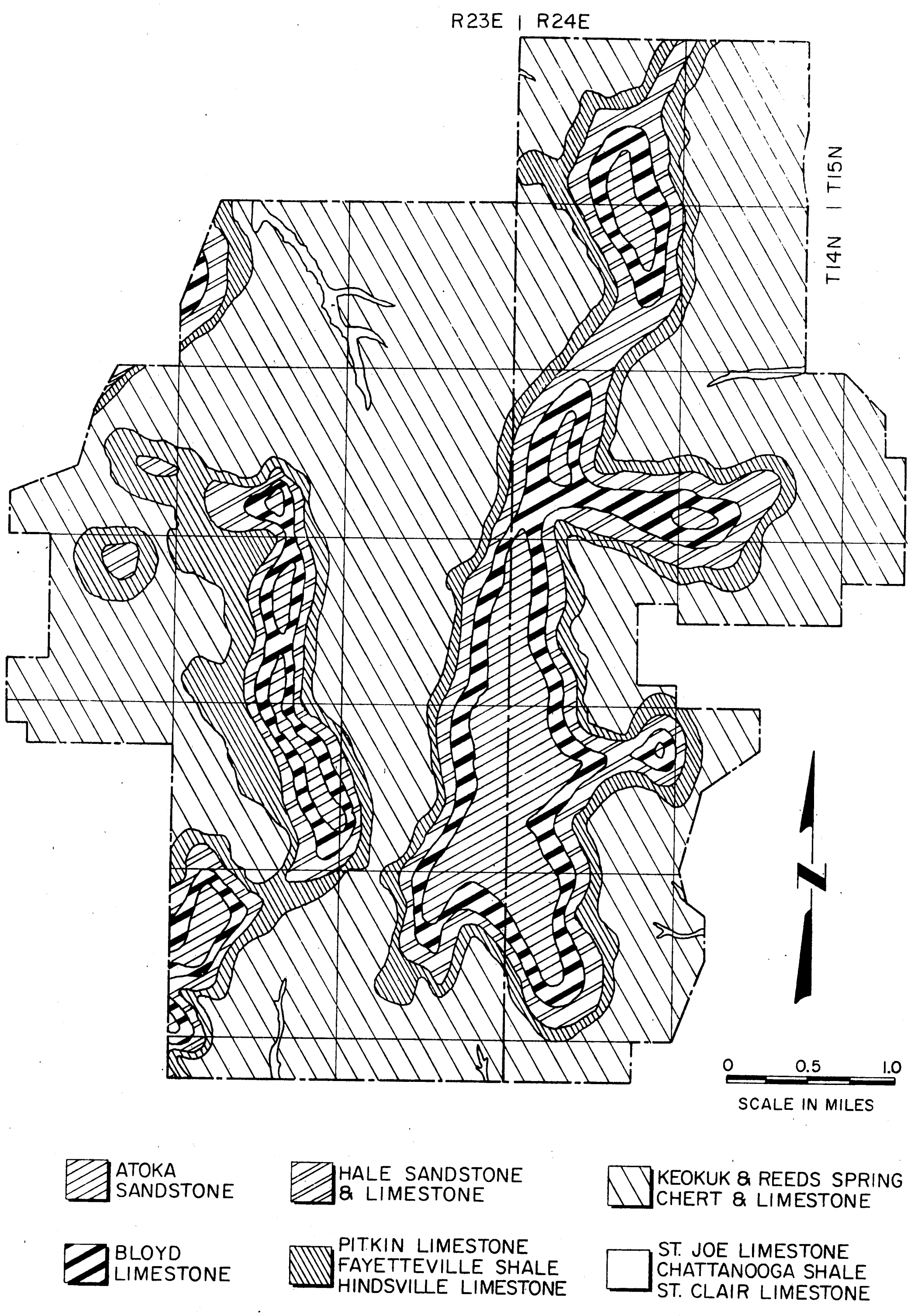


Fig. 4. Map of surface geology for the Cookson Hills Refuge

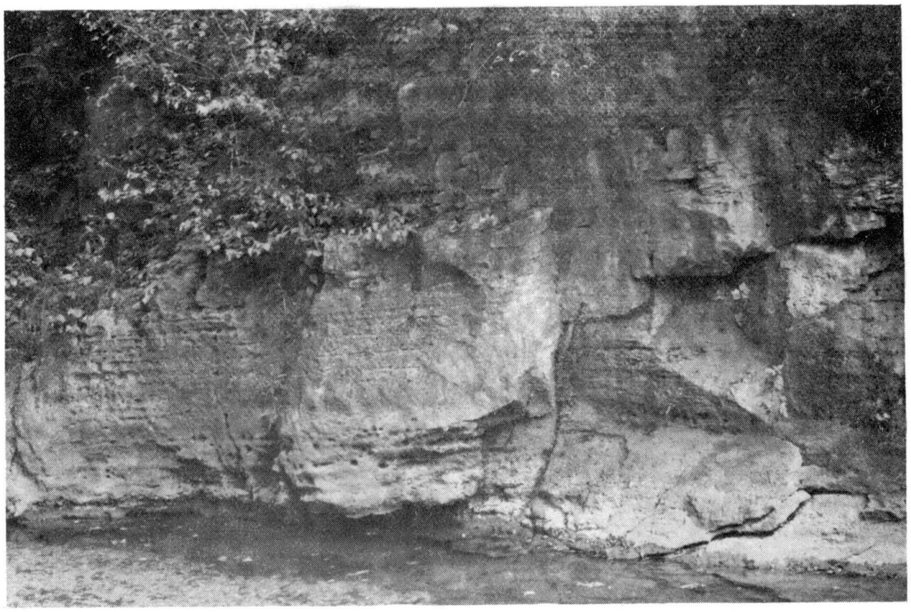


Fig. 5. Exposure of St. Clair limestone in Bolin Hollow, Section 2, T14N, R23E

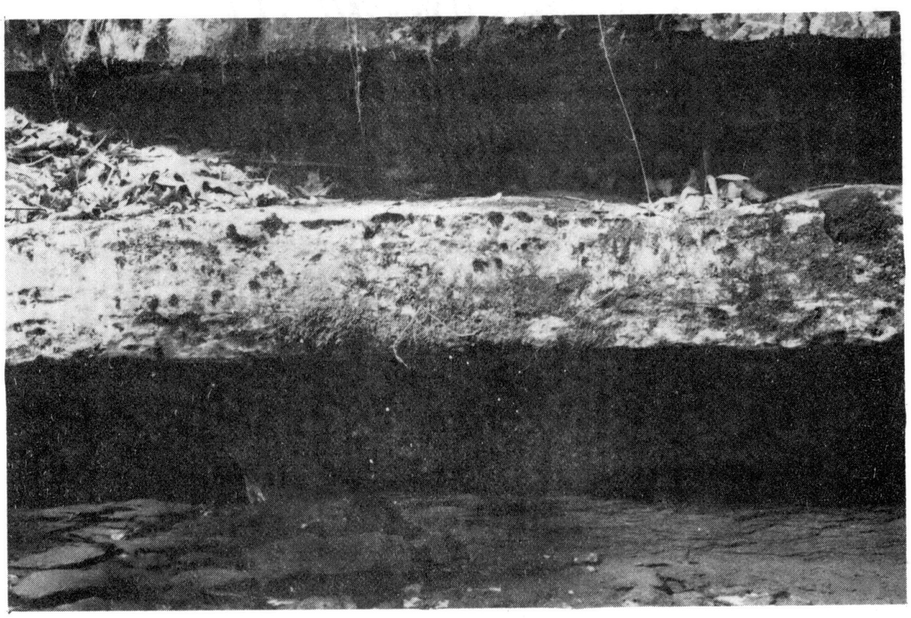


Fig. 6. Exposure of St. Joe limestone over Chattanooga black shale in Walkingstick Hollow, Section 35, T14N, R23E

black shale is described as fissile, pyritic, carbonaceous, and bituminous (Fig. 6).

Mississipian System. The St. Joe group is described by Huffman (1958) as lying unconformably over the Chattanooga formation in Walkingstick Hollow, Hastings Hollow, and Bolin Hollow on the refuge. A thickness of 5 ft is given for the strata in Hastings Hollow. It is described as interbedded grey, glauconitic limestone and green, glauconitic shale (Fig. 6).

The Reeds Spring formation rests unconformably on the St. Joe. Together with the Keokuk, collectively called the Boone formation, it is the most extensively exposed formation on the refuge. Thickness given by Huffman (1958) for the Reeds Spring is 49 ft on the refuge. It is described as "nearly equal amounts of thin, alternating, fine-grained, dense, thin-bedded limestone and dark-grey to blue-grey chert" (Huffman, 1958) (Fig. 7).

The Keokuk formation lies unconformably over the Reeds Spring. On the refuge, thickness varies from 96 to 135 ft. The Keokuk formation consists of massive white-to-buff and grey-mottled fossiliferous chert interbedded with stringers and masses of blue-grey, dense, fine-grained limestone (Fig. 8).

The Hindsville rests conformably on the Keokuk formations. The Hindsville formation varies in thickness from 9 to 32 ft on the refuge. The Hindsville is variable, but is generally a grey, medium-crystalline, thick-bedded, fossiliferous limestone. It is characterized by a strong bituminous odor (Fig. 9).

The Fayetteville formation lies conformably on the Hindsville. It ranges from 24 to 28 ft thick. Together the Fayetteville and Hindsville

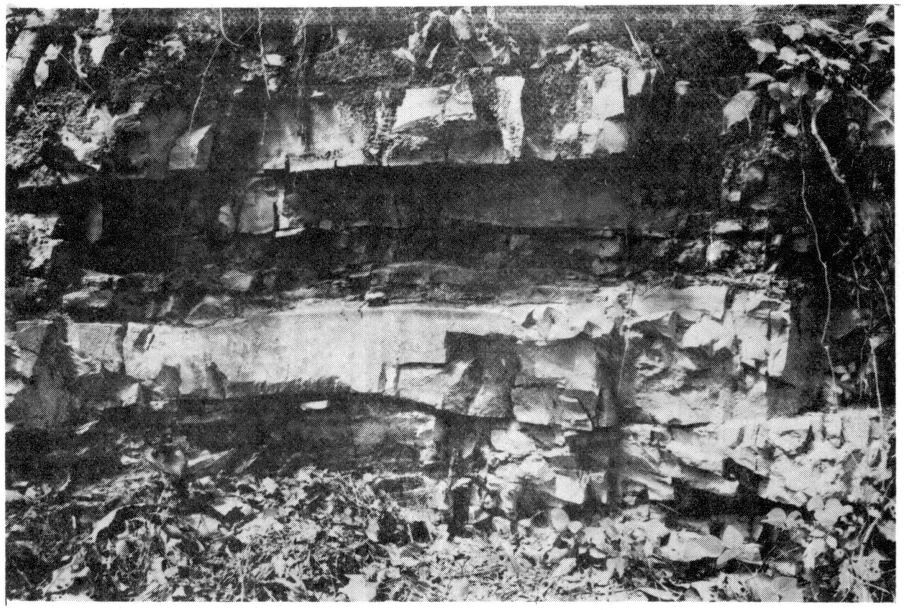


Fig. 7. Exposure of Reeds Spring chert and limestone in Bolin Hollow, Section 1, T14N, R23E

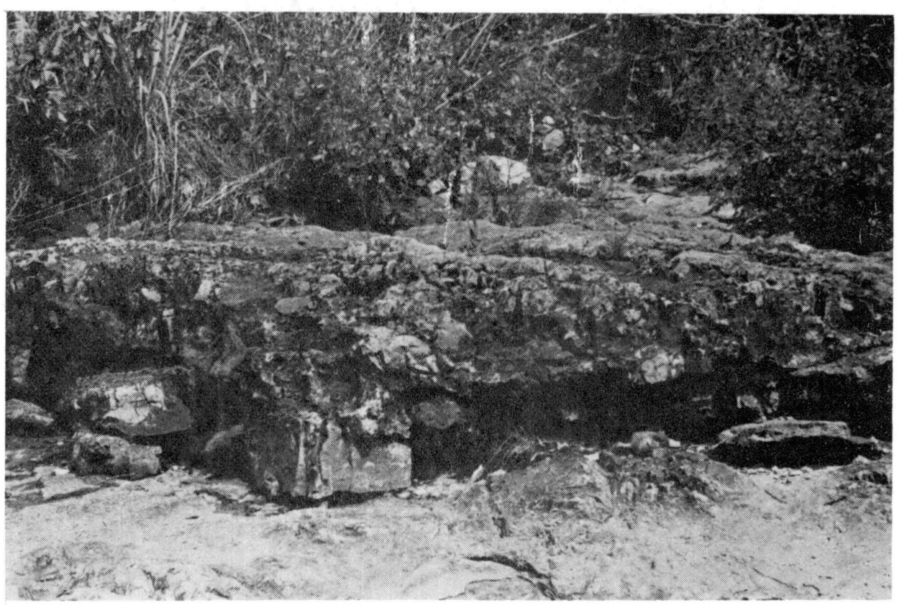


Fig. 8. Exposure of Keokuk chert and limestone in Bolin Hollow, Section 24, T14N, R23E

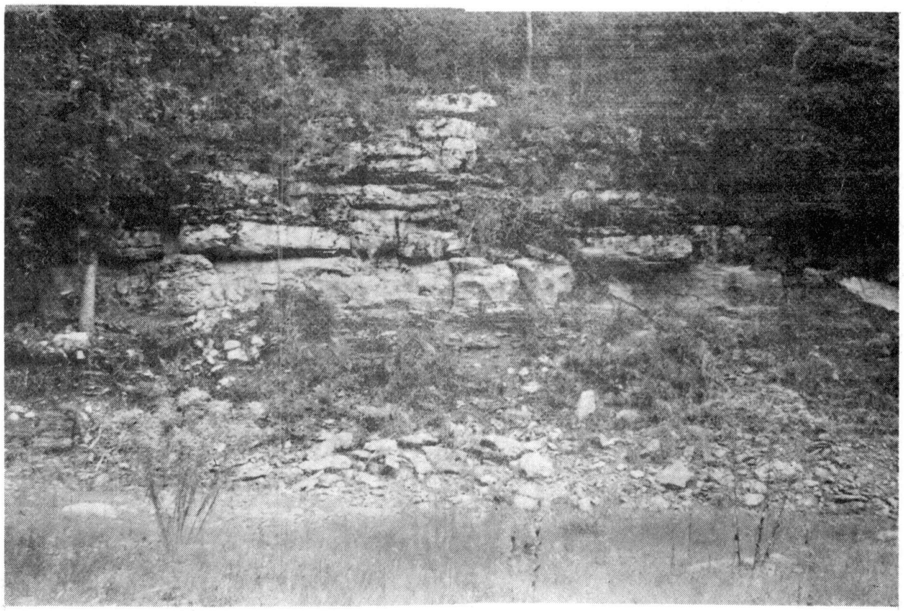


Fig. 9. Exposure of Hindsville limestone on Beaver Mountain, Section 23, T14N, R23E

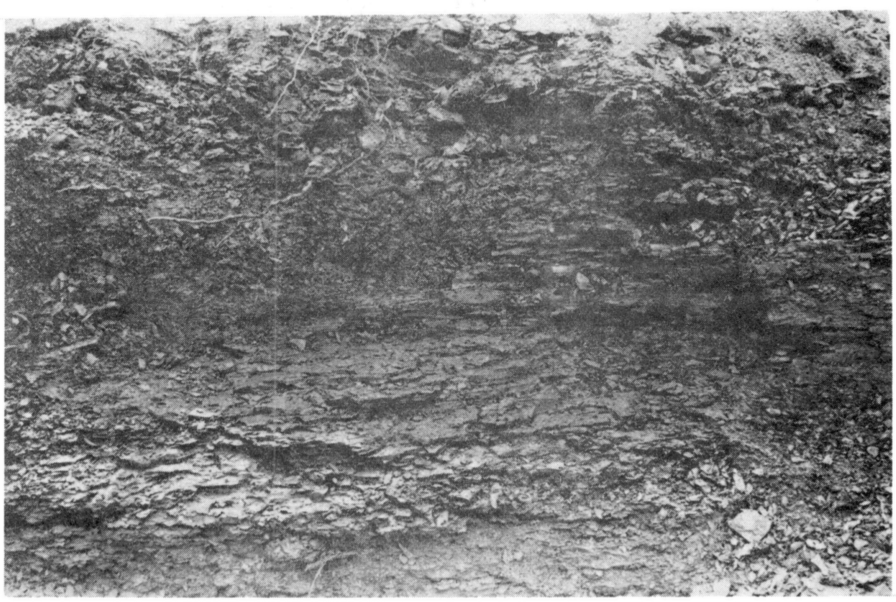


Fig. 10. Exposure of Fayetteville black shale along road on the Refuge, Section 11, T14N, R23E

formations form benches along the sides of the two major north-south ridges on the refuge. The lower portion is a black, fissile shale; the upper portion is interbedded, bluish-grey limestone and black shale (Fig. 10).

The Pitkin formation rests conformably upon the Fayetteville. Thickness on the refuge is given as 19 ft. With the overlying Hale formation it forms steep bluffs along the sides of the two major ridges on the refuge. The Pitkin is a grey to blue-grey, finely crystalline-to-lithographic limestone (Fig. 11).

Pennsylvanian System. The oldest Pennsylvanian unit in northeast Oklahoma is the Hale formation. On the refuge it rests unconformably over the Fayetteville formation. It varies in thickness from 58 ft to 98 ft. The basal portion is a calcarious sandstone that weathers with a characteristic pitted appearance. The basal member grades upward into a sandy limestone. The upper portion of the Hale is a blue-grey to brown, fine-to-medium crystalline, fossiliferous limestone (Fig. 12).

The Bloyd formation has a conformable and gradational contact with the underlying Hale. It is from 154 to 160 ft thick. The Bloyd forms slopes between the cliff-forming ledges of the underlying Hale and the overlying Atoka along the sides of the main ridges. It consists of variable limestones interbedded with shales, sandstones, and siltstones (Fig. 13).

The Atoka formation caps the highest ridges on the refuge. The thickest section is 205 ft in depth at the south end of Beaver mountain. Much of the Atoka has been removed by erosion. The highest ridges are nearly level on top and appear to be remnants of a peneplain. The Atoka consists of interbedded sandstones, siltstones, and shales (Fig. 14).

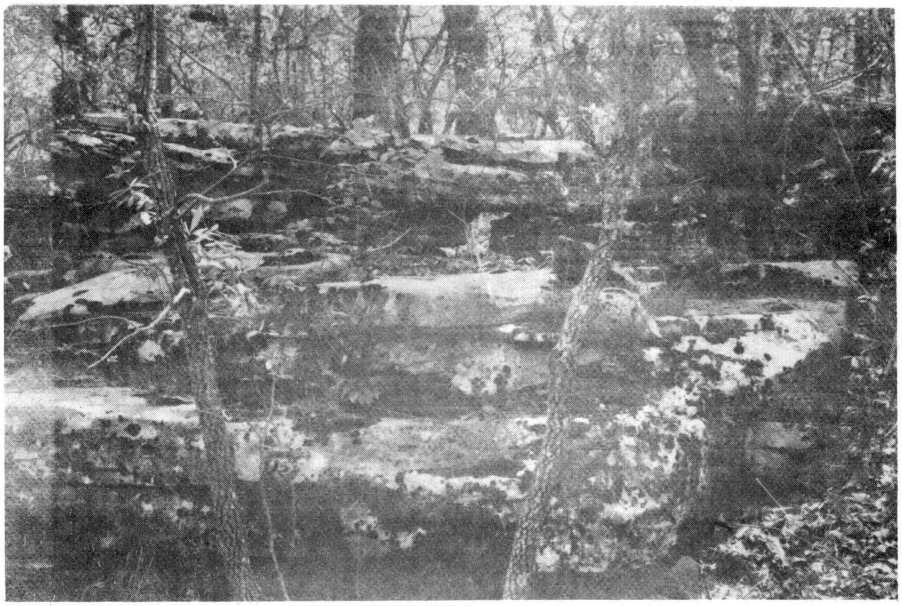


Fig. 11. Exposure of Pitkin limestone on Beaver Mountain, Section 6, T14N, R24E

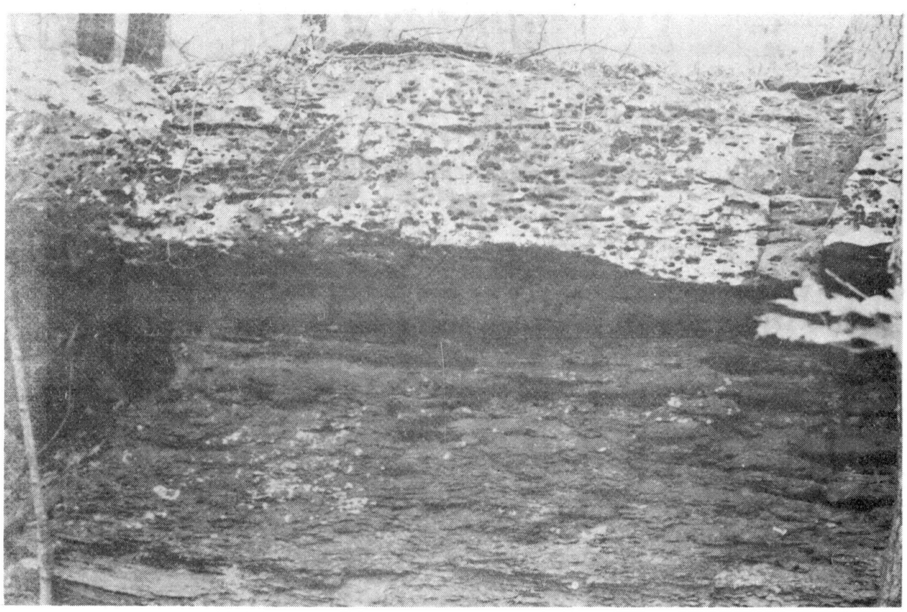


Fig. 12. Exposure of calcarious sandstone which is the basal member of the Hale formation, Section 24, T14N, R23E

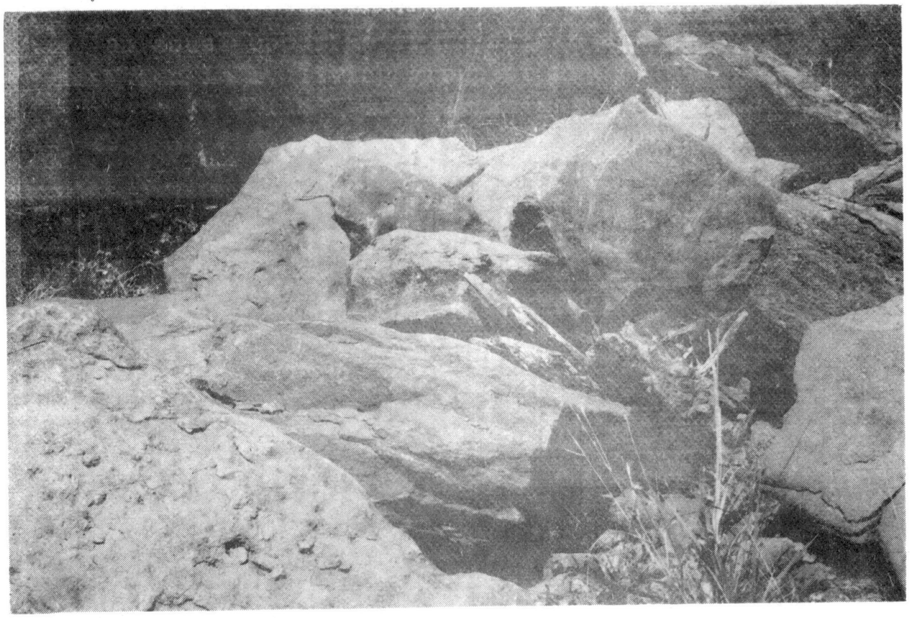


Fig. 13. Exposure of Bloyd limestone on Beaver Mountain, Section 25, T14N, R23E

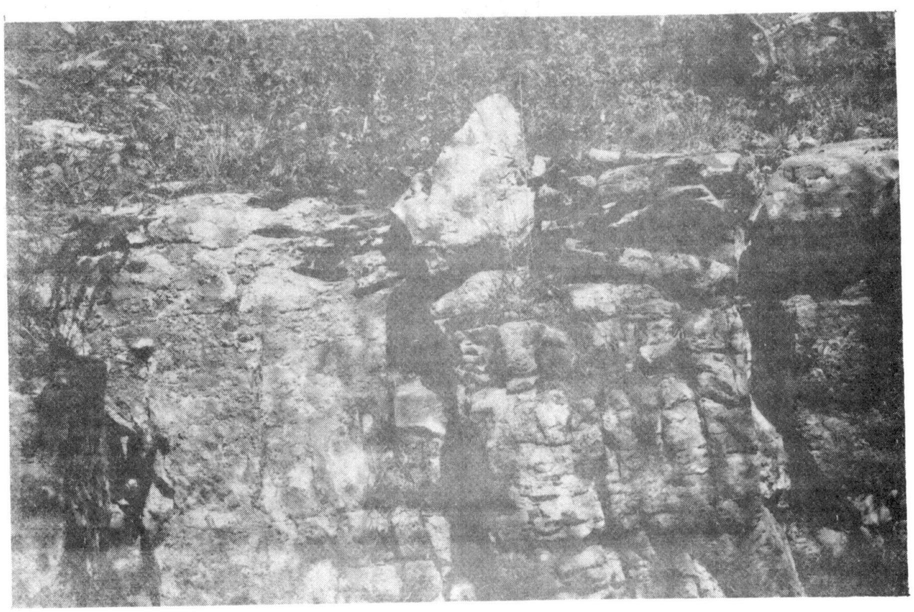


Fig. 14. Exposure of Atoka sandstone on Beaver Mountain, Section 25, T14N, R23E

Soils

In the Ozark Plateau soils, vegetation, landform, and geology have been relatively stable interacting systems throughout the Pleistocene despite climatic fluctuations (Braun 1950, Steyermark 1959).

The soils on the refuge include the same soils that occur on 77.8 percent of the land area in Adair, Cherokee, and Delaware Counties in northeast Oklahoma. These are mostly upland forest soils, but include lesser areas of bottomland forest soils and prairie soils. As on the refuge, upland forest soils in the Clarksville and Linker series are the most extensive soils in the three-county area.

In the current system of soil classification, six taxonomic levels are used. From the highest rank down, these levels are soil order, suborder, great group, subgroup, family, and series (Soil Survey Staff 1960). Four soil orders are represented by the soils on the refuge. These are Inceptisols, Mollisols, Alfisols, and Ultisols. The brief definitions of these orders that follow are paraphrased from Soil Classification, a Comprehensive System, 7th Approximation (Soil Survey Staff 1960).

Inceptisols are soils of humid regions that have altered horizons that have lost bases or iron and aluminum but still have some weatherable minerals. They do not have illuvial horizons that are enriched with silicate clays that contain aluminum or with amorphus mixtures of aluminum and organic carbon. Horizons of accumulation of translocated silica, iron, or bases are allowed in Inceptisols; named diagnostic horizons of accumulation of translocated aluminum in lattice or amorphous clays, gypsum, or more soluble salts are not allowed. Inceptisols occur in subhumid to humid regions. Where evapotranspiration exceeds precipitation during some time of the year, they are normally restricted to post-Pleistocene surfaces. Inceptisols are considered "young" soils.

Mollisols are very dark colored, basic, rich soils of grasslands. They usually have a surface horizon that is relatively thick, dark colored, humus rich, with bivalent cations dominant on the exchange complex, and with moderate-to-strong structure. They occur over extensive areas in subhumid to semiarid regions. The dominant vegetation is usually grass, although a few mollisols have formed under forests where the parent material is rich in calcium. Mollisols are "mature" soils of grasslands.

Alfisols are soils that have a surface horizon that is too light in color, too low in organic matter, or too thin, to be a mollisol; or the surface horizon is massive and hard when dry. Alfisols usually have a subsurface horizon of accumulation of silicate clays. They have moderate-to-high base saturation on the exchange complex, and available moisture in them drops below the wilting point during at least 90 days during the growing season. Alfisols are "mature" soils of forests or grasslands in subhumid-to-humid regions.

Ultisols are soils that have a subsurface horizon of accumulation of silicate clays, but have a low base saturation on the exchange complex. There is usually an excess of precipitation over evapotranspiration during part of the year. Release of bases by weathering usually equals or is less than loss by leaching. Most of the bases are held in the upper few inches of the soil and in the vegetation. They are soils of warm humid climates that have a seasonal deficit of precipitation. They are usually on Pennsylvanian or older surfaces and are formed from wide variety of parent materials. Ultisols are "old" soils of forested regions.

The classification of the soils on the refuge is in accordance with Cole (1970) and is given in Table 1.

Table 1. Soils of the Cookson Hills refuge classified according to the soil survey of Cherokee and Delaware Counties, Oklahoma (Cole 1970)

Series	Family	Subgroup	Order
Clarksville	Loamy-skeletal, siliceous, mesic	Typic Paleudult	Ultisol
Elsah	Loamy-skeletal, mixed, nonacidic, mesic	Dystric Fluventic Eutrochrept	Inceptisol
Hector	Loamy, siliceous, thermic	Lithic Dystrochrept	Inceptisol
Linker	Fine-loamy, siliceous, thermic	Typic Hapludult	Ultisol
Sallisaw	Fine-loamy, mixed, thermic	Ultic Paleudalf	Alfisol
Staser	Fine-loamy, mixed, thermic	Fluventic Hapludoll	Mollisol
Summit	Fine, montmorillonitic, thermic	Vertic Argiudoll	Mollisol
Talpa	Loamy, mixed, thermic	Lithic Haplustoll	Mollisol

Distribution of soils on the refuge is shown on the map in Fig. 15.

The amounts of the different kinds of soils on the refuge is shown in Table 2.

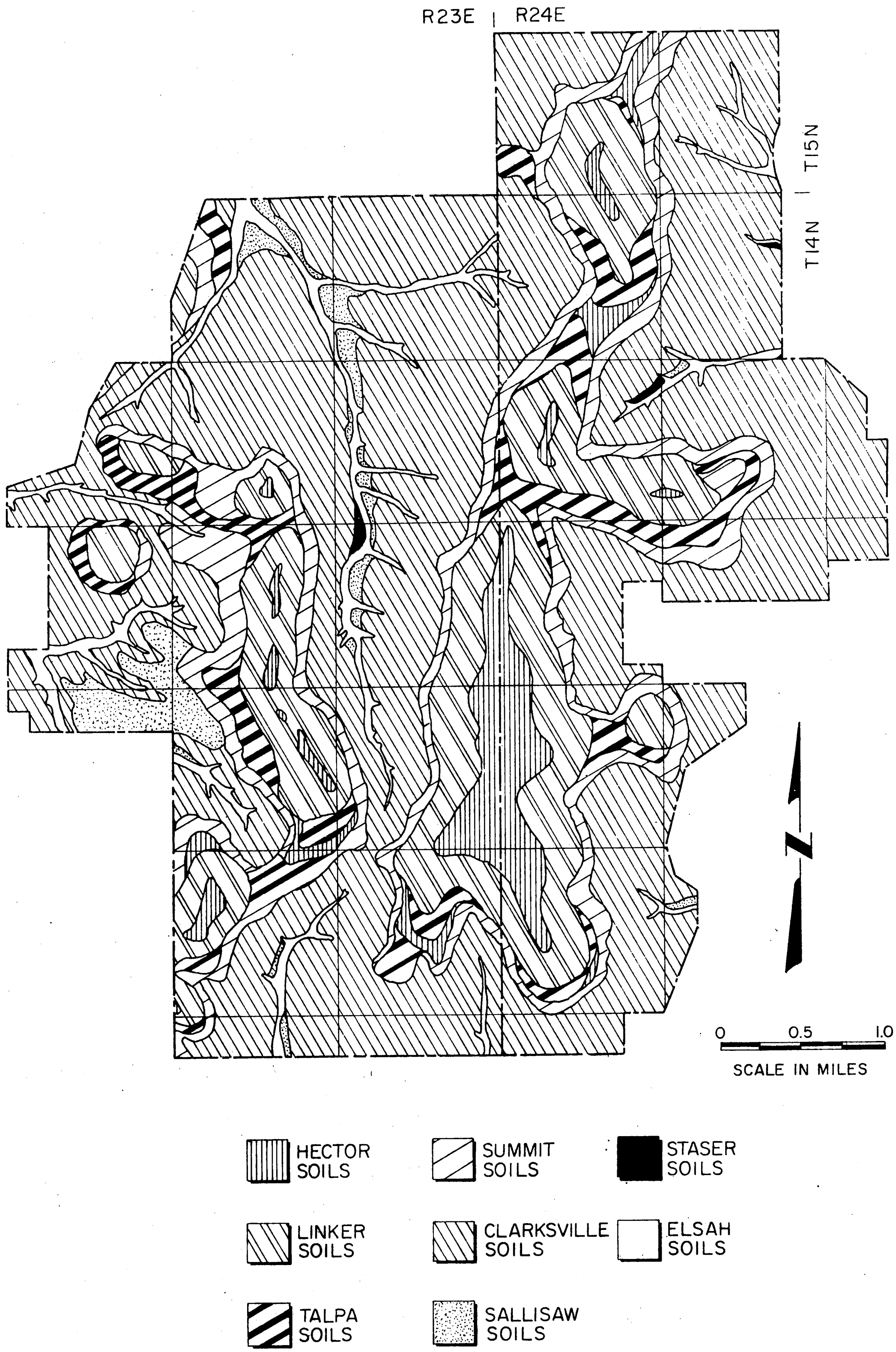


Fig. 15. Soil map of the Cookson Hills Refuge

Table 2. Comparative extent of different soils of the Cookson Hills Refuge by acres and by percent of total area

Soil Series	Acres	Percent
Clarksville	8,090	58.07
Elsah	650	4.68
Hector	675	4.84
Linker	2,050	14.70
Sallisaw	465	3.34
Staser	35	.23
Summit	1,300	9.34
Talpa	670	4.80

Relationships of Soils to Landform and Geology

Soils are defined as natural bodies of mineral and organic matter which change or have changed in response of climate and organisms (Buol et al. 1973). Jenny (1941) states that soils are the expression of the soil-forming factors, climate, living organisms, topography, parent material, and time. These factors influence the soil-forming processes of addition, removal, translocation, and transformation (Simonson 1959). If the principle of dynamic equilibrium (Hack 1960) is accepted as the explanation for control of landforms, then so long as climate and vegetation are stable the units will remain constant. Hack (1960) considered landforms to be open systems that quickly attain equilibrium and then are maintained as graded systems. Differences in landforms can be explained by differences in the physical and mineralogical character of the bedrock and particularly the hardness of bedrock or differences in the processes acting on the bedrock. Slopes on resistant rock, i.e. sandstone or chert, will be steeper than slopes on softer limestones and shales. Similarly, slopes in coarser-textured materials will be steeper than slopes in fine-textured materials. When streams reach equilibrium and become graded, deposition and removal of alluvium in stream valleys will balance. After equilibrium is attained, topography will tend to remain unchanged until conditions change.

A possible fate for a soil on a stable landform is to persist indefinitely, its profile developing down into parent material at the same rate at which erosion removes soil material from its surface (Buol et al. 1973). The rate at which the bedrock weathers can be in equilibrium with the rate erosion removes material from the surface of a soil. Highly weathered Ultisols develop over resistant rock that weathers slowly into material that erodes slowly. The least-developed Entisols can develop in resistant rock that weathers into easily eroded material. Entisols are also common in stream bottoms where alluvium is deposited and removed at relatively rapid rates.

The soils on the refuge have predictable relationships to landform and geology (Fig. 16 and Fig. 17).

The Hector series occurs on level to gently sloping (3 to 8 percent) areas in sandstones. Hector soils are classified in the order of Inceptisols. These are relatively young soils which lack significant development of genetic horizons. Sandstone is resistant to weathering. On level areas of Atoka sandstone the regolith is shallow and the

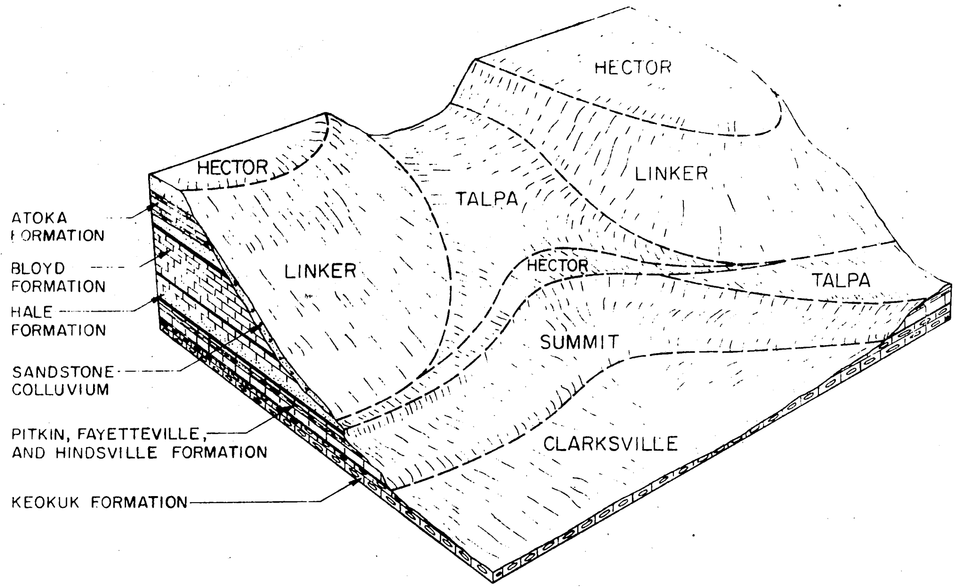


Fig. 16. Block diagram showing the relationships of Hector, Linker, Talpa, and Summit soils to geology and landform on the Cookson Hills Refuge

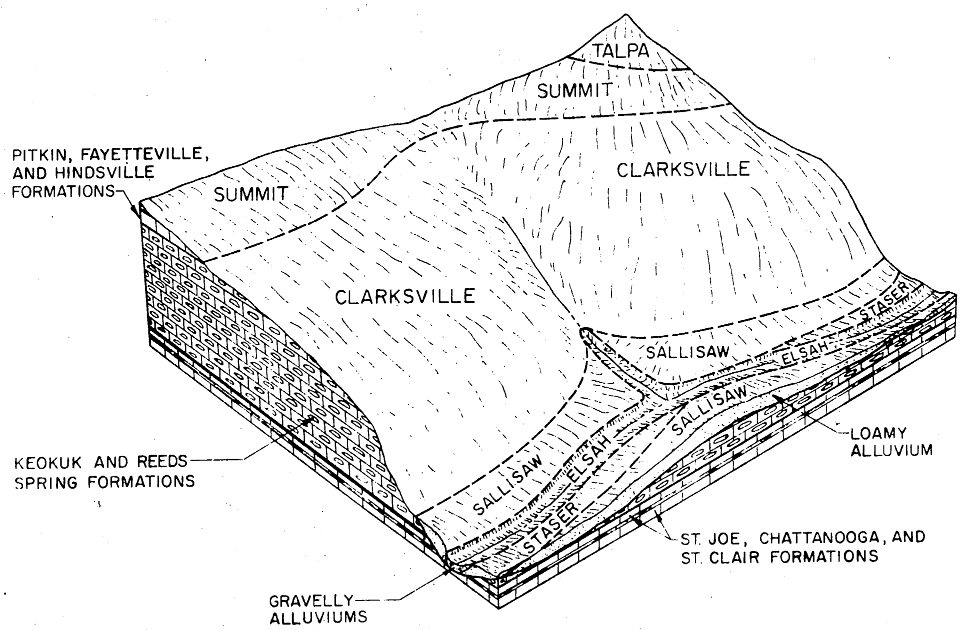


Fig. 17. Block diagram showing the relationship of Clarksville, Sallisaw, Staser, and Elsah soils to geology and landform on the Cookson Hills Refuge

percentage of weatherable minerals transformed into clay minerals is low. Rate of leaching of minerals and erosional loss of soil are in equilibrium with weathering so that the Hector series that is young in degree of development is maintained on an old land surface. Hector soils also develop in the Hale formation in saddles and on the ends of ridges. These sites are also level to gently sloping and there is little addition of soil materials from higher areas (Fig. 16).

The Linker series occurs on upper slopes of the main ridges in sandstone and sandstone colluvium. Linker soils are classified in the order of Ultisols. Soil profiles are deep and well developed and most of the weatherable minerals have been transformed into clay minerals and most soluble bases have been lost through leaching. Clays have been translocated from the A horizon and concentrated in the B horizon. Linker soils occur in Atoka sandstone and colluvium from the Atoka on the upper slopes of the main ridges. Small areas of Linker also occur on the ridge tops in the Atoka in low areas and where thin interbedded layers of shale are exposed (Fig. 16).

Talpa soils develop over limestone on steep-to-gentle slopes where there is little accumulation of soil materials. Talpa soils are classified in the order of Mollisols. These are mineral soils with a relatively thick, dark-colored surface horizon which is high in organic matter and soft when dry. The base saturation of the cation exchange capacity is greater than 50 percent and divalent cations dominate the exchange complex. Talpa is a shallow Mollisol with an A horizon lying on limestone bedrock. On gentle slopes weathering of the limestone into soil material balances loss by erosion. On steep slopes transport of soil material from upslope helps maintain equilibrium with erosion.

Talpa soils are present in Bloyd, Hale, and Pitkin limestones in saddles and on the ends of ridges where colluvium is absent. Scattered areas of Talpa are present along the sides of the main ridges on Pitkin limestone where the limestone does not form bluffs. Small areas of Talpa are also present on steeper slopes of Hindsville limestones (Fig. 16).

Summit soils occur on the benches formed in the Fayetteville shale and Hindsville limestone and also on extensive level areas of the Hindsville. It is classified as a Mollisol. It is deeper than the Talpa series and has a clayey B horizon.

Both the Summit and Talpa series develop over limestone or limestone and shale. Shales are consolidated clay minerals and they change into clay by mechanical weathering. The limestones weather rapidly enough to maintain a high level of base saturation on the exchange complex in equilibrium with leaching losses. Shale and limestone weather into fine-textured soil materials that are easily transported by water. Slopes on limestone and shale tend to be gentler than on sandstone or chert unless they are controlled by a cap or more resistant rock or are covered by colluvium of coarser-textured material (Fig. 16).

Clarksville soils occur on the residuum of cherty limestone. They are classified in the order of Ultisols, and like the Linker series are deep, base poor, and show evidence of translocated clay. The Clarksville series occurs on the ridge tops and steep slopes in the Keokuk and Reeds Spring cherty limestones. The limestone matrix has been removed by solution weathering and the residual chert consists of gravel and stones to 12 and 14 in in diameter. These coarse fragments have a steep angle of repose and slopes formed of this material can be very steep. The chert weathers slowly into silt and clay and is poor in cations for release by weathering. The equilibrium between weathering and leaching maintains a low level of bases on the exchange complex of Clarksville soils (Fig. 17).

The Sallisaw series occurs on the terraces of old alluvium. It is classified in the order of Alfisols. Alfisols are soils with medium-to-high base saturation on the exchange complex and with accumulation of silicate clays in the B horizon. Base saturation is more than 35 percent in the illuvial horizon. The surface horizon is generally lighter in color than is allowed for the limits of Mollisols, or it contains less than 1 percent organic matter, or has massive structure. The old alluvial terraces have been stable for a sufficiently long period for soil-forming processes to develop distinct soil horizons. Some of the alluvial material is derived from limestone. Release of bases by chemical weathering plus additions by leaching and runoff from slopes above the terraces maintain base saturation at a relatively high level in equilibrium with losses by leaching (Fig. 17).

The Staser series occurs on the flood plain in the larger valleys. They are on areas of the flood plains that are high enough to escape frequent flooding and have not been subject to recent reworking of the alluvium by stream action. The Staser series is classified in the order of Mollisols. The alluvium is base rich and Staser soils also receive bases from slopes above them through runoff and leaching. The position in valley bottoms maintains favorable soil-moisture relations for abundant plant growth from runoff and lateral movement of soil water. The plentiful supply of litter is sufficient to maintain organic matter content of the A horizon above 1 percent. Lack of frequent addition of soil materials by flooding and disturbance from reworking by streams permit soil building process to develop well-defined horizons in the soil (Fig. 17).

Elsah soils occur in stream valleys on the flood plains subject to frequent flooding. The Elsah series is classified in the order of Inceptisols. Profile development is inhibited in Elsah series because of deposition and reworking of alluvium by stream action (Fig. 17).

Descriptions of the Soils

Descriptions of the soils are taken from Cole (1970).

Clarksville Series. Clarksville soils are deep and have a cherty, medium-textured surface horizon and a cherty, fine-to-moderately-fine-textured subsoil. The A1 horizon is a dark-greyish-brown to greyish-brown, slightly acid, cherty-silt loam, 2 to 3 inches thick. The A2 horizon is a greyish-borwn to light-grey, strongly acid, cherty-silt loam, 6 to 8 inches thick. The B1 horizon is strong-brown to reddish-yellow, very strongly acid, very cherty, silty-clay loam, 3 to 14 inches thick. The B2t horizon is strong-brown to reddish-yellow, very strongly acid, very cherty, silty-clay loam, 12 to 30 inches thick. The B3 horizon consists of interlayers of chert beds and cherty silty-clay loam or cherty-silty clay. Its color is brownish-yellow and contains brown, yellowish-red, and grey mottles. The pH is very strongly acid. Clarksville soils are Ultisols that form in cherty limestone on very gentle to steep slopes under forest vegetation. They are highly permeable and well-drained to excessively drained. Available moisture and fertility are low (Fig. 18).

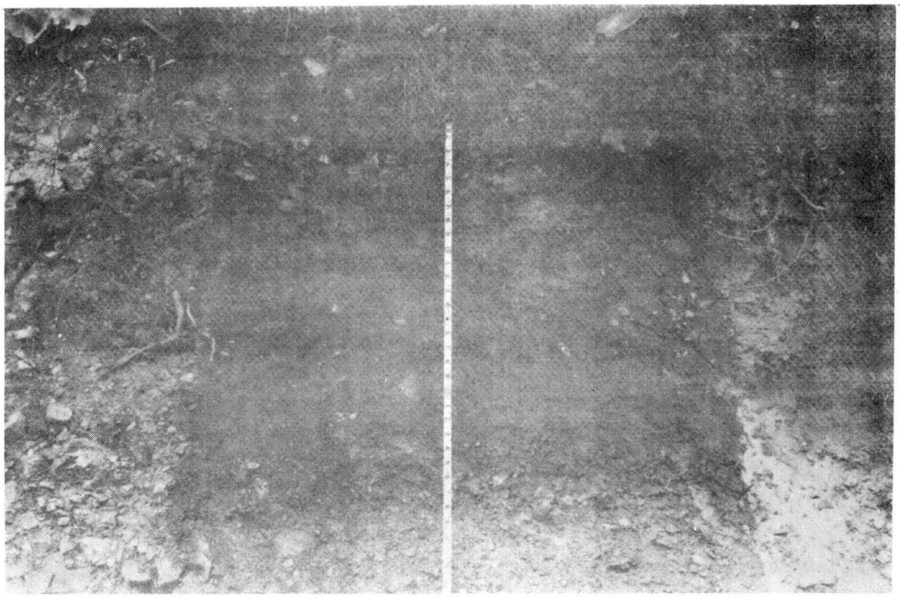


Fig. 18. Profile of Clarksville soil in a road cut in Bolin Hollow, Section 12, T14N, R23E

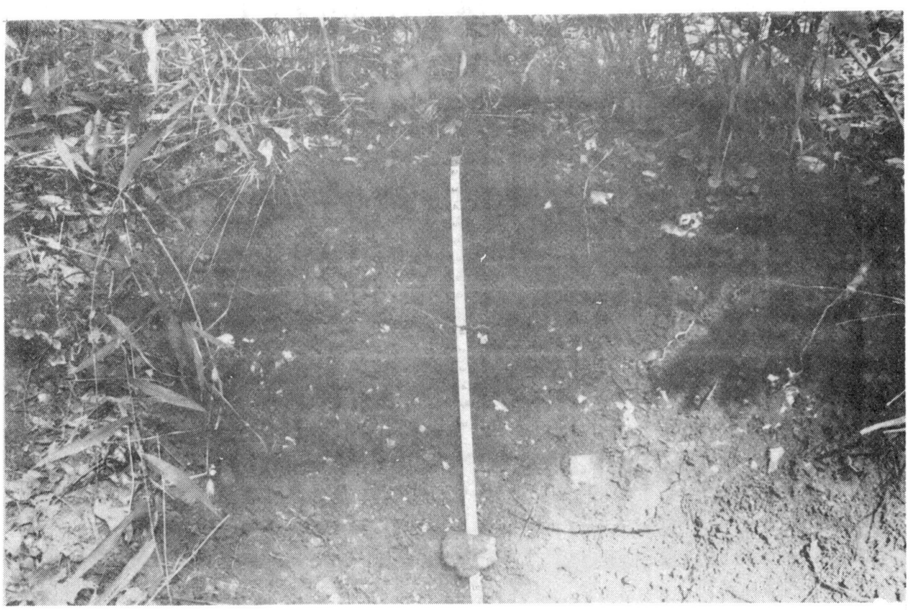


Fig. 19. Profile of Elsah soil exposed in a stream bank in Bolin Hollow, Section 13, T14N, R23E

Elsah Series. Elsah soils are deep soils having a gravelly, medium-textured surface layer and subsoil. The A1 horizon is dark brown to pale brown, medium acid, very gravelly loam to very gravelly silty loam, 7 to 20 inches thick. The B horizon is dark greyish brown to light greyish brown, medium acid, very gravelly loam. Elsah soils are Inceptisols that form in gravelly alluvium on frequently flooded stream bottoms. They are rapidly permeable and excessively drained. Available moisture capacity is low, but the water table is often within the root zone. They have a high organic matter content and are fairly fertile (Fig. 19).

Hector Series. Hector soils are very shallow to shallow medium-textured soils lying over sandstone. The A1 horizon is dark brown to brown, slightly acid, fine sandy loam, 5 to 10 inches thick. The B horizon is strong-brown to reddish-yellow, strongly acid, fine sandy loam, 2 to 12 inches thick. The R horizon is sandstone bedrock. Hector soils are Inceptisols that form in sandstone on gentle-to-moderate slopes. They are moderately rapidly permeable and are excessively drained. Available moisture capacity and fertility are low (Fig. 20).

Linker Series. Linker soils are moderately deep and consist of a moderately coarse-textured surface layer lying over moderately fine-textured subsoil. The A1 horizon is dark brown to brown, medium acid, fine-sandy loam, 2 to 3 inches thick. The A2 horizon is brown to light brownish-grey, medium acid, fine-sandy loam, 2 to 8 inches thick. The B1 horizon is yellowish-red to reddish-yellow, medium-acid loam, 4 to 9 inches thick. The B2t horizon is yellowish-red to reddish-yellow, medium acid, light-clay loam, 10 to 20 inches thick. The B3 horizon is yellowish-red to reddish-yellow, medium acid, light-clay loam, 4 to 8 inches

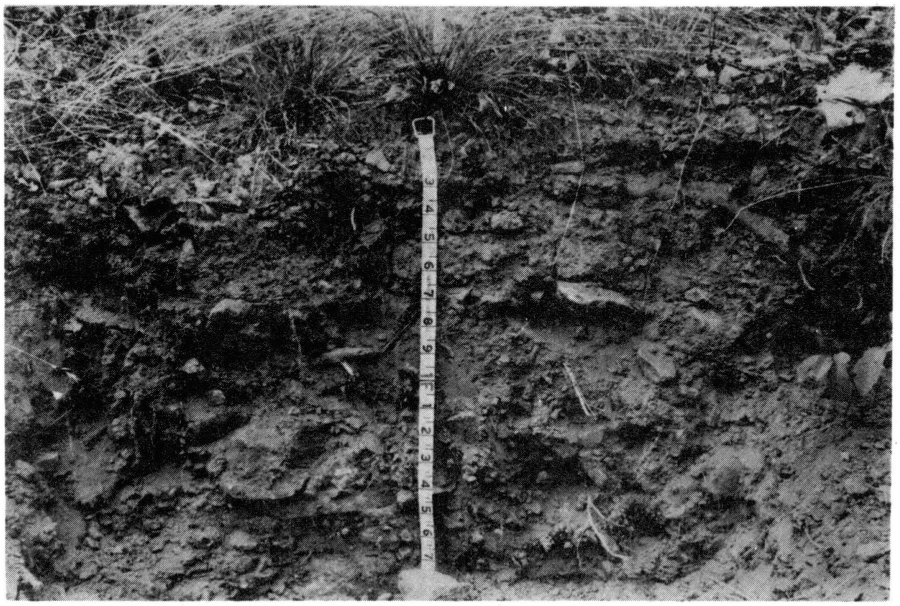


Fig. 20. Profile of Hector soil exposed along road on Beaver Mountain, Section 18, T14N, R24E

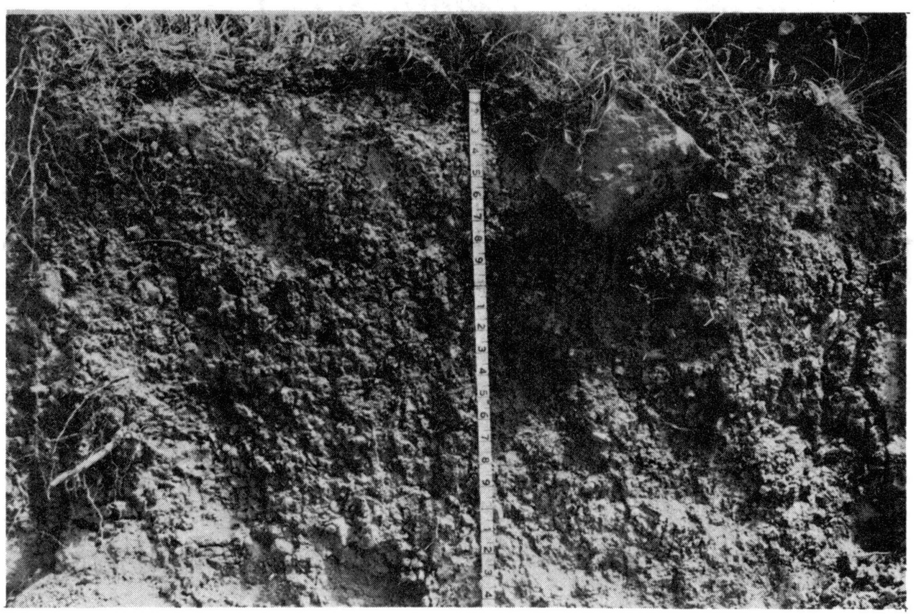


Fig. 21. Profile of Linker soil exposed in road on Beaver Mountain, Section 25, T14N, R23E

thick. Linker soils are Ultisols that form in material weathered from sandstone on gentle-to-steep slopes. They are moderately permeable and well drained. Linker soils have fair available-moisture capacity, contain moderate amounts of organic matter in the A horizon, and are fairly fertile (Fig. 21).

Sallisaw Series. Sallisaw soils are deep gravelly soils that have a medium-textured surface layer lying over a moderately fine-textured subsoil. The A1 horizon is dark brown to pale brown, slightly acid, gravelly silt loam, 7 to 14 inches thick. The B1 horizon is strong brown to reddish-yellow, strongly acid, gravelly silt loam, 5 to 10 inches thick. The B2t horizon is strong brown to reddish-yellow, strongly acid, gravelly, silty-clay loam. The lower part of the B2t may be discontinuous. Sallisaw soils are Alfisols that form in alluvium on benches along streams. They are moderately permeable and well drained. The high content of gravel in the subsoil limits available moisture. Fertility is moderately high (Fig. 22).

Staser Soils. Staser soils are deep gravelly soils that have a medium-textured surface layer and subsoil. The A1 horizon is a very dark to dark greyish-brown, slightly acid, gravelly loam, 8 to 18 inches thick. The B21 horizon is dark brown to pale brown, medium acid, gravelly, heavy loam, 10 to 20 inches thick. The B22 horizon is dark brown to light brown, medium acid, gravelly loam, 10 to 20 inches thick. The C horizon is dark brown to brown, medium acid, very gravelly loam. Staser soils are Mollisols that form in alluvium on infrequently flooded streambottoms. They have moderately rapid permeability and are well drained. Available moisture is moderately low because of the gravel content; fertility is high (Fig. 23).

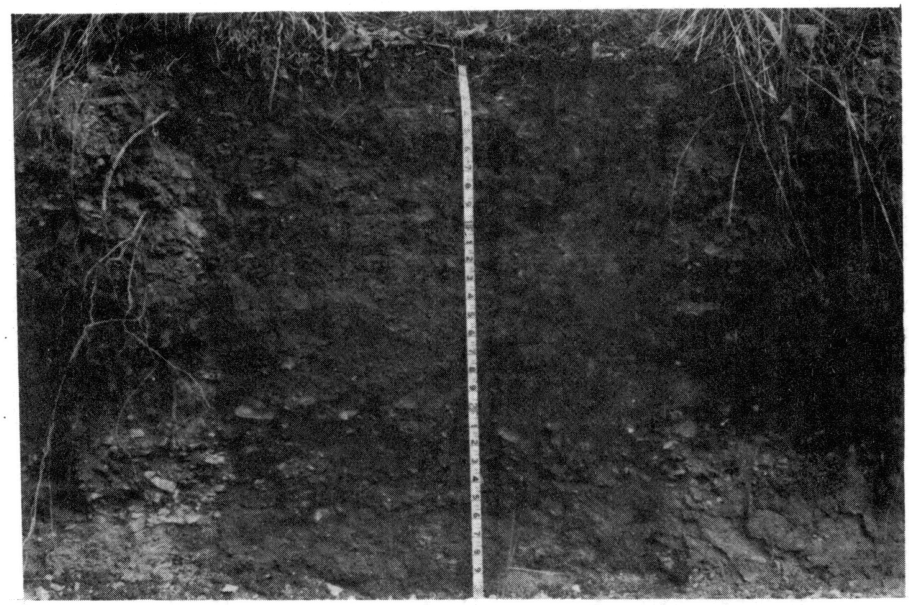


Fig. 22. Profile of Sallisaw soil exposed in a road bank in Bolin Hollow, Section 2, T14N, R23E

Fig. 23. Profile of Staser soil exposed in a bank in an old field in Bolin Hollow, Section 13, T14N, R23E

Summit Series. Summit soils are deep soils with moderately fine-textured surface layer and subsoil. The A1 horizon is black to dark grey, slightly acid, silty-clay loam, 2 to 6 inches thick. The B1 horizon is very dark brown to dark brown, slightly acid, heavy-silty loam, 5 to 14 inches thick. The B2t horizon is olive-brown, moderately alkaline, silty clay, 20 to 40 inches thick. The R horizon is limestone bedrock. Summit soils are Mollisols that develop on limestone on gentle slopes. They are slowly permeable and moderately well drained. Available moisture, organic matter, and fertility are high (Fig. 24).

Talpa Series. Talpa soils are very-shallow to shallow soils having a moderately fine surface layer lying over bedrock. The A1 horizon is very dark brown to dark greyish-brown, neutral, silty-clay loam, 2 to 15 inches thick. The R horizon is limestone bedrock. Talpa soils are Mollisols that form in limestone on gentle-to-steep slopes. They have moderately slow permeability and are well drained. Available moisture capacity is low because of the shallow profile. Organic matter content and fertility are high (Fig. 25).

A summary of physical and chemical characteristics of the soils of the refuge is presented in Table 3.

Climate

Oklahoma has the continental type of climate (Wahlgren 1941). Temperature fluctuates widely daily and seasonally, and precipitation varies seasonally. Warm, moist, air masses from the Gulf of Mexico and cool dry air from the Arctic region and the Pacific Ocean influence the climate (Cole 1970). Pacific and Arctic air masses dominate weather patterns during winter months, whereas Gulf air exerts major influence

Fig. 24. Profile of Summit soil exposed in a pit in a meadow, Section 24, T14N, R23E

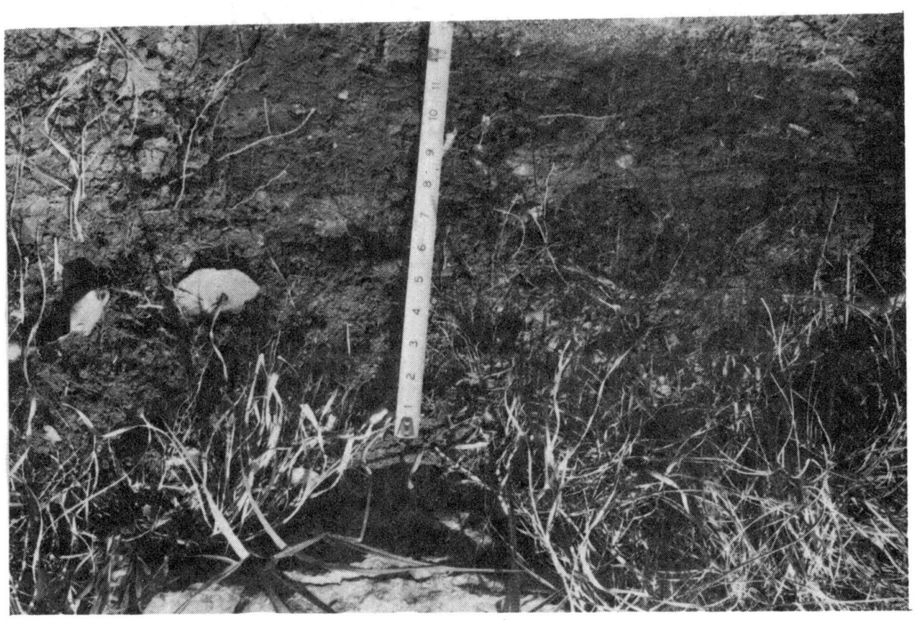


Fig. 25. Profile of Talpa soil exposed along a road on Beaver Mountain, Section 6, T14N, R24E

Table 3. Some physical and chemical characteristics of soils on the Cookson Hills State Game Refuge (Cole 1970)

Soil Series	Depth from Surface of Typical Profile (Inches)	Texture	Available Water Capacity (Inches per Inch of Soil)	pH	Permeability (Inches per Hour)
Clarksville	0-10	Very cherty silt loam	.08	5.1-5.6	6.3-10.0
	10-40	Very stony silty clay loam	.06	4.5-5.5	
	40-60	Chert beds	.05	4.5-5.5	
Elsah	0-60	Very gravelly loam	.05	5.6-7.3	5.3-20.0
Hector	0-15	Fine sandy loam	.10	5.1-6.5	2.0-6.3
Linker	0-6	Fine sandy loam	.12	4.5-6.0	.63-2.0
	6-11	Loam	.14	4.5-6.0	
	11-39	Clay loam	.17	4.5-6.0	
Sallisaw	0-18	Gravelly silt loam	.10-.14	5.6-6.5	.63-2.0
	18-32	Gravelly silty clay loam	.12-.17	4.5-6.0	
	32-60	Very gravelly silty clay loam	.08	4.5-6.0	
Staser	0-24	Gravelly loam	.10-.14	6.1-7.3	2.0-6.3
	24-43	Gravelly silt loam	.10-.14	5.6-7.3	
	43-60	Very gravelly loam	.05	5.6-7.3	

Table 3 (Continued)

Soil Series	Depth from Surface of Typical Profile (Inches)	Texture	Available Water Capacity (Inches per Inch of Soil)	pH	Permeability (Inches per Hour)
Summit	0-17	Silty clay loam	.17	5.6-7.3	.06-1.0
	17-48	Silty clay	.15	6.1-8.4	
Talpa	0-9	Silty clay loam	.17	6.1-7.3	.20-.63

on weather in the other three seasons. The heaviest rains occur during spring and fall when the two types of air masses shift rapidly back and forth across the region. Precipitation in summer ususally comes from convection thunderstorms.

Winters in the Cookson Hills region are short, mild, and dry. January is the coldest month of the year. December and January are the driest months. Summers are hot and long. July and August are the warmest months. The wettest months are April, May and June during the spring and September and October during fall.

Mean annual temperature is 60° F. Seasonal range of mean temperature is 42° F. January is the coldest month with a mean temperature of 38° F and July is the warmest month with a mean temperature of 81° F. Daily temperature fluctuations average 24° F (Cole 1970). The mean length of the growing season is 207 days. Mean date for the last frost in spring is April 6 and mean date for the first frost in fall is October 30 (Wahlgren 1941).

Yearly precipitation totals average slightly over 43 in. Seasonal distribution of precipitation is 37 percent in spring, 23 percent in summer, 21 percent in fall, and 19 percent in winter. December and January are the driest months, averaging 2.33 in of precipitation for each month. May is the wettest month of the spring, averaging 6.14 in of rainfall, and September is the wettest month of the fall, averaging 4.00 in of precipitation. Snow may occur from November to April. Total annual snowfall averages 6 in. There is snow cover on the ground an average of 12 days per year; and the snow cover is deeper than 1 in for 3 days per year (Cole 1970, Warth and Polone 1965).

Data for temperature and precipitation from Cole (1970) are given in Table 4.

Table 4. Temperature and precipitation at Tahlequah, Cherokee County, Oklahoma for the years 1931 to 1960 (Cole 1970)

Month	Average Daily Maximum Temperature F	Average Daily Minimum Temperature F	Average Monthly Total Precipitation (Inches)
January	49.8	27.4	2.33
February	54.6	30.8	2.79
March	62.2	37.3	3.17
April	72.5	48.5	4.63
May	79.4	55.9	6.14
June	87.7	65.3	5.10
July	93.2	68.8	3.00
August	93.6	67.7	3.05
September	86.7	59.7	4.00
October	75.6	48.6	3.67
November	61.6	35.8	2.89
December	52.7	30.0	2.33

Additional climatic data from Cole (1970) are for relative humidity, cloudiness, sunshine, evaporation, and wind. Relative humidity in winter averages 80 percent at night and 60 percent in the afternoon. For summer the relative humidity averages nearly 85 percent at night and 55 percent in the afternoons. On the average there are 130 clear days, 95 partly cloudy days, and 140 cloudy days per year. Possible sunshine ranges from 48 percent in January to 73 percent in August. Evaporation from open water averages 48 in per year; there is a deficit of 5 in between precipitation and evaporation annually. During the growing season there is a 9.6 in deficit between precipitation and evaporation; more than 6 inches of this deficit occurs in July and August. Winds are predominantly from the south to southeast during all months of the year except January and February when northerly winds prevail. Average windspeeds range from 12 mph in March to 8 mph in July and August.

Vegetation

Present Day Vegetation Types on the Cookson Hills State Game Refuge

The vegetation on the refuge is predominantly second-growth oak-hickory forest. Grasslands or savannah occur on some of the ridge tops on Hector soils and on some gentle slopes on Summit and Talpa soils. There are 22 meadows containing a total area of 270 acres maintained on level to gently sloping Clarksville, Hector, Sallisaw, and Summit soils. About 65 acres in 18 old fields are in various stages of secondary succession on Clarksville, Sallisaw, and Staser soils. Meadows, old fields, and the major vegetation types are shown in Fig. 26.

Officially Described Forest Types

Many forest stands on the refuge conform to descriptions of Society of American Foresters (1954) forest cover types. Descriptions of these forest cover types and their relationships to soils and topography follow.

Type 40 Post Oak-Black Oak. Post oak (*Quercus stellata*) and black oak (*Q. velutina*) or blackjack oak (*Q. marilandica*) are dominant. The most common associates are mockernut hickory (*Carya tomentosa*) and black

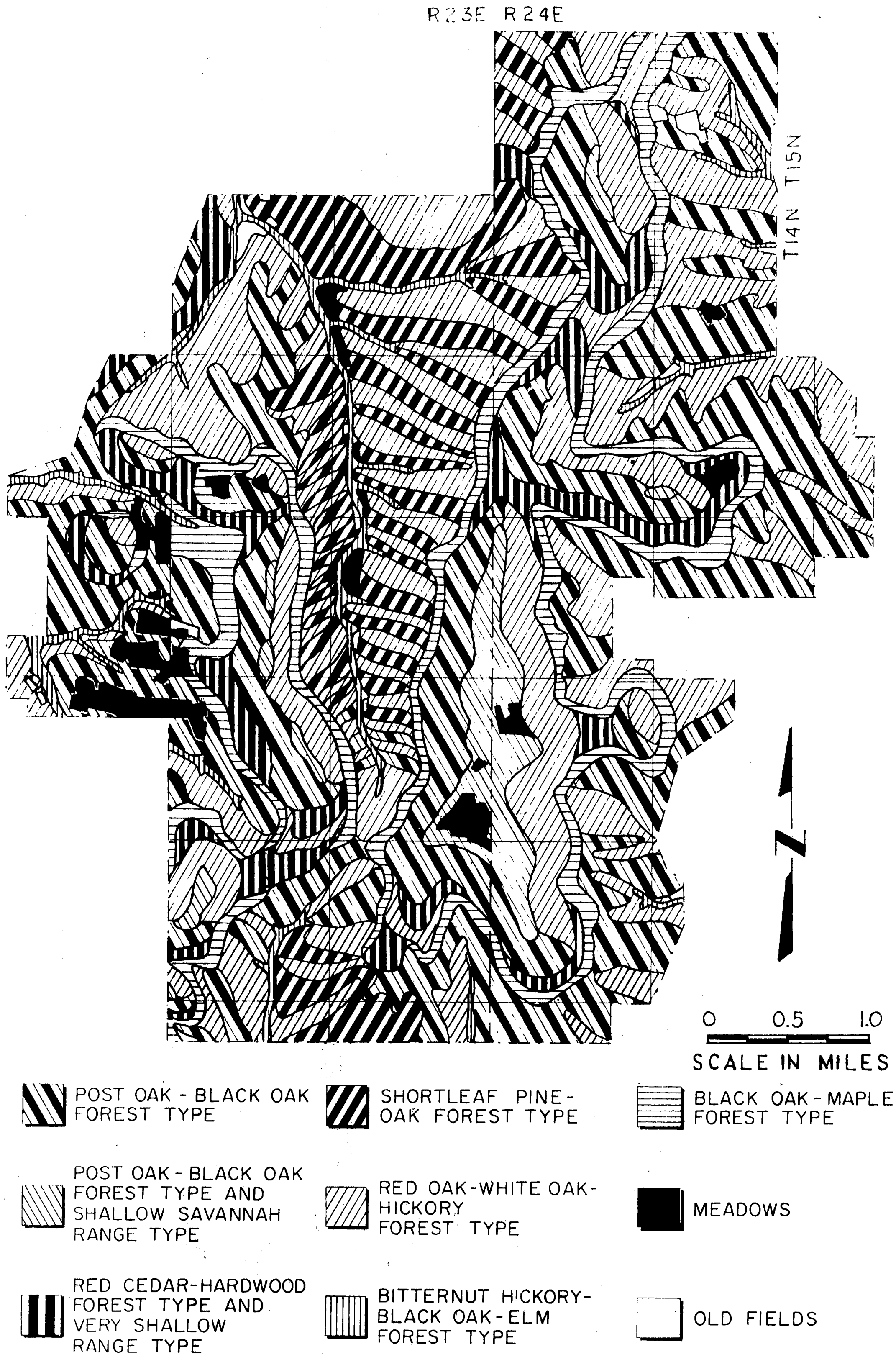


Fig. 26. Map of Cookson Hills Refuge showing distribution of major forest and grassland types, meadows, and old fields

hickory (C. texana). Other common associates are post-oak grape (Vitis Linsecumii), few-flowered panic grass (Panicum oligosanthes), broomsedge (Andropogon virginicus), sedge (Carex sp.), creeping bush-clover (Lespedeza repens), and goldenrod (Solidago sp.).

The type, or its post oak-blackjack oak variant, occurs on level ridge tops in Hector soils (Fig. 27). The common associates here are white oak (Q. alba), winged elm (Ulmus alata), hackberry (Celtis occidentalis), fragrant sumac (Rhus aromatica), purpletop (Tridens flavus), rock dropseed (Muhlenbergia sobolifera), soft-leaved panic grass (Panicum malacophyllum), and panicled tick-trevoil (Desmodium paniculatum). When present on drier southerly-to-westerly-facing slopes in Linker soils, the type contains (Fig. 28) walnut (Juglans nigra), shagbark hickory (C. ovata), chinquapin oak (Q. Muehlenbergii), winged elm, american elm (U. americana), redbud (Cercis canadensis), black locust (Robinia pseudoacacia), sugar maple (Acer saccharum), persimmon (Diospyros virginiana), white ash (Fraxinus americana), American plum (Prunus americana), saw greenbriar (Smilax Bona-nox), fragrant sumac, frost grape (Vitis vulpina), hairy wood-chess (Bromus purgans), broad-leaved spikegrass (Uniola latifolia), virginia wildrye (Elymus virginicus), tick-trefoil, butterfly-pea (Clitoria mariana), hog-peanut (Amphicarpa bracteata), black snakeroot (Sanicula canadensis), arrow-leaved aster (Aster sagittifolius), and black-eyed susan (Rudbeckia hirta). The type lies on ridge tops and south to west slopes in Clarksville soils (Fig. 29). On ridge tops in the Clarksville soils, common associates are walnut, chinquapin oak, winged elm, sassafras (Sassafras albidum), southern red oak (Q. falcata), black locust, persimmon, plum, coralberry (Symphorocarpos orbiculatus), butterfly-pea, hog-peanut, horsemint

Fig. 27. Stand of post oak-black oak type on Hector soil

Fig. 28. Stand of post oak-black oak type on southwest facing slope in Linker soil

Fig. 29. Stand of post oak-black oak type on a ridge top in Clarksville soil

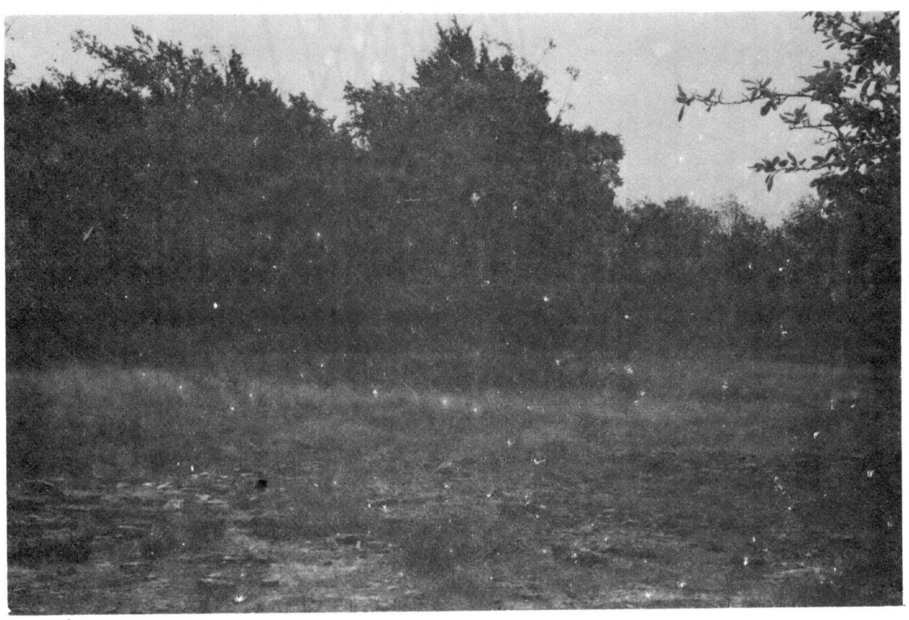


Fig. 30. Stand of eastern red cedar-hardwood type in Talpa soil

(*Monarda Russelliana*), tick-trefoil, and black-eyed susan. On upper slopes in Clarksville soils associates are short-leaf pine (*Pinus echinata*), white oak, sassafras, black locust, winged sumac (*R. copallina*), smooth sumac (*R. glabra*), farkleberry (*Vaccinium arboreum*), slender bush-clover (*Lespedeza virginica*), butterfly-pea, hog-peanut, and arrow-leaved aster. On lower slope positions additional associates are southern red oak, ozark chinquapin (*Castaenea ozarkensis*), black gum (*Nyssa sylvatica*), flowering dogwood (*Cornus florida*), and deerberry (*Vaccinium staminium*). The type is climax.

Type 46 Eastern Red Cedar and Type 48 Eastern Red Cedar-Hardwoods. Eastern red cedar (*Juniperus virginiana*) is dominant in Type 46. In Type 48 dominance is shared with chinquapin oak, winged elm, and hackberry. Common associates are black, mockernut and shagbark hickories, persimmon, white ash, american plum, redbud, saw greenbriar, roughleaf dogwood (*C. Drummondii*), hairy wood-chess, broadleaved spikegrass, purpletop, canada wildrye (*E. canadensis*), rock dropseed, sedge, prairie-tea (*Croton monanthogynus*), three-seeded mercury (*Acalypha gracilens*), and toothed spurge (*Euphorbia dentata*).

Both types occur as "cedar glades" in the Talpa-rock outcrop complex and along cliff escarpments (Fig. 30). Type 46 is temporary and is succeeded by Type 48, which may be the climax on these sites.

Type 50 Black Locust. Black locust is dominant. Associate species depend on site and are from the type that is climax for the particular site.

Type 50 occurs most commonly in Linker and Summit soils but also is present in Hector, Clarksville, Staser, and Sallisaw soils (Fig. 31). The black locust type is temporary.

Fig. 31. Stand of black locust type in an old field in Sallisaw soil

Fig. 32. Stand of white oak-red oak-hicory type on east-facing slope in Linker soil

Type 52 White Oak-Red Oak-Hickory. Dominant species are white oak, northern red oak (Q. rubra) or black oak, and black and mockernut hickory. Common associates are post oak, chinquapin oak, and hairy wood-chess.

This type occurs in Sallisaw soils and on north-to-east facing slopes in Linker and Clarksville soils. In Linker soils, the white oak-black oak-hickory variant is common (Fig. 32). Associates are walnut, shagbark hickory, winged elm, american elm, redbud, sugar maple, white ash, saw greenbriar, fragrant sumac, soft-leaved panic grass, sedge, smooth ruellia (Ruellia strepens), and wing-stem (Actinomeris alternifolia). In Clarksville soils associates are american hop-hornbeam (Ostrya virginiana), ozark chinquapin, sassafras, sugar maple, black gum, flowering dogwood, post-oak-grape, deerberry, broad-leaved spikegrass, broomsedge, tick-clover, creeping bush-clover, butterfly-pea, hog-peanut, and goldenrod (Fig. 33). In Sallisaw soils associates are walnut, bitternut hickory (C. cordiformis), american hop-hornbeam, southern red oak, red mulberry (Morus rubra), sycamore (Platanus occidentalis), carolina buckthorn (Rhamnus caroliniana), flowering dogwood, white ash, virginia creeper (Parthenocissus quinquefolia), post-oak-grape, coral-berry, few-flowered panic grass, hog-peanut, horsemint, and smooth ruellia (Fig. 34). White oak, red oak, and hickory characterize the climax on these sites.

Type 64 Sassafras-Persimmon. Sassafras and persimmon are dominant. Associate species are black and mockernut hickory, post oak, chinquapin oak, black oak, winged elm, american elm, hackberry, black locust, white ash, chinabriar, blackberry (Rubus ozarkensus), smooth and winged sumac,

Fig. 33. Stand of white oak-red oak-hickory type on east-facing slope in Clarksville soil

Fig. 34. Stand of white oak-red oak-hickory in Sallisaw soil

coralberry, japanese chess (Bromus japonicus), purpletop, broomsedge, canada wild-rye, johnson-grass (Sorghum halapense), and sericea lespedeza (L. cuneata).

The type occurs on abandoned fields in Hector, Clarksville, Staser, and Sallisaw soils. The sassafras-persimmon type is a temporary type that pioneers on disturbed sites (Fig. 35).

Type 76 Shortleaf Pine-Oak. Shortleaf pine, post oak, and blackjack oak are dominants. Associated species are black hickory, mockernut hickory, white oak, black oak, southern red oak, sassafras, smooth, winged, and fragrant sumac, farkleberry, little bluestem (Andropogon scoparius), broomsedge, creeping bush-clover, slender bush-clover, butterfly-pea, hog-peanut, goldenrod, and arrow-leaved aster.

This type occurs only on south-to-east-facing slopes in Clarksville soils (Fig. 36). The pine-oak type appears to be climax on these sites on the refuge.

Type 95 Black Willow. The dominant species is black willow (Salix nigra). Associated species are occasional american elm, sycamore, boxelder (Acer negundo), persimmon, roughleaf dogwood, white avens (Geum canadense), tick-trevoil, Korean lespedeza (L. stipulacea), three-seeded mercury, toothed spurge, black snakeroot, fragrant bedstraw (Galium triflorum), and white snakeroot (Eupatorium rugosum).

The black willow type occurs sporadically along stream banks and on gravel bars (Fig. 37). It is a temporary type.

Grassland Types

Grassland types occur on three kinds of sites. These are loamy-prairie-range sites on Summit soils, very-shallow-range sites on Talpa

Fig. 35. Stand of sassafras on edge of a meadow in Clarksville soil

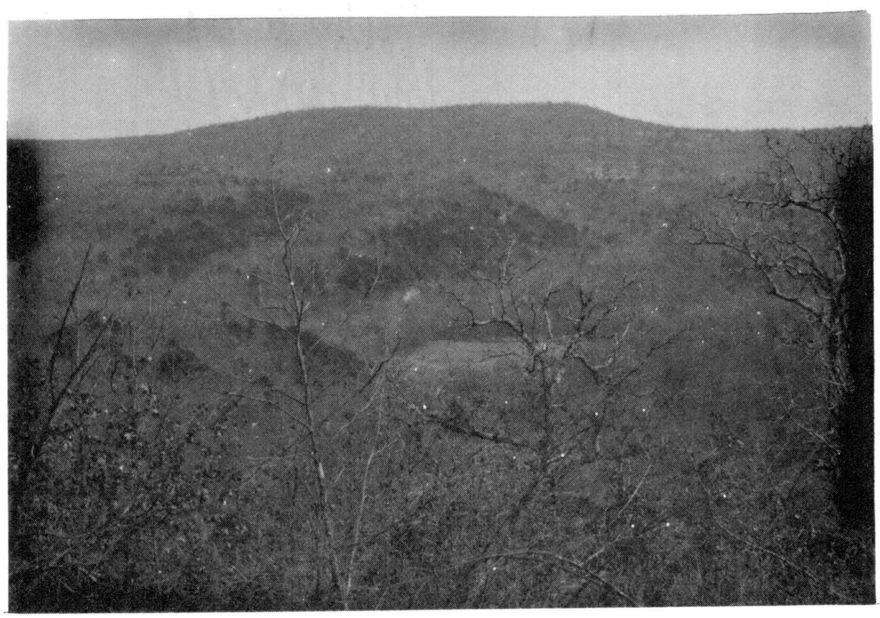


Fig. 36. Stand of shortleaf pine-oak on south-facing slopes in Clarksville soil

Fig. 37. Stand of black willow along a stream bank in Elsah soil

Fig. 38. Loamy-prairie range site converted to meadow on Summit soil

soils, and shallow savannah-range-sites on Hector soils (Warth and Polone 1965, Cole 1970).

Loamy Prairie Range Site. Dominant grass species are big bluestem (*Andropogon Gerardii*), little bluestem, indian grass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Associates are eastern gamagrass (*Tripsacum dactyloides*), purpletop, rock dropseed, nodding wild-rye, broomsedge, silvery beardgrass (*Andropogon saccharoides*), cat-claw sensitive briar (*Schrankia uncinata*), illinois bundleflower (*Desmanthus illinoensis*), creeping bush-clover, tall ironweed (*Vernonia altissima*), goldenrod, black-eyed susan, and common ragweed (*Ambrosia artemisiifolia*). Woody invaders are catclaw greenbriar, roughleaf dog-wood, coralberry, black oak, chinquapin oak, winged elm, white ash, hawthorn, and persimmon.

The loamy-prairie-range sites occur on Summit soils that are level to gently sloping. These sites have been converted to meadows or are invaded by woody species (Fig. 38).

Very Shallow Range Sites. Dominant species are big bluestem, little bluestem, indiangrass, and sideoats grama (*Bouteloua curtipendula*). Associates are silvery beardgrass, illinois bundle-flower, prairie clovers (*Petalostemum* spp.), creeping bush-clover, prickly pear (*Opuntia compressa*), blazing-star (*Liatris squarrosa*), gumweed (*Grindelia lanceolata*), annual broomweed (*Gutierrezia dracunculoides*), black-eyed sysan, fragrant sumac, and coralberry.

The very-shallow-range sites occur on the Talpa-rock outcrop complex and intermingle with eastern red cedar-hardwood and plum thicket types (Fig. 39).

Fig. 39. Very-shallow range site on Talpa soil-rock outcrop complex

Fig. 40. Shallow-savannah range type on level site in Hector soil

Shallow Savannah Range Site. Dominant grasses are little bluestem, big bluestem, and indiangrass. Associates are broomsedge, purpletop, few-flowered panic grass, rock dropseed, creeping bush-clover, tick-clover, prairie-tea, nodding wild-rye, slender bush-clover, goldenrod, and black-eyed susan. The overstory is the post oak-black oak type.

The shallow-savannah-range type occurs on ridge tops in Hector soils (Fig. 40).

CHAPTER IV

HISTORY OF LAND USE IN THE STUDY AREA

Vegetation Prior to Settlement

Field notes of the surveys of the subdivision lines of townships T14N,R23E (Gibson and Haskbusch 1898), T14N,R24E (Johnson et al. 1898), and T15N,R24E (Jones and Morse 1898) and the field notes of the survey of the north boundary of Township 14 N, Range 24 E (Wilkinson et al. 1897) were analyzed for characteristics of the vegetation existing on the refuge area before the presence of white settlers.

Records of witness trees on 51 section lines that are wholly or partially in the present boundaries of the Cookson Hills State Game Refuge were analyzed for frequency of occurrence. Oak, hickory, and elm were not identified by species in the field notes. Oaks occurred on 100 percent of the section lines and hickory was present on 98 percent of the lines. The frequency of elm was 45 percent. Frequency of trees that were identified by species was 31 percent for shortleaf pine, 10 percent for walnut, 8 percent for red cedar, 4 percent for white ash, and 2 percent for black locust. "Brush" and "briars" occurred on 8 percent of the lines. Grassland types were not mentioned in the field notes for any of the lines within the present boundaries of the refuge.

Elm was present on 13 township subdivision lines in T14N,R23E, all

Bolin Hollow, and on two lines in T15N,R24E. Walnut was present on three lines in T14N,R23E and on one line in T14N,R24E. Red cedar was on four lines in T14N,R23E. Ash and black locust were in T14N,R24E. "Brush" and "briars" occurred on one line in T14N,R24E.

Data from 155 witness trees were analyzed for density, basal area, relative density, and relative dominance using methods listed by Phillips (1959). The data were analyzed for the refuge as a whole; to stratify the data by soils and slope aspect would result in insufficient data for reasonable estimates in any of the soil series-slope aspect classes. Most oak trees were identified by species in the field notes; hickory and elm were not.

Total density was 24.77 trees per acre and basal area was calculated as 20.53 sq ft per acre. These figures must be regarded as minimal. Size was one of the criteria surveyors used to select witness trees, and small trees close to section and quarter section corner markers were ignored in favor of larger trees that were farther away. The smallest witness tree recorded on the refuge was 51 in in diameter. Number of trees, relative density, and relative dominance (Phillips 1959) are given in Table 5.

Influence of Human Activity

The Osage Indians were the first tribes recorded living in northeast Oklahoma. They were hunters and farmers. Their corn fields and permanent villages were located in the valleys along the major streams in the area. When not engaged in growing their crops, the Osage moved westward to temporary camps on the prairies to hunt bison (Wright 1957).

Activities of the Osage probably had little effect on vegetation in the area of the refuge.

Table 5. Relative frequency and relative dominance of witness trees of township subdivision lines on the Cookson Hills Refuge

Species	Number of Trees	Relative Frequency	Relative Dominance
Shortleaf pine	1	.64	1.37
Black walnut	3	1.93	1.19
Hickory	10	6.45	5.01
White oak	26	16.77	20.31
Post oak	39	25.16	22.31
Northern red oak	47	30.32	32.87
Black oak	4	2.58	3.24
Southern red oak	4	2.58	2.89
Blackjack oak	2	1.29	.55
Oak spp.	8	5.16	4.93
Elm	8	5.16	4.45
Mulberry	1	.64	.27
White ash	2	1.29	.55

Cherokee Indians began moving from the southeastern United States and settling in northwest Arkansas early in the nineteenth century. In 1838 they traded their lands in Arkansas for land in northeast Oklahoma. In 1839 these early settlers were joined by Cherokee immigrants from North Carolina and Tennessee (McReynolds et al. 1961). The Cherokees were farmers and had adopted the agricultural methods and crops of their white neighbors in their homeland in Georgia, Tennessee, and the Carolinas. After settlement in Oklahoma their principal crops were corn and wheat (Warth and Polone 1965).

The earliest white settlements in the area were the trading village of Three Forks, near the confluence of the Arkansas, Verdigris, and Neosho Rivers, and the military posts of Fort Smith and Fort Gibson (Morris and McReynolds 1965). These earliest white men were merchants and soldiers whose presence had little or no effect on vegetation in the area of the refuge.

The Cherokee Nation remained generally free of intrusion by white men until after the Civil War. Renegades and outlaws sought refuge in the Indian Nations, and when the Missouri-Kansas-Texas Railroad was completed in the early 1870's, some white settlers began to move into the Cherokee Nation (McReynolds et al. 1961).

In the 1890's the Dawes Commission began preparation for dissolving the Indian Nations by arranging for individual allotments of Indian lands and bargaining for the unallotted land. The Curtis Act of 1898 authorized the individual allotments to Indians and the establishment of a Territorial Government (McReynolds et al. 1961).

The effects of early settlement by Cherokee and white people apparently was negligible in the area of the refuge. The field notes of the township subdivision lines (Gibson and Haskenbusch 1898, Johnson et al. 1898, and Jones and Morris 1898) mention the Missouri-Kansas-Texas Railroad and farm settlements in the valley of Sallisaw Creek east of the present refuge and farms along Elk Creek west of the refuge. Only one farmstead, located in the northeast quarter of Section 22, T14N, R23E, was recorded within the present boundaries of the refuge.

Some settlement occurred after 1900. Meadows and abandoned fields within the present boundaries of the refuge total 335 acres, and during the course of this investigation eight cabin foundations were located.

Prior to 1910 there was no commercial timber harvest. The area was open range. Some fields were cleared and some oak was cut for rail fences (Orville "Cy" Curtis and Joseph Fletcher, Sr., personal communication).

Commercial timber harvest began in 1910 when a sawmill was established at the north end of Bolin Hollow. Sawed and planted lumber was hauled over Beaver Mountain to be transported to markets by the Missouri-Kansas-Texas Railroad. This mill operated from 1910 to 1920. Pine was harvested from 1910 to 1915 and the mill continued to operate by sawing hardwoods until 1920. Highgrading by individuals for supplemental income began in the 1920's and continued through the 1940's. Hickory and ash were cut for tool handles, white oak for barrel staves, and oak and black gum were cut for railroad ties (Orville "Cy" Curtis and Joseph Fletcher, Sr., personal communication).

In 1951 the area was established as the Cookson Hills State Game Refuge by the Oklahoma Department of Fish and Game (Anonymous 1954). Since establishment, the area has been managed as a deer refuge and management area by the Oklahoma Department of Fish and Game and its successor, the Oklahoma Department of Wildlife Commission.

Fire

There are no detailed records of fires on the area before it was established as a game refuge. Mention of a severe fire in the Cookson Hills is made in the May, 1945 issue of Oklahoma Fish and Game (Anonymous 1945). After the Cookson Hills Refuge was established detailed fire reports were kept. A summary of these records is given in Table 6 and location of the areas burned is shown in Fig. 41.

Table 6. Date, location, acreage, and estimated severity of fires on the Cookson Hills State Game Refuge from 1954 to 1967

Date	Location	Acres Burned	Severity
May 17, 1954	Sec. 1, T14N, R23E and Sec. 30, T15N, R24E	350	Severe
Mar 30, 1955	Sec. 23 & 26, T14N, R23E	600	Severe
May 6, 1955	Sec. 12, T14N, R23E	10	Light
Mar 31, 1956	Sec. 10, T14N, R23E	5	Moderate
Sept 17, 1956	Sec. 13, T14N, R23E	1	Light
Apr 5, 1957	Sec. 12, T14N, R23E	2	Light
Feb 14, 1960	Sec. 5, T14N, R24E	1/4	Moderate
May 6, 1960	Sec. 32, T15N, R24E	1	Moderate
Jan 22, 1961	Sec. 23, T14N, R23E	3	Light
Apr 17, 1962	Sec. 1, T14N, R23E	3	Moderate
May 6, 1962	Sec. 1, T14N, R23E and Sec. 31, T15N, R24E	25	Moderate
May 7, 1962	Sec. 15, T14N, R23E	150	Light
Mar 20, 1963	Sec. 2, T14N, R23E	60	Not given
Mar 21, 1963	Sec. 2, T14N, R23E	40	Not given
Mar 25, 1963	Sec. 31, T14N, R23E	160	Not given
Mar 28, 1963	Sec. 36, T14N, R23E	35	Not given
Apr 30, 1963	Sec. 17, T14N, R24E	150	Not given
May 7, 1963	Sec. 35, T14N, R23E	1	Not given
May 7, 1963	Sec. 26 & 35, T14N, R23E	45	Not given
Apr 13, 1964	Sec. 1, 2, & 12, T14N, R23E	650	Severe
May 1, 1966	Sec. 5, T14N, R24E and Sec. 32, T15N, R24E	1 & 1/2	Not given
May 2, 1966	Sec. 26 & 35, T14N, R23E	690	Severe
Mar 1, 1967	Sec. 16, T14N, R24E	10	Moderate
Mar 23, 1967	Sec. 11, 12, 13, 14, 23, & 24, T14N, R23E	1,465	Severe

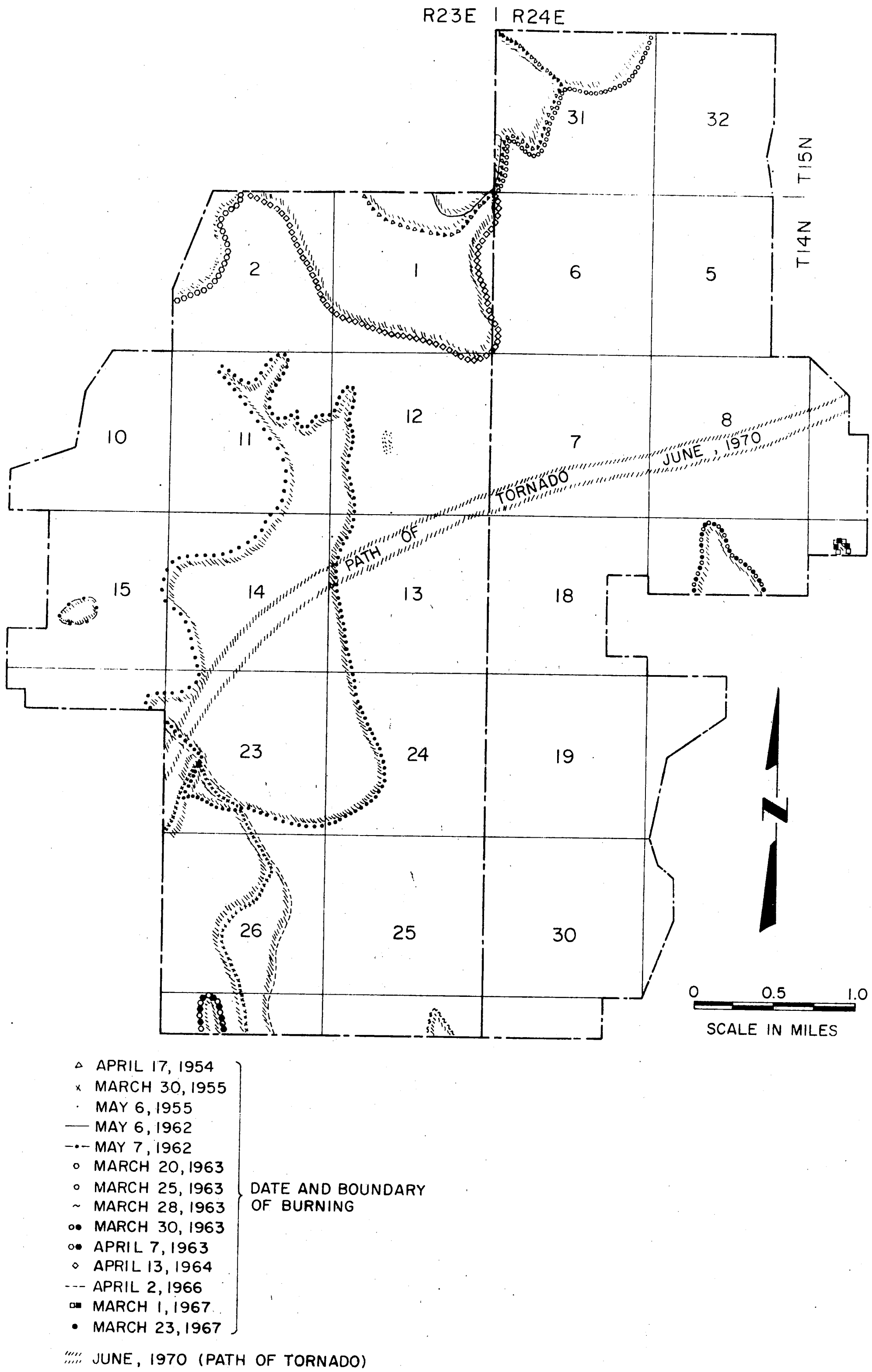


Fig. 41. Map of the Cookson Hills Refuge showing the location of fires of more than 10 acres from 1954 to 1967 and path of a tornado in June 1970

Weather

High winds and tornados are infrequent in the region, but in June 1970 a tornado struck the refuge. It entered the refuge at the southwest corner and moved northeasterly across the refuge. Considerable damage was caused to trees along a course 1/4 to 1/2 mile wide and 5 miles long. The path of this storm is shown in Fig. 41.

The effects of weather are usually restricted to stress from lack of moisture during drouthy periods and wind and ice damage to trees during severe winters.

CHAPTER V

METHODS AND MATERIALS

Design

From the discussion in Chapter II it is concluded that the continuum concept (Curtis and McIntosh 1951) most accurately describes the distribution of plants in relation to their environments. The poly-climax theory (Odum 1953) can also be an accurate model for plant distribution and is a more useful model for management purposes (Bill T. Crawford, personal communication).

Jenny's (1941) model for soils states that a soil (S) is the function of the interaction between parent material (PM), climate (C), living organisms (LO), topography or relief (R), and time (T).

$$S = f\ PM, C, LO, R, T$$

Jenny's model can be rearranged to serve as a model for the distribution of vegetation (V) in a polyclimax. This model can be refined by adding a factor called disturbance (D) to include the effects of fire, severe weather, and the activities of man.

$$V = f\ S, C, R, PM, T, D$$

The modified model states that the vegetation on a site is the result of interactions of the soil, climate, relief or topography, parent material or surface geology, time, and disturbance. Briefly it predicts that the vegetation will be similar on sites having similar ecological conditions. A randomized block design (Steele and Torrie 1960) was selected to test the hypothesis that vegetation is similar on sites that are ecologically similar.

Definition of Blocks

The sampling blocks for this study were defined by the variables: soil series, topography or position, and disturbance from logging and agriculture. Parent material was assumed constant for each soil series. Underlying geological material was an independent variable for soils in transported parent material, and was used to distinguish blocks in Elsah soils in alluvium in stream bottoms. Fire as a disturbance factor was not used in the definition of blocks because the records are incomplete before 1951 and because the variation in time and severity of the fires recorded would have resulted in an unwieldly number of blocks. Time and climate were assumed to be constant factors in this study.

Selection of Sampling Method

Three vegetation sampling methods, which could be applied to all vegetation: trees, shrubs, grasses, and forbs, were selected for evaluation. The methods tested were quadrats, point center quarter, and line intercepts (Phillips 1959). Quadrat sizes used were 1/200, 1/100, and 1/50 acre. Line intercepts used were 100 ft, 200 ft, 250 ft, and 500 ft long. In the point-center-quarter method 18 points were used. The number of vegetation samples drawn from each variant of each method ranged from 3 to 18. A record of time required for completion was kept for each sample. Variances were calculated from frequency for quadrats and the point-center-quarter method and from cover for line intercepts. The number of samples required for 95 percent confidence level was calculated with the formula

$$n = \frac{t_1^2 \, s^2}{d^2} \quad \text{(Steel and Torrie 1960:85)}$$

where n is the number of samples required, t_1 is the tabulated t value for the desired confidence interval and the degrees of freedom of the initial sample and d is one-half the width of the desired interval. The number of samples required was multiplied by the average time required to sample with each variant of each method to estimate the total time required to sample with each method. Results are presented in Table 7.

Table 7. Number of samples drawn, average time, number of samples needed, total time required for point-center-quarter, quadrat, and line-intercept methods

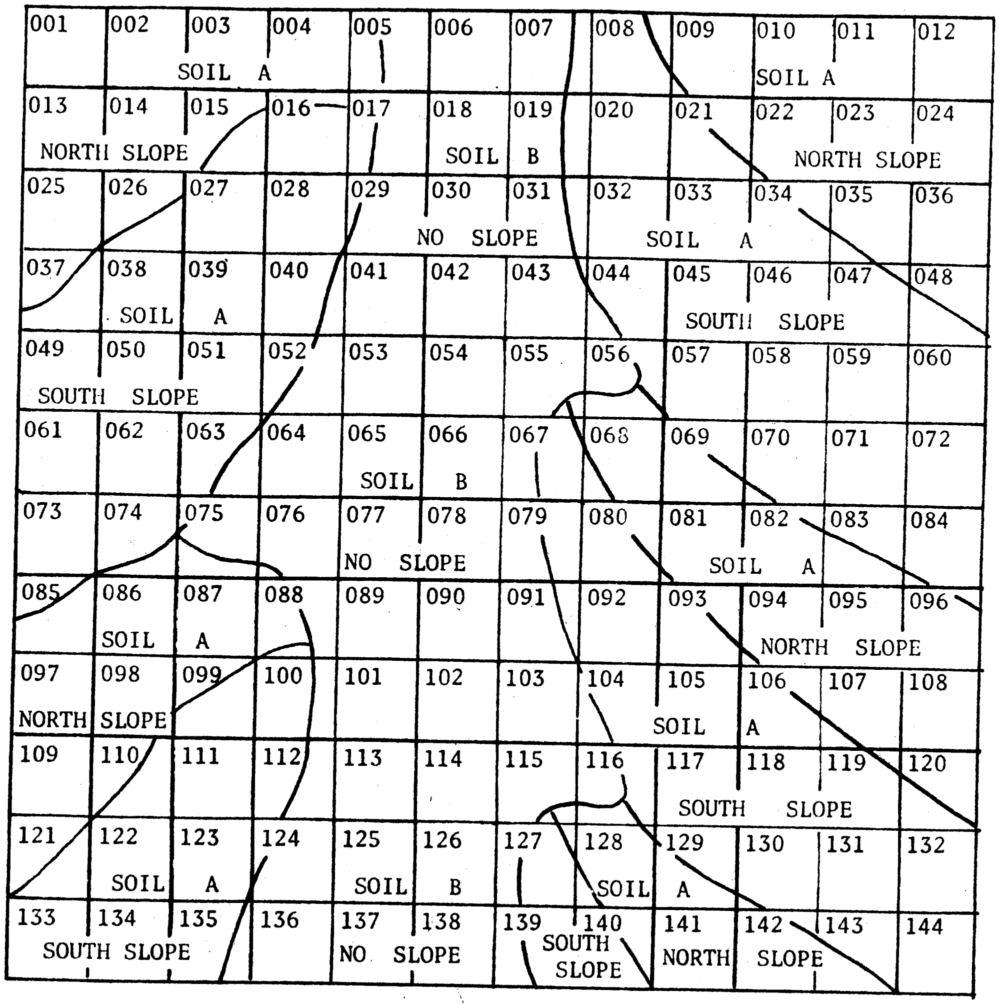
Method	No. Samples Drawn	Average Time Per Sample (Min)	No. Samples Required	Total Time Required (Min)
Point Center Quarter	18	60	43	2580
100-ft Line	15	105	21	2205
200-ft Line	6	210	15	3150
250-ft Line	6	240	12	2880
500-ft Line	3	320	23	7360
1/200-Acre Quadrat	3	40	1061	42440
1/100-Acre Quadrat	3	110	1178	129580
1/50-Acre Quadrat	3	160	345	55200

The point-center-quarter method and the shorter line intercepts were found most economical in number of samples needed and total time required. The larger number of samples required with the 500-ft line and the quadrats may be due to the small number of samples drawn with each method. Selection of the 250-ft line instead of the 100-ft line was made because fewer samples were needed with the longer line. Choice of line intercepts over the point-quarter-center method was made because of the fewer samples needed for the line and because lines are less biased by relative frequencies of different species. The point-center-quarter method oversamples abundant species and undersamples the less-abundant species. It was determined that 100-ft lines were adequate for estimates of tree reproduction and woody shrubs and vines and that 50-ft lines were adequate for grasses and forbs.

Randomization of Sampling

A map of the refuge was prepared showing soil series, slope aspect, meadows, and old fields. For Elsah soils in stream bottoms, underlying chert or limestone and flood plain or stream bank position were also indicated. The boundaries of fires greater than 20 acres in area were also drawn on the map in order to stratify randomization within blocks. A grid was drawn on the map with lines spaced at 1/4-mile scale intervals. A number was assigned to each square in the grid. Starting with 001 in the left-most square in the top row, consecutive numbers were assigned to squares across rows from left to right beginning in the top row and proceeding downward to the bottom row. An example is shown in Fig. 42.

A table was prepared for each block that listed the number of every



Soil A, North Slope Aspect = Block 1

Soil A, South Slope Aspect = Block 2

Soil B, No Slope = Block 3

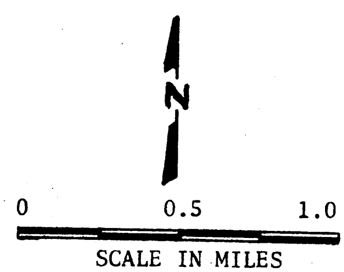


Fig. 42. Schematic diagram illustrating a method of superimposing a grid of numbered squares and how soil series and slope aspects are arranged in blocks

grid square in which the block (soil series-slope aspect, position, disturbance) was present. The numbers were also stratified by fire. Next, three-digit numbers were drawn from a table of random numbers (Steel and Torrie 1960:428-431). Numbers in the table of grid numbers that matched numbers drawn from the table of random numbers indicated the squares to be sampled for the block. Drawing of squares was stratified by fire history within each block. Drawing of random numbers concluded when the required number of samples had been drawn from each block. An example is given in Table 8 wherein matching numbers are underlined.

Table 8. Table of grid square numbers for Sampling Block 1 from Fig. 42 and random numbers drawn to match five grid numbers from Block 1

Grid Square Numbers*	Random Numbers From Table*
Block 1	
001, 002, 002, 004, 005, 008,	400, 053, 524, 649, 440, 402, 954,
009, 010, 011, 012, 013, 014,	439, 083, 043, 260, 908, 020, 102,
015, 016, 017, 021, 022, 023,	934, 492, 602, 078, 372, 541, 560,
024, 025, 026, 034, 035, 036,	235, 484, 630, 811, 337, 433, 879,
037, 047, 048, 055, 056, 068,	128, 410, 989, 268, 664, 027, 176,
069, 070, 074, 075, 076, 080,	151, 839, 583, 728, 635, 070, 796,
081, 082, 083, 084, 085, 087,	115, 074, 160, 504, 136, 756, 610,
088, 093, 094, 095, 096, 097,	650, 591, 985, 672, 668, 308, 627,
098, 099, 106, 107, 109, 110,	328, 159, 886, 944, 982, 375, 531,
115, 116, 119, 120, 121, 127,	822, 284, 071, 753, 045, 324, 842,
128, 129, 130, 140, 141, 142,	151, 939, 281, 734, 388, 322, 286,
143	831, 125, 210, 355, 651, 757, 523,
	875, 011

*Matching numbers are underlined.

Collection of Data

Use of Three-Component Line-Intercept Transects

Each sample of vegetation was made on a transect of three superimposed line intercepts. A 250-ft line was used for trees 1 in or greater in diameter at breast height. A 100-ft line was used for tree reproduction (less than 1 in in DBH) and for woody shrubs and vines. A 50-ft line was used for grasses and forbs. All three lines had a common center point (Fig. 43).

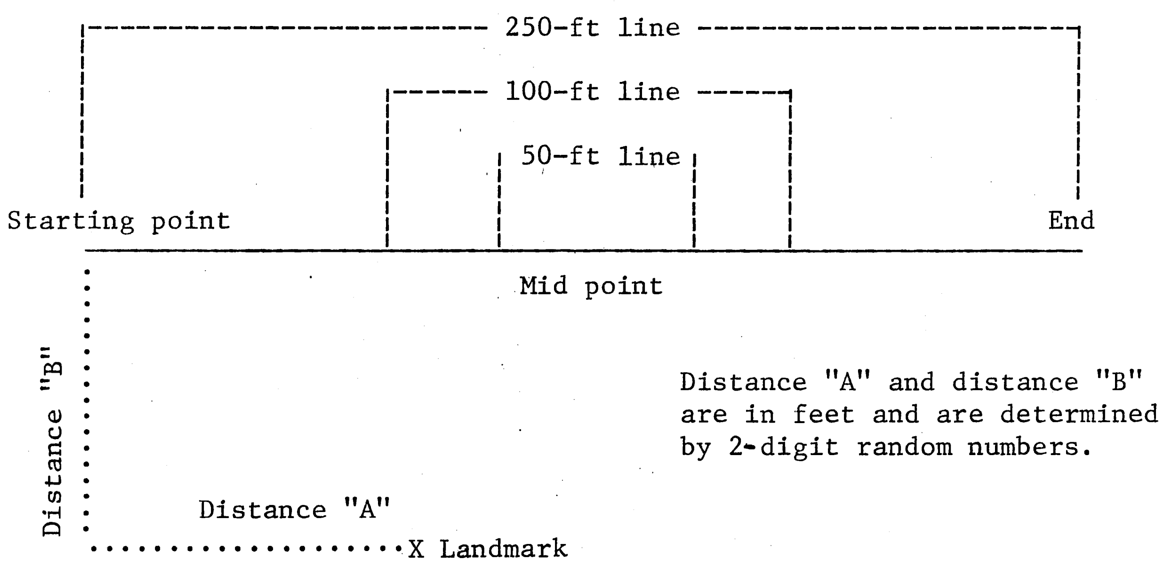


Fig. 43. Layout of three-component line intercept transect and method to locate randomly starting point of the intersect

Landmarks were fence corners, large trees, or rocks selected arbitrarily for their conspicuousness. The direction in which transects were extended was also chosen arbitrarily. On slopes they were placed across slope contours. Where possible the transects were run straight up and down slope. If the transect was longer than the slope or would cross into a different soil series, then it was placed at an angle across the slope to permit the greatest elevational difference between ends without running off the slope or crossing onto a different soil series. In meadows, old fields, and other level sites, the transect was run on a line that passed through the landmark and the starting point.

The starting point for the transects was located by the use of two, two-digit random numbers. Starting from a landmark, a two-digit number was drawn to determine the number of feet to travel for distance "A". Then a two-digit number was drawn for the number of feet on distance "B". On slopes, distance "A" was parallel to the contour unless location of the landmark in relation to fences, large rock outcrops, or other obstructions made it impractical to follow the contour. In old fields and meadows, distance "A" extended into the area at a right angle from the boundary. On other level sites, distance "A" was usually north or south from the landmark unless fences or slopes interfered, in which cases the direction was east or west. The choice of direction for distance "A" was arbitrarily selected at the landmark to avoid obstructions on slopes and level sites. Distance "B" was always at a right angle to distance "A" and its direction was selected arbitrarily. On slopes, if "A" was parallel to the contour then "B" ran upslope if the landmark was at the bottom of the slope and downslope if the landmark was near the top. If "A" ran up or down slope then "B" was extended away from any obstructions. In meadows and old fields, "B" was parallel with and toward the midpoint of the boundary near which the landmark was located. On other level sites, "B" was in a direction away from slopes, fences, or other boundary of the site.

The starting point for a transect was marked with a 3-ft length of 9-gauge wire driven into the ground. A loop was twisted at the upper end of the wire and a 10-to-12-in length of blaze orange forester's flagging tape was tied in the loop.

The forms used to record data from the transects are shown in Fig. 44. Data recorded were identification of the transect, map location, rock strata, soil series, slope aspect, class of slope grade, date of most recent fire, transect azmuth from starting point, and random numbers for distances "A" and "B" to locate the starting point. Vegetation data recorded were species, length of intercept of each species, diameter at breast height (4.5 ft above ground) for trees; basal diameter for tree reproduction, shrubs and woody vines; and distance from base of plant to the line, height, and crown diameter for trees, shrubs, and woody vines. For grasses and forbs, intercepts only were recorded.

Crown intercept was measured by sighting the edges of crowns above the tape with a plumb stick and noting the readings on the tape at the points where it was intercepted by the crown edges. The differences between the readings was recorded as the length of intercept for the plant. Intercepts were recorded to the nearest 1/2 ft for trees and to the nearest 1/10 ft for all other classes of vegetation. For trees the DBH was measured to the nearest 1/10 in with a forester's tape. On tree coppices, the diameter of the largest stem was used. For tree reproduction, shrubs, and woody vines, basal diameter was measured to the

Line-Intercept Record Sheet

________ Area   ________ County   ________ Range, Township & Section   ________ Date & Recorder

________ Strata   ________ Soil   0-5%( ) 5-20%( ) 20-50%( ) Slope   N( ) E( ) S( ) N( ) Aspect

________ Burn Hist.   ________ Grid No.   ________ Line No.   ________ Length   ________ Elev.   Remarks:________

Species	Length of Intercept (ft)	Distance to base (ft)	D.B.H. or Stem Dia. (in)	Crown Dia. (in)	Height (ft)	Remarks

Fig. 44. Form used to record data on line intercepts

nearest 1/10 in at the surface of the soil. For coppices and clones the basal diameter was measured as the distance between the outer sides of the the two stems farthest apart. Distances to the base was measured to the nearest 1/10 in at a right angle to the line. Height of tree reproduction, shrubs and vines under 10 ft was measured directly with a pocket tape measure and recorded to the nearest 1/10 ft. Triangulation was used to measure height of trees and of tree reproduction, shrubs, and vines over 10 ft high. Height of tree reproduction, shrubs and vines over 10 ft was estimated to the nearest 1/2 ft. Height of trees was estimated to the nearest foot. Crown diameter was measured across the widest point that a measurement or an accurate measurement could be made. For tree reproduction, shrubs and vines under 10 ft high, crown diameter was measured directly to the nearest 1/10 ft with a pocket tape measure. For trees, tree reproduction, shrubs, and vines over 10 ft high, crown diameter was estimated by triangulation. Crown diameter was estimated to the nearest foot for trees and to the nearest 1/2 ft for tree reproduction, shrubs, vines over 10 ft high.

To estimate height and crown diameter by triangulation a base line of 60 ft for trees less than 45 ft high or 120 ft for trees over 45 ft high was paced from the base of the trunk. A pocket tape measure was held 30 in from the worker's eye and the apparent height and crown diameter of the tree were measured in inches. The sighting measurement was multiplied by .5 for the short baseline or .25 for the long baseline to convert to an estimate of height and crown diameter in feet. On slopes, the baseline was paced off from the tree parallel with slope contour. On level sites the baseline was paced off in whichever direction gave the least interference by other trees to the line of sight.

The estimates were checked by using the triangulation method to measure known vertical and horizontal distances two or three times while recording data on each transect.

Analysis of Data

Intercepts are the measure analyzed for this study because (1) lines estimate cover by the intercepts and other measures are biased by the size of the plants, and (2) no other measure was recorded for grasses and forbs.

Summarization of the Intercepts

The intercepts were summarized by species on every transect for each class of vegetation. To maintain orthogonality of species the assumption was made that every species encountered on any of the transects could be present on all other transects. When a species was not present on a transect a value of 0.0 was recorded for it in the summarization. A symbolic representation of the summarization is given in Table 9.

Analysis of Variance

The analysis of variance (AOV) is "an arithmetic process for partitioning a total sum of squares into components associated with recognized sources of variation" (Steele and Torrie 1960:99). In this study AOV was used to detect sources of variation and to select species and blocks for further analysis. In the design used, transects are the observations, species are the variables, and blocks are the treatments.

Table 9. Symbolism of summaries of vegetative cover by species on transects grouped into blocks

Transect Species	Block 1				Block 2			Block 3					Total Species
	1	2	3	Species Total	1	2	Species Total	1	2	3	4	Species Total	
1	X_{111}	X_{121}	X_{131}	$X_{1.1}$	X_{122}	X_{122}	$X_{1.2}$	X_{113}	X_{123}	X_{133}	X_{143}	$X_{1.3}$	$X_{1..}$
2	X_{211}	X_{221}	X_{231}	$X_{2.1}$	X_{222}	X_{222}	$X_{2.2}$	X_{213}	X_{223}	X_{233}	X_{243}	$X_{2.3}$	$X_{2..}$
3	X_{311}	X_{321}	X_{331}	$X_{3.1}$	X_{322}	X_{322}	$X_{3.2}$	X_{313}	X_{323}	X_{333}	X_{343}	$X_{3.3}$	$X_{3..}$
Transect Total	$X_{.11}$	$X_{.21}$	$X_{.31}$	$X_{..1}$	$X_{.22}$	$X_{.22}$	$X_{.22}$	$X_{.13}$	$X_{.23}$	$X_{.33}$	$X_{.43}$	$X_{..3}$	$X_{...}$

Analyses of variation were performed separately for each class of vegetation.

AOV's were calculated by using the Means Procedure of the Statistical Analysis Systems (Service 1972), on the IBM 360/65 computer at the Oklahoma State University Computer Center, to compute sums and sums of squares for species and for transects within blocks. The sums of squares obtained with the Means Procedure (Service 1972) are corrected sums of squares; a correction term was calculated and added to the transect and species sums of squares to obtain uncorrected sums of squares for AOV's between blocks. A desk calculator was used to complete the AOV's.

To prepare the summarized data for computation of sums and sums of squares, a separate card was used for every species on every transect. To enter all species as variables of transects would exceed the capacity of Statistical Analysis System programs for number of variables and number of continuation cards permitted. By using a separate card for each species on each transect the cost of computer use was reduced by sorting the data on a card sorter before reading the data into the computer. Information punched on each card included a block number, transect number, a species number, a code number for class of vegetation, and sum of intercepts for the species on the transect.

The first tests of significance were for variation between blocks, between species among blocks, and species x block interaction. Using the following notation and example in Table 9 the sums of squares for sources of variation are calculated as follows:

Species = i　　Number of species = r

Transects = j　　Number of transects = s_k

Blocks = k　　Number of blocks = t

$$\text{Correction Term} = C = \frac{X^2_{...}}{r(\Sigma s_k)} = \frac{(X_{111} + X_{211} + \ldots + X_{243} + X_{343})^2}{3(3 + 2 + 4)}$$

$$\text{Total Sum of Squares} = \Sigma X^2_{ijk} - C =$$

$$\left(X^2_{111} + X^2_{211} + \ldots + X^2_{243} + X^2_{343}\right) - \frac{X^2_{...}}{r(\Sigma s_k)}$$

$$\text{Block Sum of Squares} = \sum\left(\frac{X^2_{..k}}{rs_k}\right) - C =$$

$$\left(\frac{X^2_{..1}}{3\cdot 3} + \frac{X^2_{..2}}{3\cdot 2} + \frac{X^2_{...3}}{3\cdot 4}\right) - \frac{X^2_{...}}{r(\Sigma s_k)}$$

$$\text{Transect Sum of Squares} = \sum\left(\frac{X^2_{.jk}}{r}\right) - C =$$

$$\left(\frac{X^2_{.11}}{3} + \frac{X^2_{.21}}{3} + \ldots + \frac{X^2_{.33}}{3} + \frac{X^2_{.43}}{3}\right) - \frac{X^2_{...}}{r(\Sigma s_k)}$$

$$\text{Species Sum of Squares} = \sum\left(\frac{X^2_{i..}}{\Sigma s_k}\right) - C =$$

$$\frac{X^2_{1..} + X^2_{2..} + X^2_{3..}}{3 + 2 + 4} - \frac{X^2_{...}}{r(\Sigma s_k)}$$

Species x Block Interaction Sum of Squares =

$$\sum \frac{X^2_{i\cdot k}}{s_k} - C - \text{Block Sum of Squares} - \text{Species Sum of Squares} =$$

$$\left[\frac{\left(X^2_{1\cdot 1} + X^2_{2\cdot 1} + X^2_{3\cdot 1}\right)}{3} + \frac{\left(X^2_{1\cdot 2} + X^2_{2\cdot 2} + X^2_{3\cdot 2}\right)}{2} + \right.$$

$$\left. \frac{\left(X^2_{1\cdot 3} + X^2_{2\cdot 3} + X^2_{3\cdot 3}\right)}{4} \right] - C - \text{Block SS} - \text{Species SS}$$

Residual Sum of Squares is obtained by subtraction

Residual Sum of Squares =

Total SS - Block SS - Transect SS - Species SS -

Species x Block Interaction SS

Calculations of F values for tests of significance in variation between blocks, species, and for species x block interaction are shown in Table 10.

The calculated F values for species and species x block interaction will be too high where $(r - 1)\Sigma(s_k - 1)$ degrees of freedom are used to compute the residual mean square (Steele and Torrie 1960:250). A quick check of significance can be made by substituting $\Sigma(s_k - 1)$ for the residual degrees of freedom to compute the residual mean square (Dr. William Warde, personal communication). The calculated F value for species and species x block interaction will be low due to a characteristic associated with sampling with repeated measures (Winer 1971:261-308). If this substitution results in significant F values then

Table 10. Calculation of F values for blocks, species among blocks, and species x block interaction

Source	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F Value
Total	$(r\Sigma s_k) - 1$	$\Sigma X^2_{ijk} - C$		
Block	$t - 1$	$\sum\left(\frac{X^2_{..k}}{rs_k}\right) - C$	$\frac{\text{Block SS}}{\text{Block df}}$	$\frac{\text{Block MS}}{\text{Transect MS}}$
Transect	$\Sigma(s_k - 1)$	$\sum\left(\frac{X^2_{.jk}}{r}\right) - C$	$\frac{\text{Transect SS}}{\text{Block df}}$	
Species	$r - 1$	$\sum\left(\frac{X^2_{i..}}{\Sigma s_k}\right) - C$	$\frac{\text{Species SS}}{\text{Species df}}$	$\frac{\text{Species MS}}{\text{Residual MS}}$
Species x Block	$(r - 1)(t - 1)$	$\sum\frac{\left(X^2_{i\cdot k}\right)}{s_k} - C$	$\frac{\text{Species x Block SS}}{\text{Species x Block df}}$	$\frac{\text{Species x Block MS}}{\text{Residual MS}}$
Residual	$(r - 1)\Sigma(s_k - 1)$	by Subtraction	$\frac{\text{Residual SS}}{\text{Residual df}}$	

variation of the source is unquestionably significant. If a calculated F is significant with $(r - 1)\Sigma(s_k - 1)$ residual degrees of freedom and not significant with $\Sigma(s_k - 1)$ substituted as residual degrees of freedom, then further analyses are required.

To test for variation of species within blocks an AOV was performed for every block. Computation of sums of squares for these AOV's are given in the following formulas:

$$\text{Correction Term for } k^{th} \text{ block} = C_k = \frac{X^2_{..k}}{rs_k}$$

$$\text{Total Sum of Squares for } k^{th} \text{ block} = \sum_{ij} X^2_{ijk} - C_k$$

$$\text{Species Sum of Squares for } k^{th} \text{ block} = \sum_{i} \frac{X^2_{i.k}}{s_k} - C_k$$

$$\text{Transect Sum of Squares for } k^{th} \text{ block} = \sum_{j} \frac{X^2_{.jk}}{r} - C_k$$

Residual Sum of Squares for k^{th} block =

$$\text{Total } SS_k - \text{Species } SS_k - \text{Transect } SS_k$$

Calculation of F values for tests of significance between species within blocks is shown in Table 11.

To test variations between blocks for species an AOV was performed for every species. Computation of sums of squares for these AOV's are given in the following formulas:

Table 11. Calculation of F values for species and transects within blocks

Source	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F Value
Total	$rs_k - 1$	$\sum_{ij} X^2_{ijk} - C_k$		
Species	$r - 1$	$\sum_i \frac{X^2_{i.k}}{s_k} - C_k$	$\frac{\text{Species SS}}{\text{Species df}}$	$\frac{\text{Species MS}}{\text{Residual MS}}$
Transects	$s_k - 1$	$\sum_j \frac{X^2_{.jk}}{r} - C_k$	$\frac{\text{Transect SS}}{\text{Transect df}}$	$\frac{\text{Transect MS}}{\text{Residual MS}}$
Residual	$(r - 1)(s_k - 1)$	By Subtraction	$\frac{\text{Residual SS}}{\text{Residual df}}$	

Correction term for i^{th} species = $C_i = \dfrac{X^2_{i..}}{\Sigma s_k}$

Total Sum of Squares for i^{th} species = $\sum_{jk} X^2_{ijk} - C_i$

Block Sum of Squares for i^{th} species = $\sum_{k} \dfrac{X^2_{i \cdot k}}{s_k} - C_i$

Residual Sum of Squares for i^{th} species =

Total SS_i - Block SS_i

Calculation of F values for test of significance between blocks for each species is shown in Table 12.

Discriminant Analysis of Treatments

Data decks for the discriminant analysis and following analyses were prepared by using a Fortran program written by Mr. Eldean Bahm. With this program, sum of intercept values for selected species were read into the computer and new data decks were punched in which the species are variables on transects. Each transect required 9 continuation cards for the 123 species selected. For a transect, each card was punched with block number, transect number, card continuation number, and sum of intercept values for species. Each species was located in a certain field of columns on one of the continuation cards. The field of columns and continuation card number for the species must be the same on every transect.

Discriminant analysis was performed by using the DISCRIM procedure

Table 12. Calculation of F values for blocks

Source	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F Value
Total	$\Sigma s_k - 1$	$\sum_{jk} X_{ijk}^2 - C_i$		
Block	$t - 1$	$\sum_k \frac{X_{i \cdot k}^2}{s_k} - C_i$	$\frac{\text{Block SS}}{\text{Block df}}$	$\frac{\text{Block MS}}{\text{Residual MS}}$
Residual	$\Sigma (s_k - 1)$	By Subtraction	$\frac{\text{Residual SS}}{\text{Residual df}}$	

of Statistical Analysis Systems (Service 1972:190-200). Transects were the observations classified with the DISCRIM procedure and species sum of intercepts were the variables of the observations.

The classification criterion of the DISCRIM procedure is a measure of generalized squared distance. The generalized squared distance can be based on individual, within-block, covariance matrices or on a pooled covariance matrix. A test of homogeneity of within-block covariance matrices can be made and the result used to determine whether within-block covariance or pooled covariance shall be used to generate the generalized squared distances (Service 1972).

The options and parameters used with the DISCRIM procedure for this study were SIMPLE, POOL = TEST, SL POOL = .05, and LIST. The option SIMPLE tells the procedure to print the simple descriptive statistics. The option POOL = TEST tells the procedure to perform a test of homogeneity of within-block covariance matrices. If the test of homogeneity of within-block covariance matrices is significant at the level specified by the SL POOL parameter the DISCRIM procedure will use the pooled covariance matrix to generate the generalized squared distances to classify the observations. The SL POOL = .X parameter specifies the significance level for the test of within-group covariance. The LIST option instructs the procedure to print the classification results for each observation (Service 1972).

The DISCRIM procedure prints a table of pairwise squared generalized distances between blocks (Table 13) and a summary of classification performance using generalized squared distances (Table 14). When specified by the LIST option, the classification results for each observation are printed in the form shown in Table 15.

Table 13. Form of printout of discriminant analysis program for pairwise, squared, generalized distance between blocks

DISCRIMINANT ANALYSIS -- COOKSON VEGETATION

DISCRIMINANT ANALYSIS PAIRWISE SQUARED GENERALIZED DISTANCE BETWEEN GROUPS*

WHERE: $D^2(I\ J) = (\bar{X}_I - \bar{X}_J)'\ COV^{-1}\ (\bar{X}_I - \bar{X}_J) - 2\ LN\ PRIOR_J$

GENERALIZED SQUARED DISTANCE TO GROUP

FROM GROUP	1	2
1	0.00000000	2093.04375546
	2093.04375546	0.00000000

*Groups are the same as blocks.

Table 14. Form of printout of discriminant analysis program for summary of classification performance using generalized squared distance

DISCRIMINANT ANALYSIS -- COOKSON VEGETATION

DISCRIMINANT ANALYSIS SUMMARY OF CLASSIFICATION PERFORMANCE USING GENERALIZED SQUARED DISTANCE

WHERE: $D_J^2(X) = (X - \bar{X}_J)' \, COV^{-1} \, (X - \bar{X}_J) - 2 \, LN \, PRIOR_J$

NUMBER OF OBSERVATIONS* CLASSIFIED INTO GROUP**

FROM GROUP	1	2
1	6	0
2	0	7

*Observations are the same as transects.

**Groups are the same as blocks.

Table 15. Form of printout of discriminant analysis program for classification performance for each transect giving generalized squared distance to each block and probability of membership in each block

DISCRIMINANT ANALYSIS -- COOKSON VEGETATION

DISCRIMINANT ANALYSIS CLASSIFICATION RESULTS FOR EACH OBSERVATION*
GIVING GENERALIZED SQUARED DISTANCE TO EACH GROUP / POSTERIOR PROBABILITY OF MEMBERSHIP IN EACH GROUP**

WHERE: $D_J^2(X) = (X - \bar{X}_J)' \; COV^{-1} \; (X - \bar{X}_J) - 2 \; LN \; PRIOR_J$ AND $PR(J \; X) = EXP(-.5 \; D_J^2(X)) \; / \; \underset{K}{SUM} \; EXP(-.5 \; D_K^2(X))$

GENERALIZED SQUARED DISTANCE TO GROUP

OBS	FROM GROUP	CLASSIFIED INTO GROUP	1	2
1	1	1	9.166667	2342.514496
			1.0000	0.0000
2	1	1	9.166667	1994.866961
			1.0000	0.0000
3	1	1	9.166667	2105.877089
			1.0000	0.0000
4	1	1	9.166667	2105.877089
			1.0000	0.0000
5	1	1	9.166667	1958.249810
			1.0000	0.0000
6	1	1	9.166667	2105.877089
			1.0000	0.0000

Table 15 (Continued)

7	2	2	2105.615184	9.428571
			0.0000	1.0000
8	2	2	2105.615184	9.428571
			0.0000	1.0000
9	2	2	2105.615184	9.428571
			0.0000	1.0000
10	2	2	2125.334968	9.428571
			0.0000	1.0000
11	2	2	2063.895400	9.428571
			0.0000	1.0000
12	2	2	2105.615184	9.428571
			0.0000	1.0000
13	2	2	2105.615184	9.428571
			0.0000	1.0000

*Observations are the same as transects.

**Groups are the same as blocks.

Cluster Analysis of Species

Cluster analysis is a class of numerical techniques used to classify objects based on similarity coefficients (Sokal and Sneath 1963). The cluster analysis program used to group species for this study was written by McCammon and Wenninger (1970). It uses weighted-pair group (Sokal and Sneath 1963) means of a generalized distance matrix to determine linkages. A single linkage between a pair of species or species groups is made and a new generalized distance from the linked pair to every other species or species group is computed in every cluster cycle.

For this investigation it was necessary to transform the distance matrices from correlation matrices. Distance matrices computed directly from sums of intercepts were biased by the great differences in sums of intercepts between species. Correlation matrices standardized the measure of relationships between species.

An example of the cluster analysis using intercepts for 30 species from the Clarksville South to West aspect block will be used. Names and identification numbers for the 30 species are given in Table 16. A correlation matrix was generated by the computer and the results punched onto cards. The correlation matrix is given in Table 17.

The clustering program was read into the computer with the correlation matrix deck of computer cards entered as the data. The correlation matrix was transformed into a generalized distance matrix (Table 18).

Table 16. Name and identification number of 27 species from blocks used in example of cluster analysis shown in Tables 17, 18 and 19, and Figs. 45, 46 and 47*

Species Names	Identification No.	Species Names	Identification No.
PINUS ECHINATA (Tree)	1	CELTIS OCCIDENTALIS & C. LAEVIGATA (Reproduction)	15
CARYA TOMENTOSA & C. TEXANA (Tree)	2	PRUNUS AMERICANA (Reproduction)	16
CASTANEA OZARKENSIS	3	SMILAX BONA-NOX	17
QUERCUS ALBA (Tree)	4	RHUS AROMATICA	18
Q. VELUTINA (Tree)	5	PARTHENOCISSUS QUINQUIFOLIA	19
Q. FALCATA (Tree)	6	VACCINIUM STAMINEUM	20
SASSAFRAS ALBIDUM (Tree)	7	SYMPHOROCARPOS ORBICULATUS	21
RHUS GLABRA & R. COPALLINA (Tree)	8	CAREX sp.	22
CORNUS FLORIDA (Tree)	9	DESMODIUM CUSPIDATUM	23
DIOSPYROS VIRGINIANA (Tree)	10	ACALYPHA GRACILENS	24
VIBURNUM PRUNIFOLIUM (Tree)	11	MONARDA RUSSELIANA	25
OSTRYA VIRGINIANA (Reproduction)	12	ASTER SAGITTIFOLIUS	26
QUERCUS ALBA (Reproduction)	13	RUDBECKIA HIRTA	27
QUERCUS VELUTINA (Reproduction)	14		

*The following species pairs are combined and analysed as single species because of their apparent ecological similarities and because of difficulty in field identification during winter: Carya tomentosa and C. texana, Rhus glabra and R. copallina, and Celtis occidentalis and C. laevigata.

Table 17. Cluster analysis of 27 species within Block 5--correlation matrix

Species 1	1.000																										
Species 2	-0.155	1.000																									
Species 3	0.102	-0.129	1.000																								
Species 4	-0.156	-0.064	-0.110	1.000																							
Species 5	-0.558	-0.247	0.048	0.185	1.000																						
Species 6	-0.264	-0.249	0.350	0.085	0.272	1.000																					
Species 7	-0.169	-0.018	0.191	0.220	0.035	-0.110	1.000																				
Species 8	-0.135	0.485	-0.042	0.153	-0.013	-0.116	0.209	1.000																			
Species 9	-0.004	0.223	-0.059	0.287	0.328	-0.104	-0.184	-0.059	1.000																		
Species 10	-0.172	0.576	-0.082	0.146	-0.144	-0.104	0.341	0.879	-0.117	1.000																	
Species 11	-0.135	-0.112	-0.042	-0.162	0.294	-0.116	-0.129	-0.042	-0.059	-0.082	1.000																
Species 12	-0.135	-0.138	-0.042	-0.162	0.269	0.281	-0.129	-0.042	-0.059	-0.082	-0.042	1.000															
Species 13	-0.145	-0.080	0.316	0.249	0.206	0.085	0.380	-0.072	0.262	0.175	-0.072	-0.072	1.000														
Species 14	-0.098	-0.224	0.274	-0.054	0.391	0.162	-0.005	-0.161	0.390	-0.200	-0.048	0.583	0.422	1.000													
Species 15	-0.135	-0.112	-0.042	-0.162	0.294	-0.116	-0.129	-0.042	-0.059	-0.082	1.000	-0.042	-0.072	-0.048	1.000												
Species 16	-0.135	-0.031	-0.042	0.231	-0.045	-0.047	0.491	-0.042	-0.059	0.324	-0.042	-0.042	0.741	0.178	-0.042	1.000											
Species 17	-0.121	-0.141	-0.042	-0.162	0.157	0.261	-0.129	-0.042	-0.059	-0.082	-0.042	-0.042	-0.072	0.143	-0.042	-0.042	1.000										
Species 18	0.078	0.379	-0.063	0.202	0.076	-0.175	-0.100	0.226	0.726	0.143	-0.063	-0.063	-0.109	0.146	-0.063	-0.063	-0.063	1.000									
Species 19	-0.135	-0.014	-0.042	0.190	0.389	-0.015	-0.129	-0.042	0.573	-0.082	-0.042	-0.042	0.528	0.315	-0.042	-0.042	-0.042	-0.063	1.000								
Species 20	0.068	-0.204	0.930	0.101	0.063	0.288	0.280	-0.082	-0.013	-0.157	-0.082	-0.029	0.264	0.267	-0.082	-0.082	-0.082	-0.037	-0.032	1.000							
Species 21	-0.135	-0.115	-0.042	0.643	-0.035	0.002	0.209	-0.042	-0.059	-0.082	-0.042	-0.042	-0.072	-0.188	-0.042	-0.042	-0.042	-0.063	-0.042	0.262	1.000						
Species 22	-0.274	0.180	-0.086	-0.138	0.264	-0.043	-0.073	0.509	-0.123	0.449	0.769	0.137	-0.149	-0.066	0.769	-0.086	-0.086	0.038	-0.086	-0.158	-0.086	1.000					
Species 23	-0.212	-0.030	-0.065	0.068	0.410	0.070	-0.202	-0.065	0.485	-0.049	0.207	-0.065	0.436	0.198	0.207	-0.065	-0.065	-0.099	0.887	-0.083	-0.065	0.190	1.000				
Species 24	0.095	0.282	-0.042	0.209	0.113	-0.166	-0.129	-0.042	0.795	-0.082	-0.042	-0.042	-0.072	0.242	-0.042	-0.042	-0.042	0.932	-0.042	0.008	-0.042	-0.086	-0.065	1.000			
Species 25	-0.414	0.269	-0.134	0.141	-0.094	-0.128	0.234	0.123	-0.035	0.391	-0.134	-0.134	0.519	9.038	-0.134	0.638	-0.005	-0.119	0.123	-0.187	-0.005	-0.001	0.076	-0.134	1.000		
Species 26	0.374	0.168	-0.064	0.030	-0.258	-0.174	0.028	0.551	-0.091	0.442	-0.064	-0.064	-0.110	-0.189	-0.064	-0.064	-0.064	0.087	-0.064	-0.083	-0.064	0.220	-0.100	-0.064	-0.064	1.000	
Species 27	-0.135	-0.112	-0.042	-0.162	0.294	-0.116	-0.129	-0.042	-0.059	-0.082	1.000	-0.042	-0.072	-0.048	1.000	-0.042	-0.042	-0.063	-0.042	-0.682	-0.042	0.769	0.207	-0.042	-0.134	-0.064	1.000

Table 18. Cluster analysis of 27 species within Block 5--generalized distance matrix transformed from correlation matrix

1	0.0																										
2	1.7260	0.0																									
3	1.4685	1.7006	0.0																								
4	1.7275	1.6348	1.6806	0.0																							
5	2.1383	1.8200	1.5232	1.3747	0.0																						
6	1.8378	1.8220	1.2135	1.4853	1.2952	0.0																					
7	1.7315	1.5892	1.3790	1.3493	1.5360	1.6810	0.0																				
8	1.7061	1.0646	1.6125	1.4175	1.5838	1.6868	1.3598	0.0																			
9	1.5748	1.3459	1.6303	1.2799	1.2362	1.6748	1.7554	1.6303	0.0																		
10	1.7438	0.9574	1.6529	1.4248	1.7157	1.6751	1.2232	0.4978	1.6882	0.0																	
11	1.7061	1.6831	1.6125	1.7335	1.2722	1.6868	1.6997	1.6125	1.6303	1.6529	0.0																
12	1.7061	1.7094	1.6125	1.7335	1.2983	1.2861	1.6997	1.6125	1.6303	1.6529	1.6125	0.0															
13	1.7163	1.6511	1.2494	1.3188	1.3631	1.4855	1.1810	1.6429	1.3059	1.3946	1.6429	1.6429	0.0														
14	1.6687	1.7966	1.2930	1.6244	1.1689	1.4077	1.5759	1.7323	1.1706	1.7725	1.6188	0.9482	1.1352	0.0													
15	1.7061	1.6831	1.6125	1.7335	1.2722	1.6868	1.6997	1.6125	1.6303	1.6529	0.0	1.6125	1.6429	1.6188	0.0												
16	1.7061	1.6018	1.6125	1.3373	1.6163	1.6178	1.0575	1.6125	1.6303	1.2404	1.6125	1.6125	0.7267	1.3923	1.6125	0.0											
17	1.6919	1.7123	1.6125	1.7335	1.4133	1.3071	1.6097	1.6125	1.6303	1.6529	1.6125	1.6125	1.6429	1.4276	1.6125	1.6125	0.0										
18	1.4931	1.1821	1.6338	1.3673	1.4947	1.7465	1.6714	1.3428	0.7580	1.4277	1.6338	1.6338	1.6792	1.4238	1.6338	1.6338	1.6338	0.0									
19	1.7061	1.5884	1.6125	1.3795	1.1716	1.5854	1.6997	1.6125	0.9603	1.6529	1.6125	1.6125	1.0142	1.2508	1.6125	1.6125	1.6125	1.6338	0.0								
20	1.5026	1.7758	0.3757	1.4699	1.5074	1.2782	1.2872	1.6528	1.5834	1.7286	1.6528	1.6000	1.3035	1.3004	1.6528	1.6528	1.6528	1.6083	1.6027	0.0							
21	1.7061	1.6860	1.6125	0.8718	1.6060	1.5692	1.3598	1.6125	1.6303	1.6529	1.6125	1.6125	1.6429	1.7596	1.6125	1.6125	1.6125	1.6338	1.6125	1.3053	0.0						
22	1.8487	1.3901	1.6572	1.7092	1.3039	1.6135	1.6440	1.0372	1.6943	1.1047	0.6936	1.4339	1.7205	1.6373	0.6936	1.6572	1.6572	1.5326	1.6572	1.7298	1.6572	0.0					
23	1.7840	1.6008	1.6362	1.5027	1.1478	1.5010	1.7738	1.6362	1.0639	1.6198	1.3624	1.6362	1.1196	1.3711	1.3624	1.6362	1.6362	1.6696	0.4793	1.6536	1.6362	1.3794	0.0				
24	1.4755	1.2849	1.6125	1.3604	1.4580	1.6868	1.6997	1.6125	0.6522	1.6529	1.6125	1.6125	1.6429	1.3263	1.6125	1.6125	1.6125	0.3704	1.6125	1.5625	1.6125	1.6572	1.6362	0.0			
25	1.9977	1.2986	1.7050	1.4298	1.6652	1.6994	1.3345	1.4470	1.6055	1.1687	1.7050	1.7050	1.0250	1.5326	1.7050	0.8789	1.5759	1.6898	1.4470	1.7593	1.5759	1.5723	1.4948	1.7050	0.0		
26	1.1878	1.4018	1.6344	1.5412	1.8321	1.7457	1.5424	0.9867	1.6616	1.1129	1.6344	1.6344	1.6809	1.7614	1.6344	1.6344	1.6344	1.4834	1.6344	1.6540	1.3493	1.6706	1.6344	1.6166	1.5478	0.0	
27	1.7061	1.6831	1.6125	1.7335	1.2722	1.6868	1.6997	1.6125	1.6303	1.6529	0.0010	1.6125	1.6429	1.6188	0.0005	1.6125	1.6125	1.6338	1.6125	1.6528	1.6125	0.6936	1.3624	1.6125	1.7050	1.6344	0.0

The species and species clusters in the generalized distance matrix shall be referred to hereafter in this discussion as OTU's (operational taxonomic units) (Sokal and Sneath 1963). The pair of OTU's with the least distance are joined to form a new, single OTU. For the example in Table 18 this would be OTU's 11 and 15. Next, a new generalized distance is computed between the new OTU and every other OTU in the matrix. This completes the first clustering cycle. The program continues through clustering cycles of linking the nearest pair of OTU's into a new, single OTU and computing new generalized distances until all OTU's have been linked. As an example, the results are printed as shown in Table 19.

The results may also be stored in a file in the computer and plotted as shown in Fig. 45. The vertical axis on the left side of the plot is graduated in a correlation scale. The higher a pair of OTU's are joined in the figure the weaker is the correlation between them. This scale is used to locate a horizontal line on the figure to determine clusters of OTU's linked at predetermined levels of significance. A table of significant values of correlations (Steele and Torrie 1960: 453) can be consulted to find the height on the vertical axis for the horizontal line. All OTU's with linkages below this line form clusters at the predetermined level of significance. In Fig. 46 horizontal lines are drawn at .05 and .01 levels of significance for 30 transects.

Confidence intervals can also be drawn on the figure. Tables of confidence belts (Steele and Torrie 1960:450-451) can be consulted to determine the upper and lower limits of a confidence interval about the horizontal line. In Fig. 47 confidence belts for P = .95 and P = .99

The species and species clusters in the generalized distance matrix shall be referred to hereafter in this discussion as OTU's (operational taxonomic units) (Sokal and Sneath 1963). The pair of OTU's with the least distance are joined to form a new, single OTU. For the example in Table 18 this would be OTU's 11 and 15. Next, a new generalized distance is computed between the new OTU and every other OTU in the matrix. This completes the first clustering cycle. The program continues through clustering cycles of linking the nearest pair of OTU's into a new, single OTU and computing new generalized distances until all OTU's have been linked. As an example, the results are printed as shown in Table 19.

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Table 19. Output of clustering program for 27 species in Block 5

FINAL RESULTS

NAME	NP*	ORDER**	WGR***	BGR****
RHUS AROMATICA	18			
		4	0.3704	0.3704
ACALYPHA GRACILENS	24			
		8	0.5935	0.7051
CORNUS FLORIDA (T)	9			
		19	1.0540	1.5144
PINUS ECHINATA (T)	1			
		23	1.3091	1.5194
ASTER SAGITTIFOLIUS	25			
		16	1.0035	1.1671
CARYA TOMENTOSA & C. TEXANA (T)	2			
		11	0.8399	1.0110
DIOSPYROS VIRGINIANA (T)	10			
		7	0.4978	0.4978
RHUS GLABRA & R. COPALLINA (T)	8			
		25	1.4371	1.5710
SYMPHOROCARPOS ORBICULATUS	21			
		12	0.8718	0.8718
QUERCUS ALBA (T)	4			
		22	1.2475	1.4533
SASSAFRAS ALBIDUM (T)	7			
		18	1.0356	1.1910
MONARDA RUSSELIANA	25			
		13	0.8802	0.9519
PRUNUS AMERICANA (R)	16			
		10	0.7367	0.7367
QUERCUS ALBA (R)	13			
		26	1.5117	1.6039
CASTANEA OZARKENSIS (T)	3			
		5	0.3757	0.3757
VACCINIUM STAMINEUM	20			
		15	0.9558	1.2458
QUERCUS FALCATA (T)	6			
		21	1.2315	1.4166
OSTRYA VIRGINIANA (R)	12			
		14	0.9482	0.9482
QUERCUS VELUTINA (R)	14			
		24	1.3836	1.5622
DESMODIUM CUSPIDATUM	23			
		6	0.4793	0.4793
PARTHENOCISSUS QUINQUEFOLIA	19			
		20	1.1828	1.4608
SMILAX BONA-NOX	17			
		17	1.0074	1.5816
QUERCUS VELUTINA (T)	5			
		9	0.7203	1.2801
CAREX SP.	22			
		3	0.3471	0.6936
RUDBECKIA HIRTA	27			
		2	0.0005	0.0008
CELTIS OCCIDENTALIS (R)	15			
		1	0.0	0.0
VIBURNUM PRUNIFOLIUM (T)	11			

*Identification number of species used by clustering analysis program.

**Order in which OTU's (species or species clusters are joined).

***Height on vertical axis when OTU's are joined.

****Horizontal distance between OTU's at start.

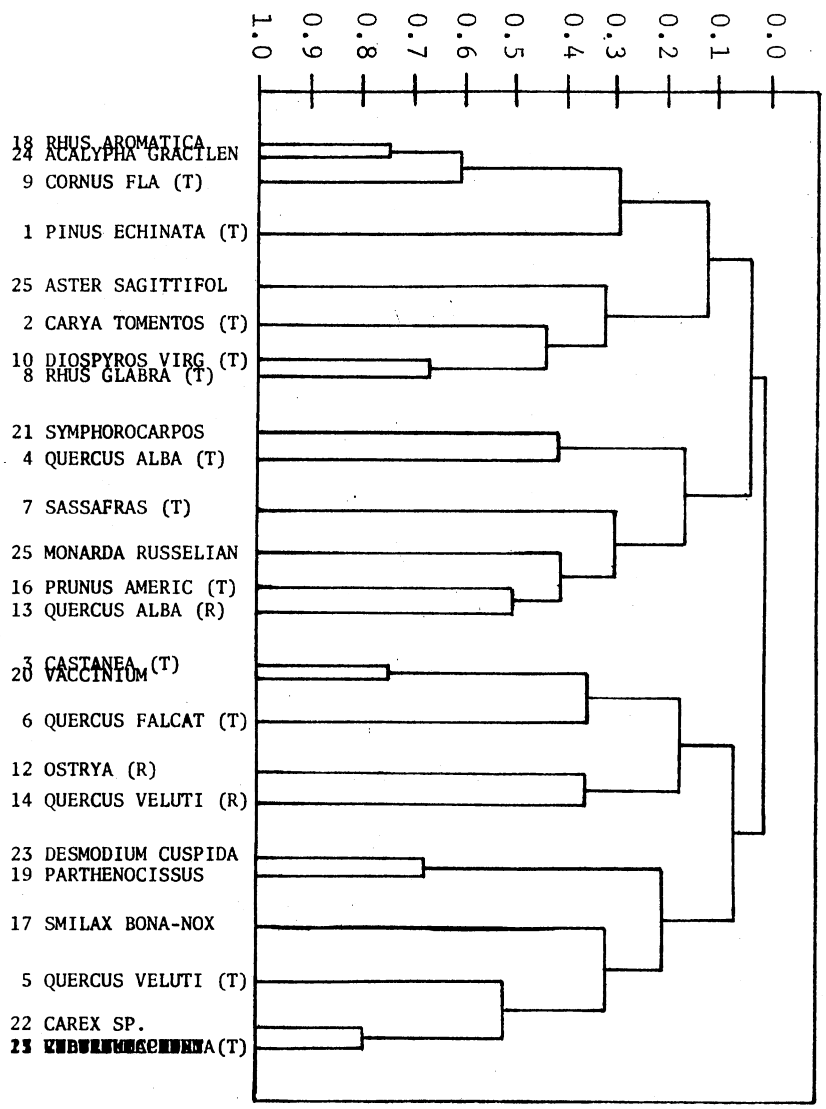

Fig. 45. Clustering dendrogram for 27 species from Block 5 plotted from the data in Table 19

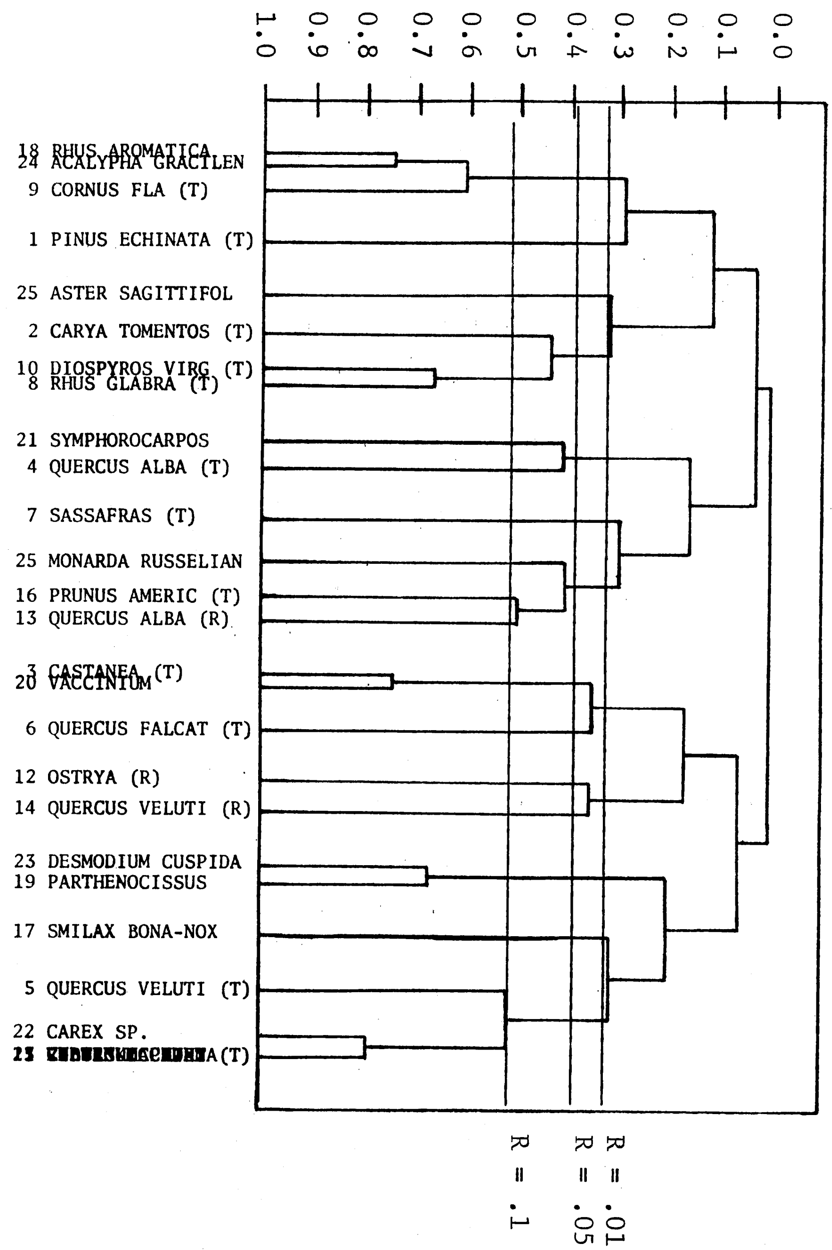

Fig. 46. Clustering dendrogram for 27 species from Block 5 with lines drawn at .01, .05 and .1 levels of significance

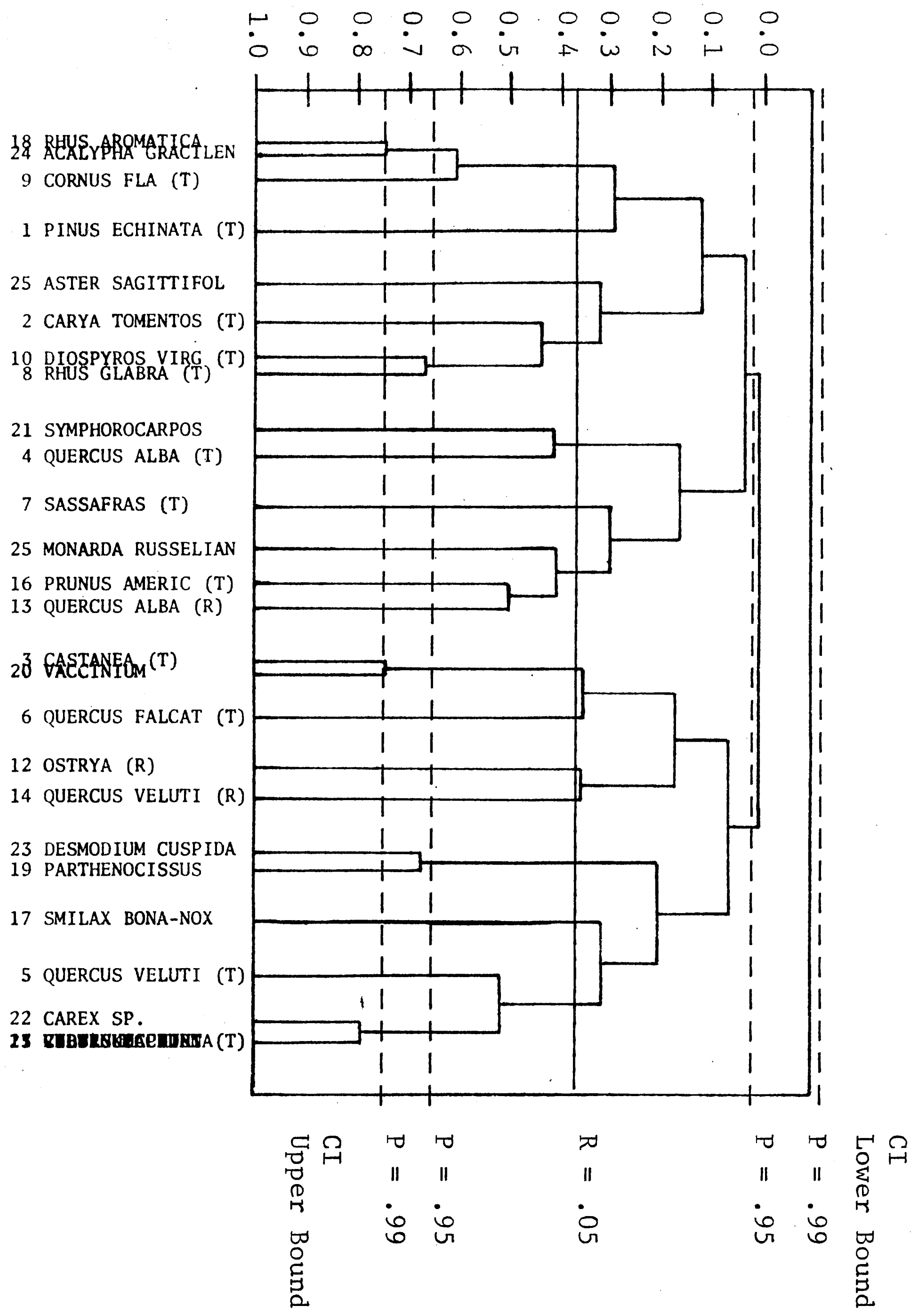

Fig. 47. Dendrogram of 27 species from Block 5 with lines for .95 and .99 confidence intervals drawn about the line drawn at the .05 level of significance

have been drawn about the horizontal line at the .05 level of significance.

CHAPTER VI

RESULTS

Collection of the Data

During the field phase of this investigation, 409 species of plants were identified on the refuge. There were 52 species of trees, 19 species of shrubs, 14 species of woody vines, 11 species of ferns, 44 species of grasses and sedges, and 170 species of forbs. The scientific and common names of the plants identified are listed in Appendix A under Table 28. Scientific names of all plants are from Waterfall (1969). Common names of trees, shrubs and woody vines, and ferns are from Fernald (1950). Common names of grasses are from Fernald (1950) or Featherly (1946). Common names of forbs are from Fernald (1950), Steyermark (1963), or Peterson and McKenny (1968). In addition, there were 32 unidentified species of grasses, sedges and forbs intercepted on the transects.

Data for grasses and forbs were collected from May to September, 1969. Data for trees, tree reproduction, shrubs, and woody vines was collected concurrently with intercepts for grasses and forbs on 68 transects from May to July, 1969. Data for trees, tree reproduction, and shrubs and vines on the remaining transects were collected from October, 1969 to July, 1970.

On the tree line intercepts, 48 species of trees and 6 species of shrubs with DBH greater than 1 in were found. The six shrub species on the refuge that grow to small-tree size are Rhus glabra, R. copallina, R. radicans, Ilex decidua, Cornus drummondii, and Vacinium arboreum. Because of confusion in field indentification, several species were paired in this study. Descriptions of habitats (Fernald 1950, Phillips et al. 1959) are similar for the species paired. The assumption was made that the paired species have similar ecological requirements and that pairing these species would have little effect on the analyses. The tree species paired are Carya tomentosa and C. texana, Celtis occidentalis and C. laevigata, Craetegus Engelmannii and C. mollis, Rhus glabra and R. copallina, and Fraxinus americana and F. pennsylvanica.

For tree reproduction 48 species were intercepted on the lines. Salix nigra and Tilia americana were absent as tree reproduction, and Sapindus Drummondii and Chionathes virginicus were present as reproduction but not as trees. Species paired are Carya tomentosa and C. texana, Ulmus rubra and U. americana, Celtis occidentalis and C. laevigata, Crataegus Engelmannii and C. mollis, and Fraxinus and F. pennsylvanica.

There were 31 species of shrubs and woody vines intercepted on the transects. Rhus glabra and R. copallina are the only shrub species paired.

On the lines for grasses and forbs there were seven species of ferns and allies, 55 species of grasses and sedges, six other monocotyledonous species, and 138 species of dicotyledonous plants. There were 32 unidentified species. The unidentified species are seven species of Panicum, four other unidentified grasses, eight species of Carex, one species of Juncus, and 11 species of unidentified dicotyledonous plants. Only the Solidago species were combined in the recording and analyses.

Analysis of Data

Analysis of Variance

Results of the analysis of variance between blocks, between species, and species x block interaction are given in Table 20. Significant differences between blocks are found for all classes of vegetation. Significant differences between species are found and significant species x block interaction is found when the residual mean square is calculated using $(r - 1)\Sigma(s - 1)$ degrees of freedom. When using $\Sigma(s - 1)$ degrees of freedom to calculate residual mean square, the F's are significant only for trees.

Table 20. Calculated F values between blocks, between species, and for species x block interaction for trees, tree reproduction, shrubs and vines, and grasses and forbs

Class of Vegetation	Residual of "B" df	Source of Variation		
		Block	Species	Species x Block
Trees	$(r - 1)\Sigma(s - 1)$	23.11**	155.20**	7.57**
	$\Sigma(s - 1)$		3.23**	.16
Tree Reproduction	$(r - 1)\Sigma(s - 1)$	2.95**	30.31**	4.29**
	$\Sigma(s - 1)$		.72	.10
Shrubs and Vines	$(r - 1)\Sigma(s - 1)$	3.03**	36.27**	4.01**
	$\Sigma(s - 1)$		1.25	.14
Grasses and Forbs	$(r - 1)\Sigma(s - 1)$	23.64**	21.69**	7.61**
	$\Sigma(s - 1)$		.11	.04

*Significant at .05.

**Significant at .01.

The results of the analysis of variance for species and transects within blocks are given in Table 21. For trees, significant differences in cover between species is found in 16 blocks. Trees are absent in Sallisaw Meadow and Summit Meadow blocks. There is no significant variation between species in Staser Old-Field and Hector South-to-West Aspect blocks. Variation in cover between transects is significant only in the Staser Old-Field block.

For tree reproduction, significant difference in cover for species is found within 15 blocks. There is no significant variation in cover between species in the Sallisaw Meadow, Summit Meadow, Staser Old-Field, Hector North-to-East Aspect, and Elsah Stream-Bank blocks. Significant difference in cover between transects for tree reproduction is found within the Clarksville North-to-East Aspect, Clarksville Ridge-Top, Clarksville South-to-West Aspect, Talpa North-to-East Aspect, and Elsah Stream-Bank blocks.

For shrubs and vines, significant variation in cover between species is found in 15 blocks. Shrubs and vines are absent in the Sallisaw Meadow block, and there is no significance between species in the Summit Meadow, Hector North-to-East Aspect, Hector South-to-West Aspect, and Elsah Stream-Bank blocks. Variation in cover between transects for shrubs and vines is found in the Sallisaw Meadow and Staser Old-Field blocks.

For grasses and forbs, significant variation in cover between species is found in 17 blocks. There is no significant difference between species in the Summit South-to-West Aspect, Hector North-to-East Aspect, and Hector South-to-West Aspect blocks. Significant variation in cover between transects for grasses and forbs is found

Table 21. Calculated F values for species and transects of trees, tree reproduction, shrubs and vines, and grasses and forbs within 20 sampling blocks

Soil-Position-Disturbance Sampling Block	Number of Transects	Trees (n = 49)		Tree Reproduction (n = 44)		Shrubs and Vines (n = 30)		Grasses and Forbs (n = 206)	
		Species	Transects	Species	Transects	Species	Transects	Species	Transects
Linker North-to-East Aspect	25	19.99**	.59	6.89**	.98	4.59**	1.41	3.96**	2.83**
Linker South-to-West Aspect	24	19.05**	.80	5.74**	1.32	10.22**	1.43	4.21**	1.12
Clarksville North-to-East Aspect	30	43.26**	.39	27.04**	14.56**	12.93**	.74	3.42**	2.77**
Clarksville Ridge-Top	23	54.55**	.48	10.57**	1.80*	10.59**	.83	8.04**	3.21**
Clarksville South-to-West Aspect	25	35.57**	.24	12.74**	1.42*	14.33**	.93	15.35**	1.09
Sallisaw Terrace	8	5.32**	.22	2.61**	1.68	2.72**	2.49*	2.67**	.78
Sallisaw Old-Field	7	6.69**	1.53	3.02**	1.58	2.34**	.86	6.08**	2.68*
Sallisaw Meadow	6	---	---	1.43	1.23	---	---	2.29**	.05
Talpa North-to-East Aspect	6	3.09**	1.06	4.23**	6.39**	6.52**	1.82	2.85**	1.54
Talpa South-to-West Aspect	14	5.86**	1.20	4.23**	1.04	9.38**	1.24	4.34**	.76
Summit North-to-East Aspect	16	18.46**	.69	3.27**	.90	6.06**	1.38	2.59**	2.28*
Summit South-to-West Aspect	9	12.53**	.77	2.00**	1.46	2.55**	1.19	.56	1.06
Summit Meadow	10	---	---	1.00	1.00	1.00	1.00	9.57**	.17
Staser Old-Field	6	1.74	3.09*	.98	1.04	2.22**	3.20**	3.92**	3.02**
Hector North-to-East Aspect	3	3.70*	.37	3.05	.69	1.17	1.32	1.06	3.46
Hector Ridge-Top	15	10.00**	1.36	4.31**	1.00	3.26**	.96	11.37**	.94
Hector South-to-West Aspect	3	2.38	1.75	3.51*	1.27	1.98	3.18	.99	4.04*
Elsah Floodplain, Chert Bedrock	14	14.93**	.27	3.59**	1.51	5.41**	1.10	7.46**	1.13

Table 21 (Continued)

Soil-Position-Disturbance Sampling Block	Number of Transects	Trees (n = 49)		Tree Reproduction (n = 44)		Shrubs and Vines (n = 30)		Grasses and Forbs (n = 206)	
		Species	Transects	Species	Transects	Species	Transects	Species	Transects
Elsah Floodplain, Limestone Bedrock	9	11.86**	.24	4.13**	.89	4.44**	1.47	4.01**	2.33*
Elsah Stream-Bank	7	5.33**	.77	1.45	3.46**	1.75	.81	4.21**	3.28**

*Significant at .05.

**Significant at .01.

within nine blocks. Difference in cover between transects is found in the Linker North-to-East Aspect, Clarksville North-to-East Aspect, Clarksville Ridge-Top, Sallisaw Old-Field, Summit North-to-East Aspect, Staser Old-Field, Hector South-to-West Aspect, Elsah Floodplain over Limestone Bedrock, and Elsah Stream-Bank Blocks.

Results of the analysis of variance between blocks by species are give in Table 22 for trees, Table 23 for tree reproduction, in Table 24 for shrubs and vines, and in Table 25 for grasses and forbs. The difference in cover between blocks is significant for 37 of 49 species or species pairs of trees, 27 of 43 species or species pairs of tree reproduction, 18 of 30 species or species pairs of shrubs and woody vines, and 107 of 206 species of grasses and forbs.

Discriminant Analysis of Transects

A summary of the classification performance for 231 transects from 16 blocks is given in Table 26. The classification performance shows 82.3 percent of the transects classified into the blocks of origin. The Clarksville Ridge-Top Block received 7 transects from 3 other blocks, Linker North-to-East Aspect received 5 transects from 3 other blocks, Linker South-to-West Aspect received 6 transects from 2 other blocks, Summit North-to-East Aspect received 6 transects from 2 other blocks, and Hector Ridge-Top received 6 transects from 4 other blocks. Sallisaw Terrace, Summit South-to-West Aspect, Hector South-to-West Aspect, and Elsah Stream-Bank received no transects from other blocks. Linker North-to-East Aspect and Linker South-to-West Aspect lost the most transects to other blocks, 7 and 6 transects respectively; and Talpa North-to-East

Table 22. Calculated F values between blocks by species for trees

Species	Calculated F Value	Species	Calculated F Value
PINUS ECHINATA	4.28**	AMELANCHIER ARBOREA	.61
JUNIPERUS VIRGINIANA	3.28**	CRATAEGUS ENGELMANNII & C. MOLLIS	1.65*
SALIX NIGRA	5.24**	CERSIS CANADENSIS	3.94**
JUGLANS NIGRA	4.80**	GYMNOCLADUS DIOICA	.67
CARYA CORDIFORMIS	22.25**	GLEDITSIA TRIACANTHOS	3.33**
C. OVATA	7.13**	ROBINIA PSEUDO-ACACIA	2.84**
C. TOMENTOSA & C. TEXANA	6.79**	RHUS GLABRA & R. COPALLINA	.94
OSTRYA VIRGINIANA	4.71**	R. RADICANS	.92
CASTANEA OZARKENSIS	2.92**	ILEX DECIDUA	1.80*
QUERCUS ALBA	12.03**	ACER RUBRUM	.92
Q. MACROCARPA	2.78**	A. SACCHARUM	9.31**
Q. STELLATA	8.06**	A. NEGUNDO	2.24**
Q. MUEHLENBERGII	5.90**	RHAMNUS CAROLINIANA	10.11**
Q. RUBRA	1.97**	TILIA AMERICANA	.48
Q. VELUTINA	8.81**	NYSSA SYLVATICA	2.37**
Q. FALCATA	2.67**	CORNUS FLORIDA	6.78**
Q. MARILANDICA	14.81**	C. DRUMMONDII	3.95**
ULMUS RUBRA	3.93**	VACCINIUM ARBOREUM	1.32
U. AMERICANA	2.63**	BUMELIA LANUGINOSA	2.85**
U. ALATA	1.20	DIOSPYROS VIRGINIANA	1.59
CELTIS OCCIDENTALIS & C. LAEVIGATA	4.68**	FRAXINUS QUADRANGULATA	.92
MORUS RUBRA	2.29**	F. AMERICANA & F. PENNSYLVANICA	4.93**
SASSAFRAS ALBIDUM	7.90**	VIBURNUM PRUNIFOLIUM	2.01**
PLATANUS OCCIDENTALIS	12.05**		
PRUNUS SEROTINA	.71		
P. AMERICANA	1.50		

*Significant at .05.

**Significant at .01.

Table 23. Calculated F values between blocks by species for tree reproduction

Species	Calculated F Value	Species	Calculated F Value
PINUS ECHINATA	1.33	PRUNUS SEROTINA	.51
JUNIPERUS VIRGINIANA	4.02**	P. AMERICANA	2.71**
JUGLANS NIGRA	.68	AMELANCHIER ARBOREA	.60
CARYA CARDIFORMIS	5.57**	CRATAEGUS ENGELMANNII & C. MOLLIS	1.22
C. OVATA	2.26**	CERSIS CANADENSIS	2.70**
C. TOMENTOSA & C. TEXANA	1.55	GYMNOCLADUS DIOICA	.91
OSTRYA VIRGINIANA	6.16**	GLEDITSIA TRIACANTHOS	2.44**
CASTANEA OZARKENSIS	1.21	ROBINIA PSEUDO-ACACIA	2.38**
QUERCUS ALBA	5.90**	ACER RUBRUM	1.19
Q. MACROCARPA	.92	A. SACCHARUM	3.09**
Q. STELLATA	2.06**	A. NEGUNDO	1.93**
Q. MUEHLENBERGII	2.15**	SAPINDUS DRUMMONDII	.50
Q. RUBRA	1.00	RHAMNUS CAROLINIANA	5.79**
Q. VELUTINA	3.95**	NYSSA SYLVATICA	.53
Q. FLACATA	1.72*	CORNUS FLORIDA	3.90**
Q. MARILANDICA	5.74**	BUMELIA LANUGINOSA	2.10**
ULMUS RUBRA & U. AMERICANA	2.57**	DIOSPYROS VIRGINIANA	1.38
U. ALATA	11.43**	FRAXINUS QUADRANGULATA	.86
CELTIS OCCIDENTALIS & C. LAEVIGATA	3.45**	F. AMERICANA & F. PENNSYLVANICA	3.13**
MORUS RUBRA	.53	CHIONATHUS VIRGINICUS	1.75*
SASSAFRAS ALBIDUM	5.30**	VIBURNUM PRUNIFOLIUM	1.76*
PLATANUS OCCIDENTALIS	5.91**		

*Significant at .05.

**Significant at .01.

Table 24. Calculated F values between blocks by species for woody shrubs and vines

Species	Calculated F Value	Species	Calculated F Value
SMILAX TAMNOIDES	1.94**	ILEX DECIDUA	.92
S. BONA-NOX	3.82**	BERCHEMIA SCANDENS	2.11**
CLEMATIS VIRGINIANA	2.71**	CEANOTHUS AMERICANA	.69
COCCULUS CAROLINUS	3.83**	CISSUS INCISA	1.54
LINDERA BENZOIN	4.51**	PARTHENOCISSUS QUINQUEFOLIA	6.42**
PHILADELPHUS PUBESCENS	.53	AMPELOPSIS CORDATA	2.61**
RUBUS TRIVIALIS	6.94**	A. ARBOREA	1.52
R. ABORIGINUM	.84	VITIS LINSECUMII	8.21**
R. OZARKENSIS	5.45**	V. VULPINA	2.92**
R. OCCIDENTALIS	.55	HYPERICUM STRAGALUM	.48
ROSA SETIGERIA	.94	CORNUS DRUMMONDII	3.01**
R. CAROLINA	.88	VACCINIUM ARBOREUM	4.79**
RHUS GLABRA & R. COPALLINA	3.08**	V. STAMINEUM	2.05**
R. AROMATICA	3.22**	CAMPSIS RADICANS	.50
R. RADICANS	.91	SYMPHORICARPOS ORBICULATUS	2.21*

*Significant at .05.

**Significant at .01.

Table 25. Calculated F values between blocks by species for herbaceous plants

Species	Calculated F Value	Species	Calculated F Value
EQUISETUM HYMALE	2.05**	M. BRACHYPHYLLA	2.12**
BOTRICHIUM VIRGINIANUM	1.74*	SPOROBOLUS ASPER	1.07
POLYSTICHUM ACROSTICOIDES	.66	BRACHYELYTRUM ERECTUM	.74
ASPLENIUM PLATYNEURON	4.13**	CYNODON DACTYLON	1.46
PELLAEA ATROPURPUREA	1.00	BOUTELOUA CURTIPENDULA	2.35**
NOTHOLAENA DEALBATA	.65	DIGITARIA SANGUINALIS	1.35
CHILANTHES FEEI	.50	PASPALUM LAEVA	3.37**
BROMUS PURGANS	2.70**	PANICUM OLIGOSANTHES	2.25**
B. JAPONICUS	22.34**	P. MALACOPHYLLUM	1.35
FESTUCA OBTUSA	3.32**	P. CAPILLARE	1.19
ERAGROSTIS CAPILLARIS	2.70**	PANICUM #1	4.85**
E. HIRSUTA	1.53	PANICUM #3	1.69*
DIARRHENA AMERICANA	3.11**	PANICUM #4	1.98*
UNIOLA LATIFOLIA	4.02**	PANICUM #6	2.53**
TRIDENS FLAVUS	3.76**	SETARIA GENICULATA	3.16**
ELYMUS CANADENSIS	3.39**	S. GLAUCA	2.26**
E. VIRGINICUS	5.17**	CENCHRUS PAUCIFLORUS	.89
HYSTRIX PATULA	1.99*	ANDROPOGON SCOPARIUS	12.14**
DANTHONIA SPICATA	.78	A. VIRGINICUS	4.83**
MUHLENBERGIA SCHREBERI	7.24**	A. GERARDII	3.87**
M. CUSPIDATA	3.02**	SORGHUM HALAPENSE	19.41**
M. SOBOLIFERA	.99	SORGHASTRUM NUTANS	.85
		TRIPSACUM DACTYLOIDES	.91

Table 25 (Continued)

Species	Calculated F Value	Species	Calculated F Value
CYPERUS sp.	6.24**	ARABIS CANADENSIS	.51
CAREX CEPHALOPHORA	2.42**	SEDUM PULCHELLUM	2.41**
CAREX #1	5.46**	POTENTILLA SIMPLEX	.82
CAREX #2	2.62**	GEUM CANADENSE	3.15**
CAREX #3	2.25**	AGRIMONIA PUBESCENS	3.06**
CAREX #5	2.62**	DESMANTHUS ILLINOENSIS	6.37**
CAREX #6	1.84*	SCHRANKIA UNCINATA	.41
CAREX #7	3.34**	CASSIA MARILANDICA	2.02**
COMMELINA ERECTA	3.08**	C. FASCICULATA	1.89*
JUNCUS sp.	2.24**	BAPTISIA LEUCOPHAEA	.08
ALLIUM CANADENSE	.89	TRIFOLIUM PRATENSE	2.97**
A. DRUMMONDII	1.56	T. REPENS	3.02**
DIOSCOREA QUATERNATA	.42	T. CAMPESTRE	2.79**
D. VILLOSA	2.87**	STYLOSANTHES BIFLORA	.53
BOEHMERIA CYLINDRICA	2.32**	PSORALEA PSORALIOIDES	4.57**
ERIOGONUM LONGIFOLIUM	.95	TEPHROSEA VIRGINIANA	1.49
RUMEX sp.	2.25**	DESMODIUM NUDIFLORUM	.52
POLYGONUM COCCINUM	2.02**	D. GLUTINOSUM	.91
P. SCANDENS	2.11**	D. ROTUNDIFOLIUM	.42
CHENOPODIUM ALBUM	.67	D. CUSPIDATUM	.79
RANUNCULUS sp.	.84	D. PANICULATUM	.47
ANEMONELLA THALICTROIDES	.29	D. RIGIDUM	4.83*
LEPIDIUM VIRGINIANUM	3.49**	LESPEDEZA PROCUMBENS	1.54

Table 25 (Continued)

Species	Calculated F Value	Species	Calculated F Value
L. REPENS	2.26**	E. SUPINA	.47
L. VIRGINICA	2.07**	HYPERICUM PUNCTATUM	1.77*
L. STUVII	.85	LECHIA TENUIFOLIA	.85
L. VIOLACEA	.48	VIOLA PEDATA	1.51
L. HIRTA	2.45**	V. VIARUM	2.41**
L. CUNEATA	12.91**	V. RAFINESQUII	2.37**
L. STIPULACEA	6.01**	PASSIFLORA INCARNATA	3.85**
CLITORIA MARIANA	5.98**	P. LUTEA	.51
STROPHOSTYLES HELVOLA	.88	OPUNTIA COMPRESSA	1.00
AMPHICARPA BRACTEATA	3.81**	CUPHEA PETIOLATA	.86
GALACTIA VOLUBILIS	1.10	SANICULA CANADENSIS	3.25**
VICIA MINUTIFLORA	2.31**	TORILIS ARVENSIS	4.56**
V. SATIVA	2.25**	CHAEROPHYLLUM PROCUMBENS	1.57
OXALIS STRICTA	2.90**	ZIZIA AUREA	.13
GERANIUM CAROLINANUM	2.91**	APOCYNUM CANNABINUM	.53
PHYLLANTHUS CAROLINIENSIS	.89	ASCLEPIAS HIRTELLA	.92
TRAGIA BENTONICIFOLIA	2.43**	CYNANCHUM LAEVE	2.85**
CROTON MONANTHOGYNUS	4.18**	IPOMOEA PANDURATA	1.71*
CROTONOPSIS ELLIPTICA	.89	HELIOTROPUM TENELLUM	2.48**
ACALYPHA GRACILENS	2.93**	LITHOSPERMUM CANESCENS	.62
EUPHORBIA DENTATA	1.41	VERBENA CANADENSIS	1.28
E. HETEROPHYLLA	1.75*	V. URTRICIFOLIA	1.76*
E. COROLLATA	.75	PRUNELLA VULGARIS	2.82**

Table 25 (Continued)

Species	Calculated F Value	Species	Calculated F Value
SALVIA AZUREA	2.36**	LIATRIS SQUARROSA	.51
CUNILA ORIGANOIDES	.96	GRINDELIA LANCEOLATA	1.20
MONARDA RUSSELIANA	3.29**	GUTIERREZIA DRACUNCULOIDES	2.36**
M. CITRIODORA	1.16	SOLIDAGO spp.	1.62
SOLANUM CAROLINENSE	1.52	ASTER AZUREUS	1.15
VERBASCUM THAPSUS	2.37**	A. SAGITTIFOLIUS	.75
SCROPHULARIA MARILANDICA	.05	A. PATENS	2.58**
GERARDIA PECTINATA	2.03**	ERIGERON STRIGOSUS	.91
RUELLIA STREPENS	1.72*	CONYZA CANADENSIS	4.57**
PLANTAGO ARISTATA	5.16**	ANTENNARIA PLANTAGINIFOLIA	1.76*
P. VIRGINICA	.88	HELIOPSIS HELIANTHOIDES	1.41
GALIUM TRIFLORUM	3.18**	RUDBECKIA HIRTA	2.07**
C. CIRCAEZENS	3.27**	ECHINECEA PALLIDA	.68
G. ARKANSANUM	1.47	HELIANTHUS HIRSUTUS	.65
SPECULARIA PERFOLIATA	1.92*	ACTINOMERIS ALTERNIFOLIA	3.77**
S. LAMPROSPERMA	7.76**	VERBASINA VIRGINICA	.67
VERNONIA ALTISSIMA	1.80*	COREOPSIS GRANDIFLORA	.82
ELEPHANTOPUS CAROLINIANUS	1.51	C. TINCTORA	.91
EUPATORIUM ALTISSIMUM	1.75*	BIDENS BIPINNATA	3.22**
E. RUGOSUM	.63	AMBROSIA ARTEMESIIFOLIA	.63
E. COELESTINUM	4.48**	HELENIUM AMARUM	7.71**
KUHNIA EUPATORIOIDES	.52	ACHILLEA LANULOSA	1.89*

Table 25 (Continued)

Species	Calculated F Value	Species	Calculated F Value
ARTEMISIA LUDOVICIANA	1.13	LACTUCA CANADENSIS	1.80*
CIRSIUM ALTISSIMUM	4.72**	HIERACIUM GRONOVII	1.75*
SONCHUS ASPER	.53		

*Significant at .05.

**Significant at .01.

Aspect lost the greatest percentages of transects, followed by Talpa South-to-West, Linker North-to-East, Linker South-to-West, and Sallisaw Terrace blocks. Hector North-to-East, Hector South-to-West, and Elsah Stream-Bank lost no transects to other blocks. Other blocks retaining a high percentage of transects are Elsah Floodplain over limestone, Elsah Floodplain over chert, Clarksville North-to-East, and Clarksville Ridge-Top.

The classification results for each transect are given in Table 27. Of the 41 transects assigned to blocks from which they did not come, 36 may be due to position of the transect close to competing blocks and/or edaphic similarities between the competing blocks. Transect 90 from Clarksville Ridge-Top assigned to Hector Ridge-Top, transects 140 and 147 from Talpa South-to-West Aspect assigned to Hector Ridge-Top, transect 198 from Hector Ridge-Top assigned to Clarksville Ridge-Top, and transect 243 from Sallisaw Terrace assigned to Linker North-to-East

Table 26. Discriminant analysis of transects from 16 blocks--summary of classification performance using generalized squared distance

From Block	Linker N-E Aspect	Linker S-W Aspect	Clarksville N-E Aspect	Clarksville Ridge	Clarksville S-W Aspect	Sallisaw Terrace	Talpa N-E Aspect	Talpa S-W Aspect	Summit N-E Aspect	Summit S-W Aspect	Hector N-E Aspect	Hector Ridge	Hector S-W Aspect	Elsah, Floodplain Chert Bedrock	Elsah, Floodplain Limestone Bedrock	Elsah Streambank
	Number of Transects Classified into Block															
Linker N-E Aspect	18	2	0	0	0	0	0	0	4	0	1	0	0	0	0	0
Linker S-E Aspect	2	18	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Clarksville N-E Aspect	0	0	27	3	0	0	0	0	0	0	0	0	0	0	0	0
Clarksville Ridge-Top	0	0	0	21	1	0	0	0	0	0	0	1	0	0	0	0
Clarksville S-W Aspect	0	0	1	3	20	0	0	0	0	0	0	1	0	0	0	0
Sallisaw Terrace	1	0	1	0	0	6	0	0	0	0	0	0	0	0	0	0
Talpa N-E Aspect	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0
Talpa S-W Aspect	0	1	0	0	0	0	1	10	0	0	0	2	0	0	0	0
Summit N-E Aspect	1	3	0	0	0	0	0	0	12	0	0	0	0	0	0	0
Summit S-W Aspect	1	0	0	0	0	0	0	1	0	7	0	0	0	0	0	0

Table 26 (Continued)

From Block	Number of Transects Classified into Block: Linker N-E Aspect	Linker S-W Aspect	Clarksville N-E Aspect	Clarksville Ridge	Clarksville S-W Aspect	Sallisaw Terrace	Talpa N-E Aspect	Talpa S-W Aspect	Summit N-E Aspect	Summit S-W Aspect	Hector N-E Aspect	Hector Ridge	Hector S-W Aspect	Elsah, Floodplain Chert Bedrock	Elsah, Floodplain Limestone Bedrock	Elsah Streambank
Hector N-E Aspect	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Hector Ridge-Top	0	0	0	1	0	0	0	0	0	0	1	13	0	0	0	0
Hector S-W Aspect	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Elsah Floodplain, Chert Bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	0
Elsah Floodplain, Limestone Bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0
Elsah Stream-Bank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7

Table 27. Discriminant analysis of transects from 16 blocks--classification results for each transect

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
1	Linker N-E Aspect	Linker S-W Aspect	15	Linker N-E Aspect	Linker N-E Aspect
2	"	"	16	"	"
3		Linker N-E Aspect	17	"	"
4	"	"	18	"	"
5	"	"	19	"	"
6	"	"	20	"	"
7	"	"	21	"	"
8	"	"	22	"	"
9	"	"	23	"	Hector N-E Aspect
10	"	Summit N-E Aspect	24	"	Linker N-E Aspect
11	"	"	25	"	"
12	"	Linker N-E Aspect	26	Linker S-W Aspect	Summit N-E Aspect
13	"	Summit N-E Aspect	27	"	Linker S-W Aspect
14	"	"	28	"	"

Table 27 (Continued)

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
29	Linker S-W Aspect	Linker N-E Aspect	44	Linker S-W Aspect	Linker S-W Aspect
30	"	Linker S-W Aspect	45	"	"
31	"	"	46	"	"
32	"	Summit N-E Aspect	47	"	"
33	"	Linker S-W Aspect	48	"	"
34	"	"	49	"	"
35	"	Hector Ridge-Top	50	Clarksville N-E Aspect	Clarksville N-E Aspect
36	"	Linker S-W Aspect	51	"	"
37	"	"	52	"	"
38	"	"	53	"	"
39	"	Linker N-E Aspect	54	"	"
40	"	Hector Ridge-Top	55	"	"
41	"	Linker S-W Aspect	56	"	"
42	"	"	57	"	Clarksville Ridge-Top
43	"	"			

Table 27 (Continued)

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
58	Clarksville N-E Aspect	Clarksville N-E Aspect	71	Clarksville N-E Aspect	Clarksville N-E Aspect
59	"	"	72	"	"
60	"	"	73	"	"
61	"	"	74	"	"
62	"	"	75	"	Clarksville Ridge Top
63	"	"	76	"	Clarksville N-E Aspect
64	"	"	77	"	"
65	"	"	78	"	"
66	"	"	79	"	"
67	"	"	80	Clarksville Ridge Top	Clarksville Ridge Top
68	"	"	81	"	"
69	"	"	82	"	"
70	"	Clarksville Ridge Top			

Table 27 (Continued)

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
83	Clarksville Ridge Top	Clarksville Ridge Top	97	Clarksville Ridge Top	Clarksville Ridge Top
84	"	"	98	"	"
85	"	"	99	"	"
86	"	"	100	"	Clarksville S-W Aspect
87	"	"	101	"	Clarksville Ridge Top
88	"	"			
89	"	"	102	"	"
90	"	Hector Ridge Top	103	Clarksville S-W Aspect	Clarksville S-W Aspect
91	"	Clarksville Ridge Top	104	"	"
92	"	"	105	"	"
93	"	"	106	"	"
94	"	"	107	"	Clarksville Ridge Top
95	"	"	108	"	Clarksville S-W Aspect
96	"	"			

Table 27 (Continued)

Transect	From Block	Classified into Block
109	Clarksville S-W Aspect	Clarksville S-W Aspect
110	"	"
111	"	"
112	"	"
113	"	Hector Ridge Top
114	"	Clarksville S-W Aspect
115	"	"
116	"	Clarksville N-E Aspect
117	"	Clarksville S-W Aspect
118	"	"
119	"	"
120	"	"
121	"	"
122	Clarksville S-W Aspect	Clarksville S-W Aspect
123	"	"
124	"	Clarksville Ridge Top
125	"	Clarksville S-W Aspect
126	"	Clarksville Ridge Top
127	"	Clarksville S-W Aspect
128	Talpa N-E Aspect	Talpa N-E Aspect
129	"	Talpa S-W Aspect
130	"	Talpa N-E Aspect
131	"	"
132	"	Talpa S-W Aspect
133	"	Talpa N-E Aspect

Table 27 (Continued)

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
134	Talpa S-W Aspect	Talpa N-E Aspect	148	Summit N-E Aspect	Summit N-E Aspect
135	"	Talpa S-W Aspect	149	"	Linker S-W Aspect
136	"	"	150	"	Summit N-E Aspect
137	"	"	151	"	"
138	"	"	152	"	"
139	"	"	153	"	"
140	"	Hector Ridge Top	154	"	"
141	"	Talpa S-W Aspect	155	"	"
142	"	"	156	"	Linker S-W Aspect
143	"	"	157	"	Summit N-E Aspect
144	"	"	158	"	"
145	"	Linker S-W Aspect	159	"	"
146	"	Talpa S-W Aspect	160	"	"
147	"	Hector Ridge Top	161	"	Linker N-E Aspect

Table 27 (Continued)

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
162	Summit N-E Aspect	Summit N-E Aspect	190	Hector Ridge Top	Hector Ridge Top
163	"	Linker S-W Aspect	191	"	"
164	Summit S-W Aspect	Talpa S-W Aspect	192	"	"
165	"	Linker N-E Aspect	193	"	"
166	"	Summit S-W Aspect	194	"	"
167	"	"	195	"	"
168	"	"	196	"	"
169	"	"	197	"	"
170	"	"	198	"	Clarksville Ridge Top
171	"	"	199	"	Hector Ridge Top
172	"	"	200	"	"
173-182	Summit, Meadow	Not Analyzed	201	"	"
183-188	Staser, Old Field	Not Analyzed	202	"	"
189	Hector Ridge Top	Hector N-E Aspect	203	"	"

Table 27 (Continued)

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
204	Hector N-E Aspect	Hector N-E Aspect	217	Elsah, Floodplain Chert Bedrock	Elsah, Floodplain Chert Bedrock
205	"	"	218	"	"
206	"	"	219	"	"
207	Hector S-W Aspect	Hector S-W Aspect	220	"	"
208	"	"	221	"	"
209	"	"	222	"	"
210	Elsah, Floodplain Chert Bedrock	Elsah, Floodplain Chert Bedrock	223	"	"
211	"	"	224	Elsah, Floodplain Limestone Bedrock	Elsah, Floodplain Limestone Bedrock
212	"	"	225	"	Elsah, Floodplain Chert Bedrock
213	"	"	226	"	Elsah, Floodplain Limestone Bedrock
214	"	"	227	"	"
215	"	"	228	"	"
216	"	Elsah, Floodplain Limestone Bedrock			

Table 27 (Continued)

Transect	From Block	Classified into Block	Transect	From Block	Classified into Block
229	Elsah, Floodplain Limestone Bedrock	Elsah, Floodplain Limestone Bedrock	240	Sallisaw Terrace	Sallisaw Terrace
230	"	"	241	"	"
231	"	"	242	"	"
232	"	"	243	"	Linker N-E Aspect
233	Elsah, Streambank Limestone Bedrock	Elsah, Streambank Limestone Bedrock	244	"	Sallisaw Terrace
234	"	"	245	"	"
235	"	"	246	"	Clarksville N-E Aspect
236	"	"	247	"	Sallisaw Terrace
237	"	"	248-254	Sallisaw, Old Field	Not Analyzed
238	"	"	255-260	Sallisaw, Meadow	Not Analyzed
239	"	"			

Aspect are not exlainable by positional proximity or edaphic similarities between the competing blocks.

Clustering Analysis

The results of the cluster analysis for 123 species in 11 blocks are shown in Figures 48 to 58. A horizontal line is drawn across each figure at the .05 level of significance. All species joined below the line are associations within the block.

In Linker North-to-East Aspect (Fig. 48) 77 species are used. There are 13 associations with 2 to 8 species in each. Eight species are not joined with any associations at the .05 level of significance.

In the Linker South-to-West Aspect block (Fig. 49) 82 species are used. There are 15 associations of 2 to 9 species each. Ten species are not joined with associations at the .05 level of significance.

In the Clarksville North-to-East Aspect block (Fig. 50) 76 species are used. There are 9 associations with 2 to 20 species each, and 12 species are unjoined with associations at the .05 level of significance.

In the Clarksville Ridge-Top block (Fig. 51) there are 78 species. There are 11 associations of 2 to 17 species each and 4 species unjoined at the .05 level of significance.

In the Clarksville South-to-West Aspect block (Fig. 52) there are 53 species. There are 12 associations and 15 species unjoined at the .05 level of significance.

In the Sallisaw Terrace block (Fig. 53) there are 85 species. They form 13 associations of 2 to 9 species each. There are 26 species unjoined to associations at the .05 level of significance.

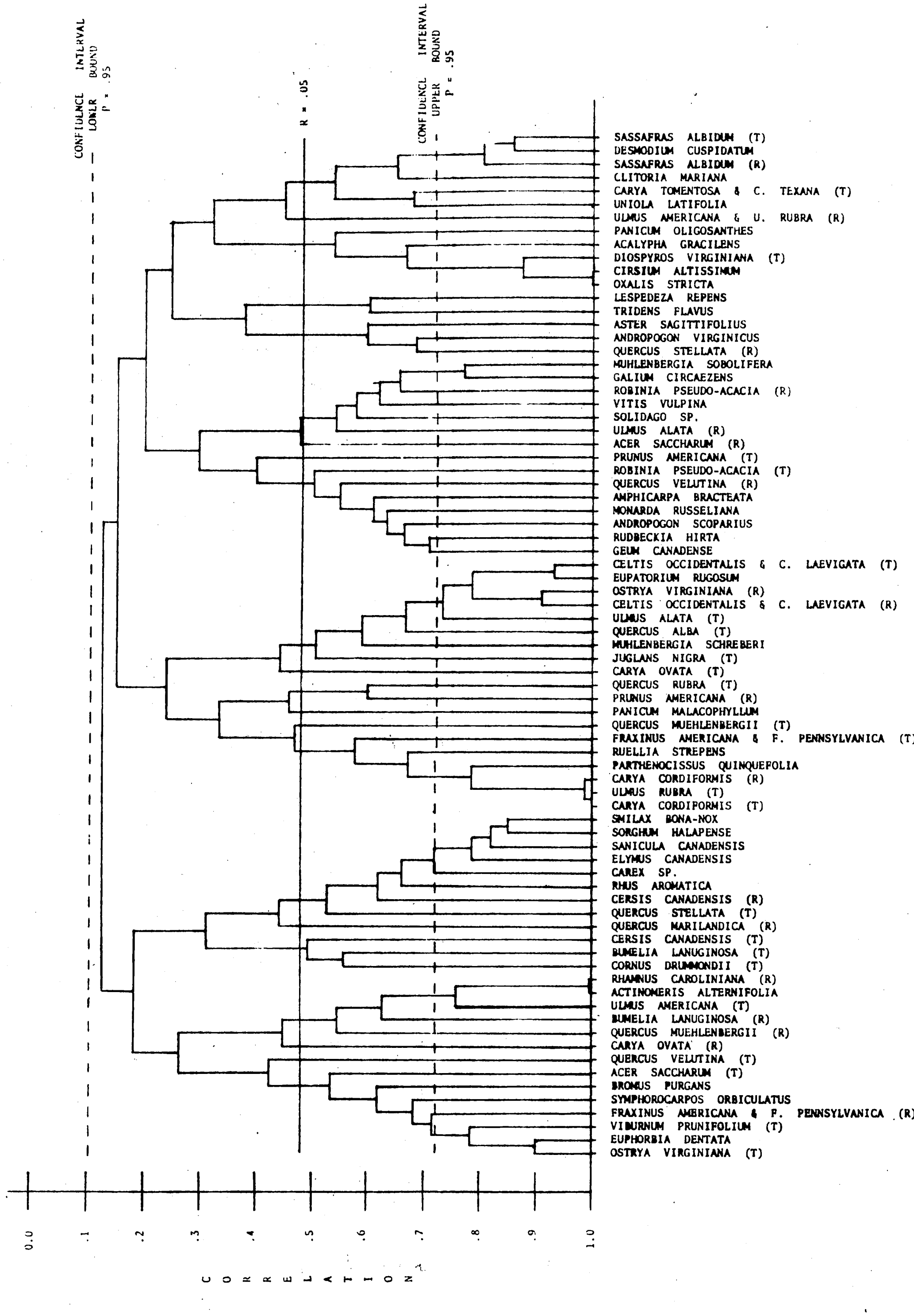

Fig. 48. Clustering dendrogram of 77 species from the Linker north-to-east aspect block

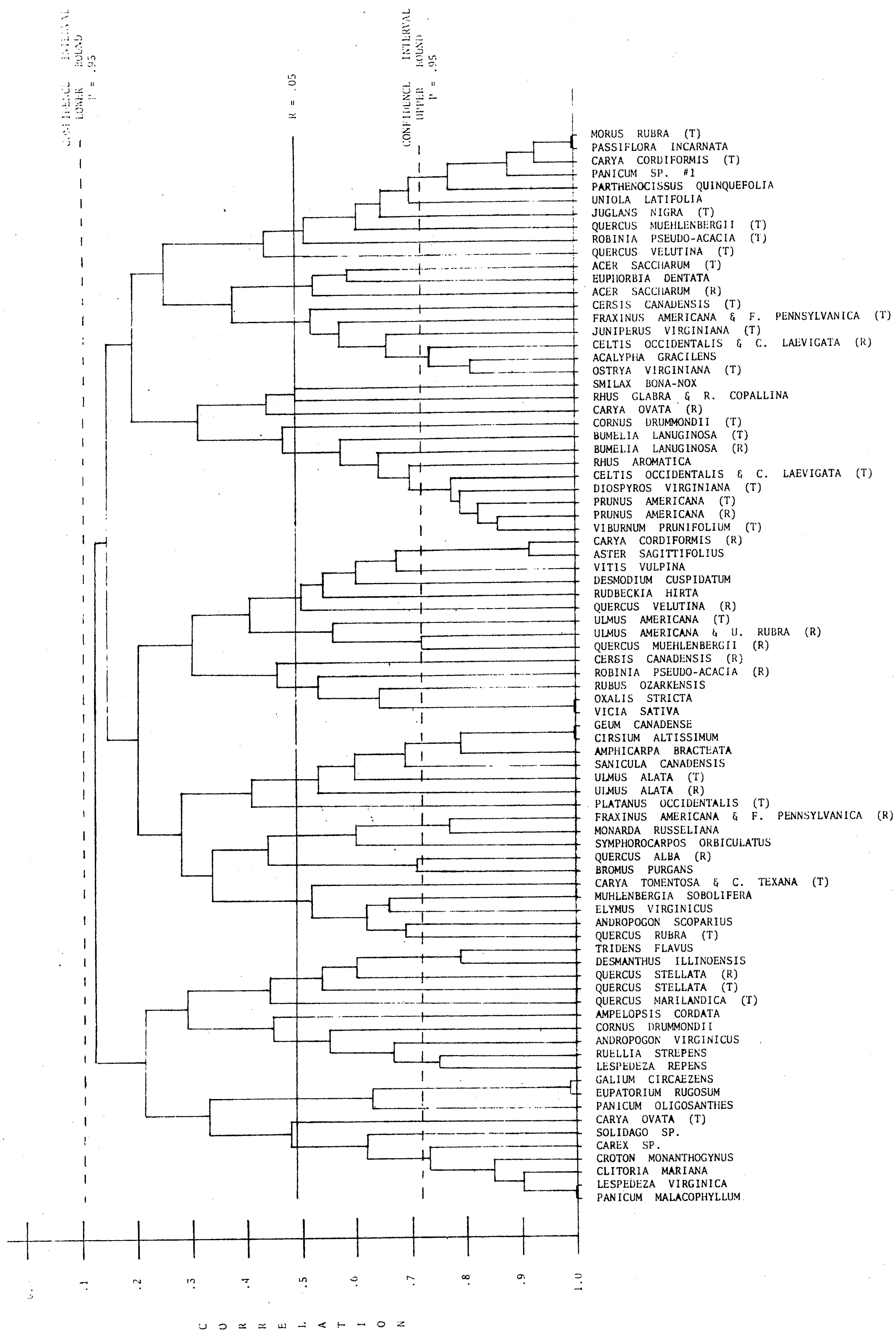

Fig. 49. Clustering dendrogram of 82 species from the Linker south-to-west aspect block

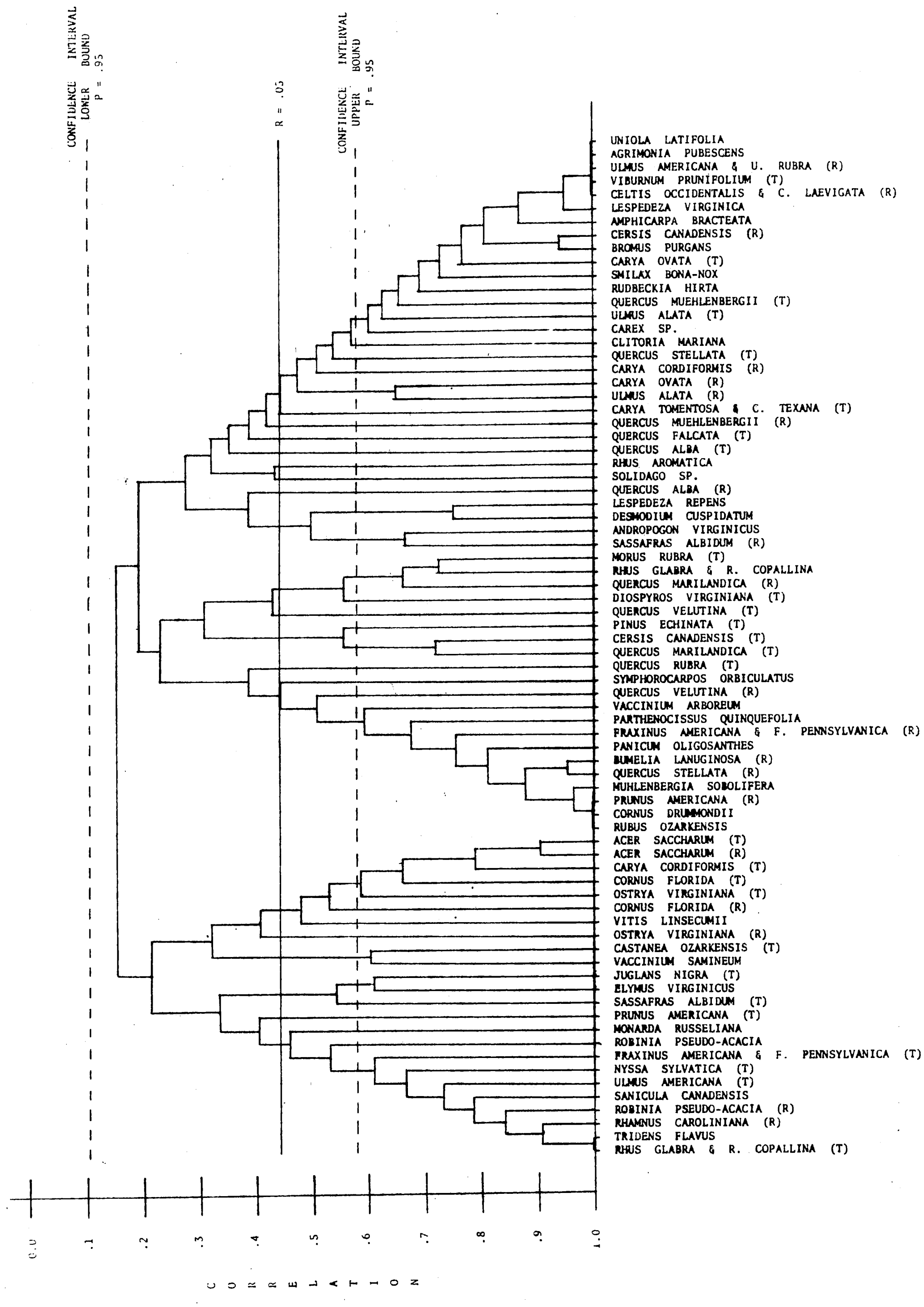

Fig. 50. Clustering dendrogram of 76 species from the Clarksville north-to-east aspect block

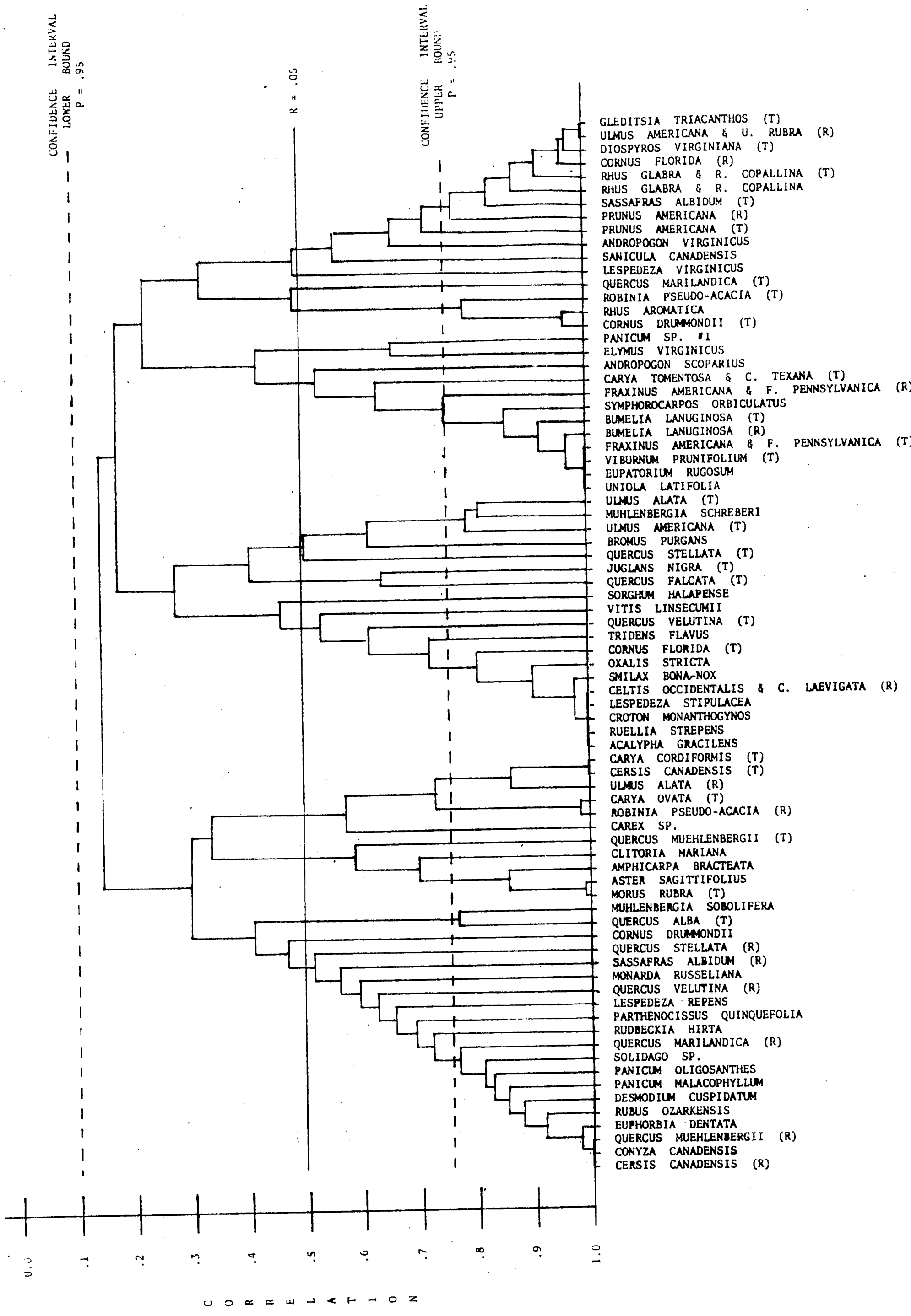

Fig. 51. Clustering dendrogram of 78 species from the Clarksville ridge-top block

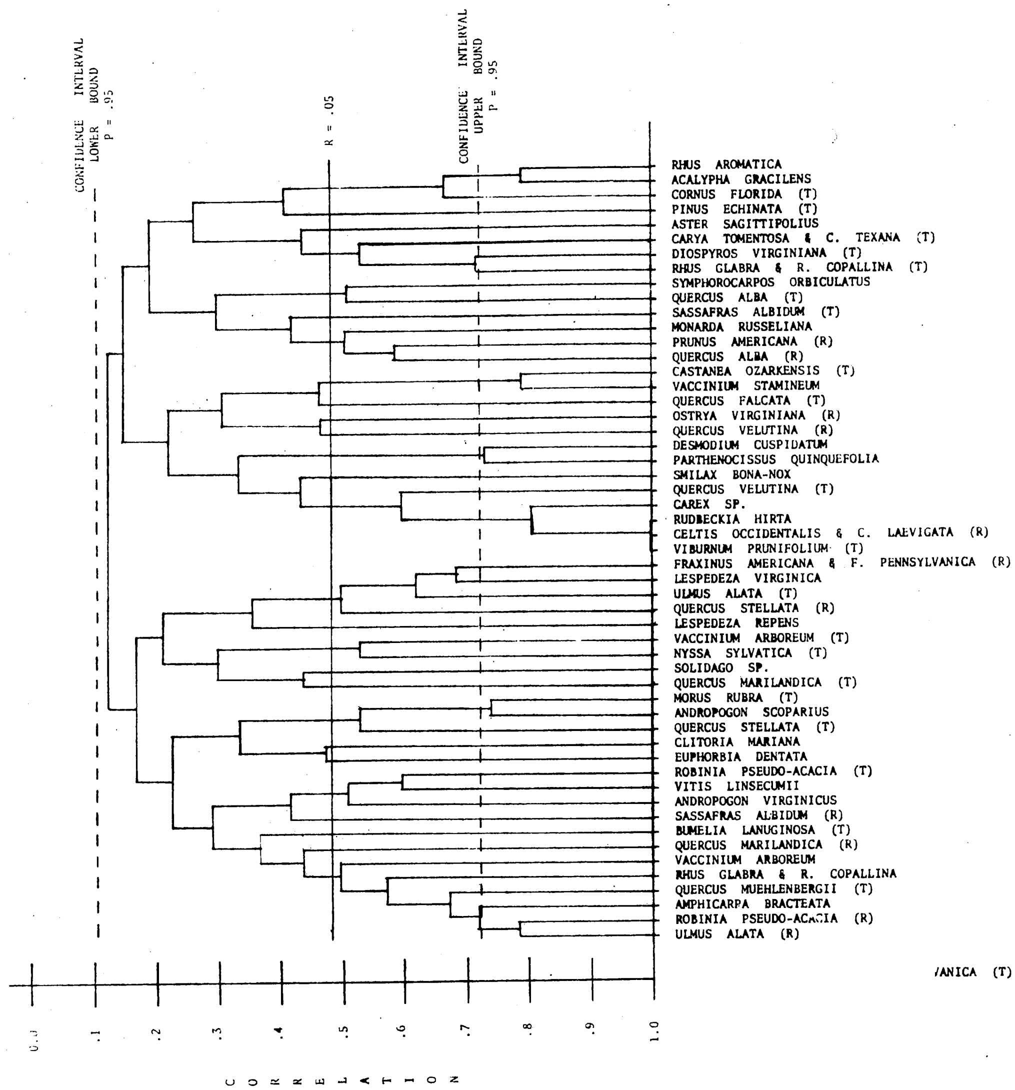

Fig. 52. Clustering dendrogram of 53 species from the Clarksville south-to-west aspect block

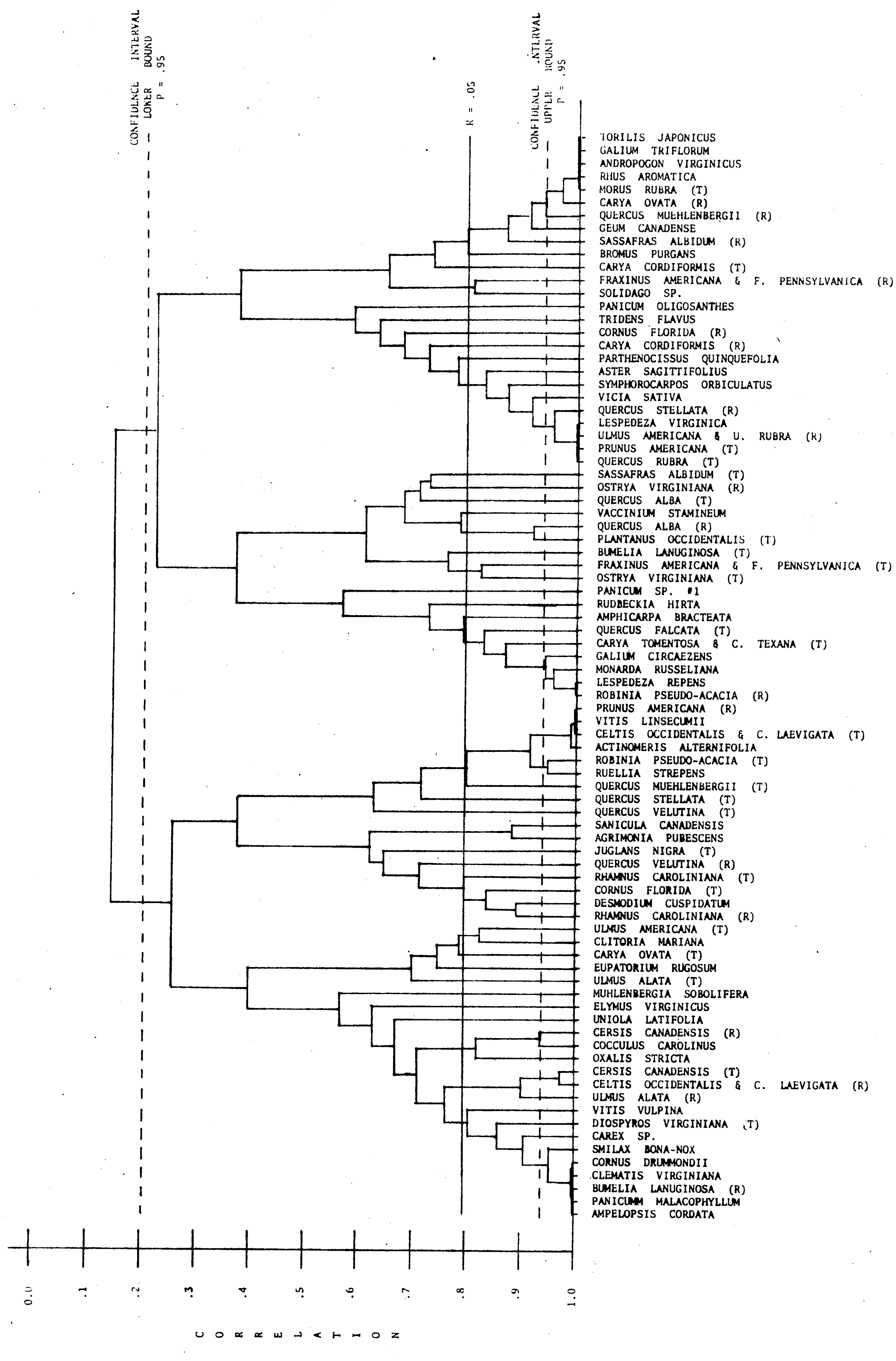

Fig. 53. Clustering dendrogram of 85 species from the Sallisaw terrace block

In the Talpa South-to-West Aspect block (Fig. 54) there are 70 species used. There are 13 associations of 2 to 10 species each, 7 species unjoined with associations at the .05 level of significance.

In the Summit North-to-East Aspect block (Fig. 55) 68 species are used. They form 8 associations of 3 to 12 species each, and 25 species are unjoined with associations at the .05 level of significance.

In the Hector Ridge-Top block (Fig. 56) 64 species are used. They form 9 associations of 4 to 14 species each, and 6 species are unjoined with associations at the .05 level of significance.

In the Elsah Floodplain over chert bedrock block (Fig. 57) 74 species are used. They form 10 associations of 2 to 11 species each, and 31 species are unjoined with associations at the .05 level of significance.

In the Elsah Stream-Bank block (Fig. 58) 84 species are used. They form 9 associations of 2 to 12 species each, and 31 species are unjoined with associations at the .05 level of significance.

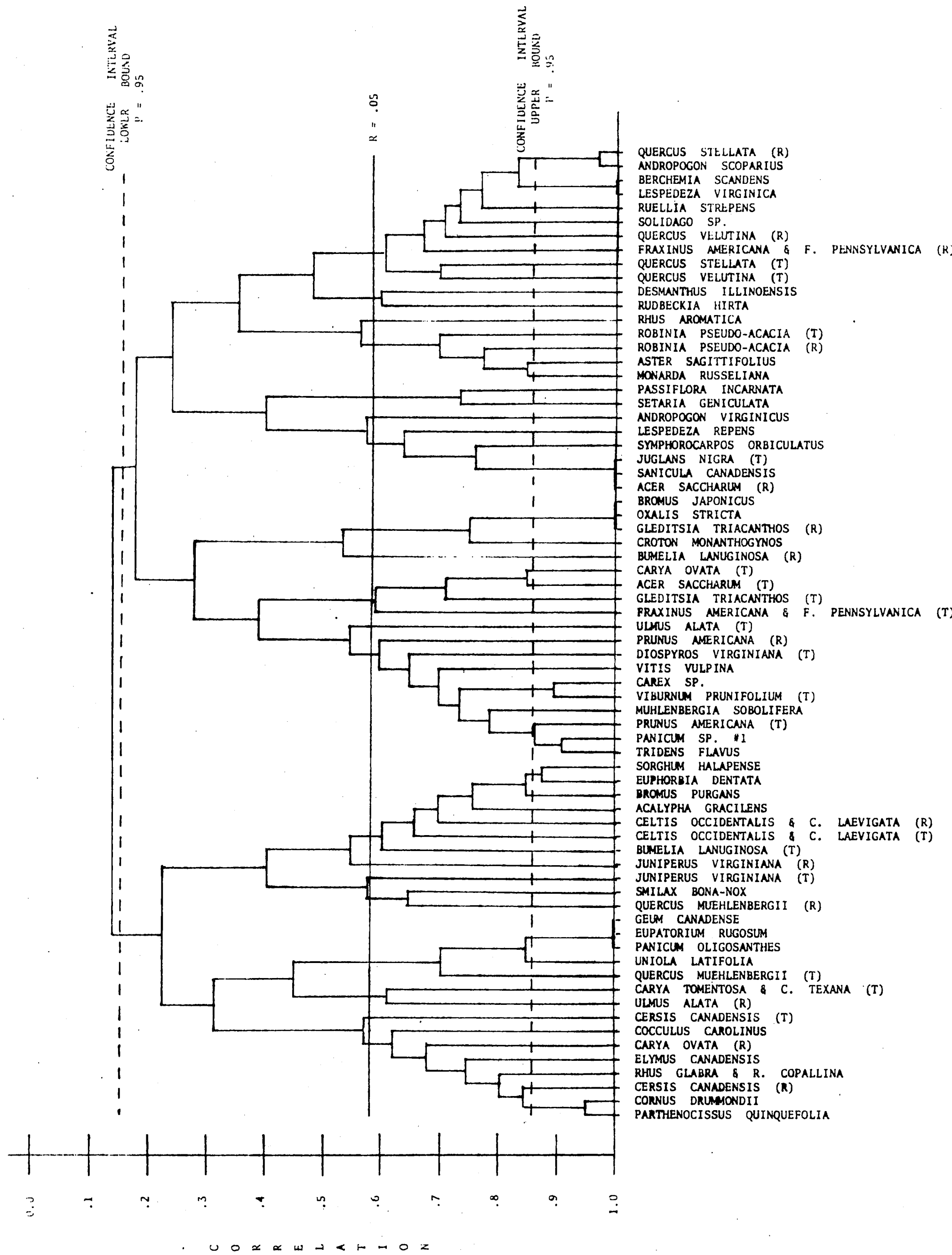

Fig. 54. Clustering dendrogram of 70 species from the Talpa south-to-west aspect block

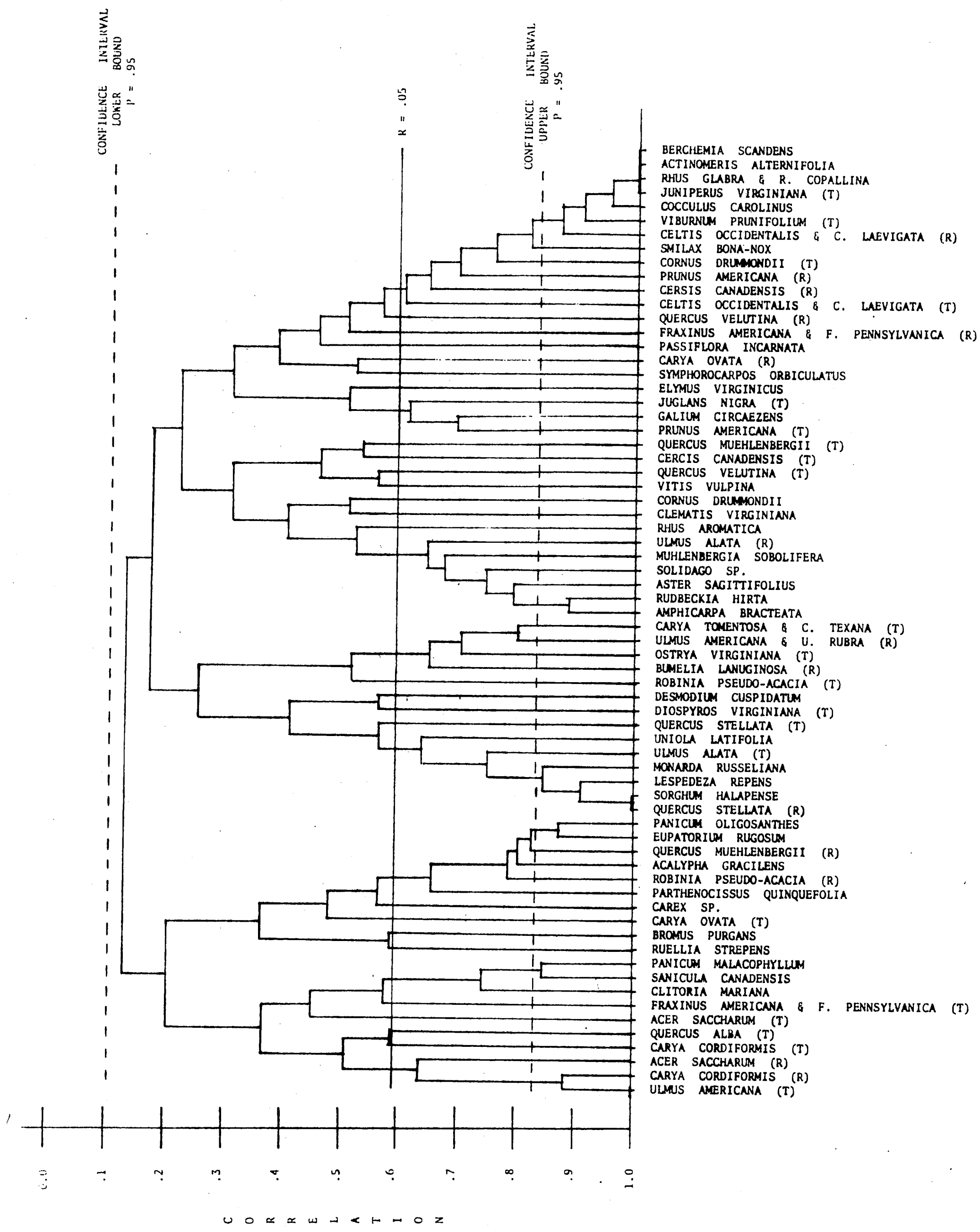

Fig. 55. Clustering dendrogram of 68 species from the Summit north-to-east aspect block

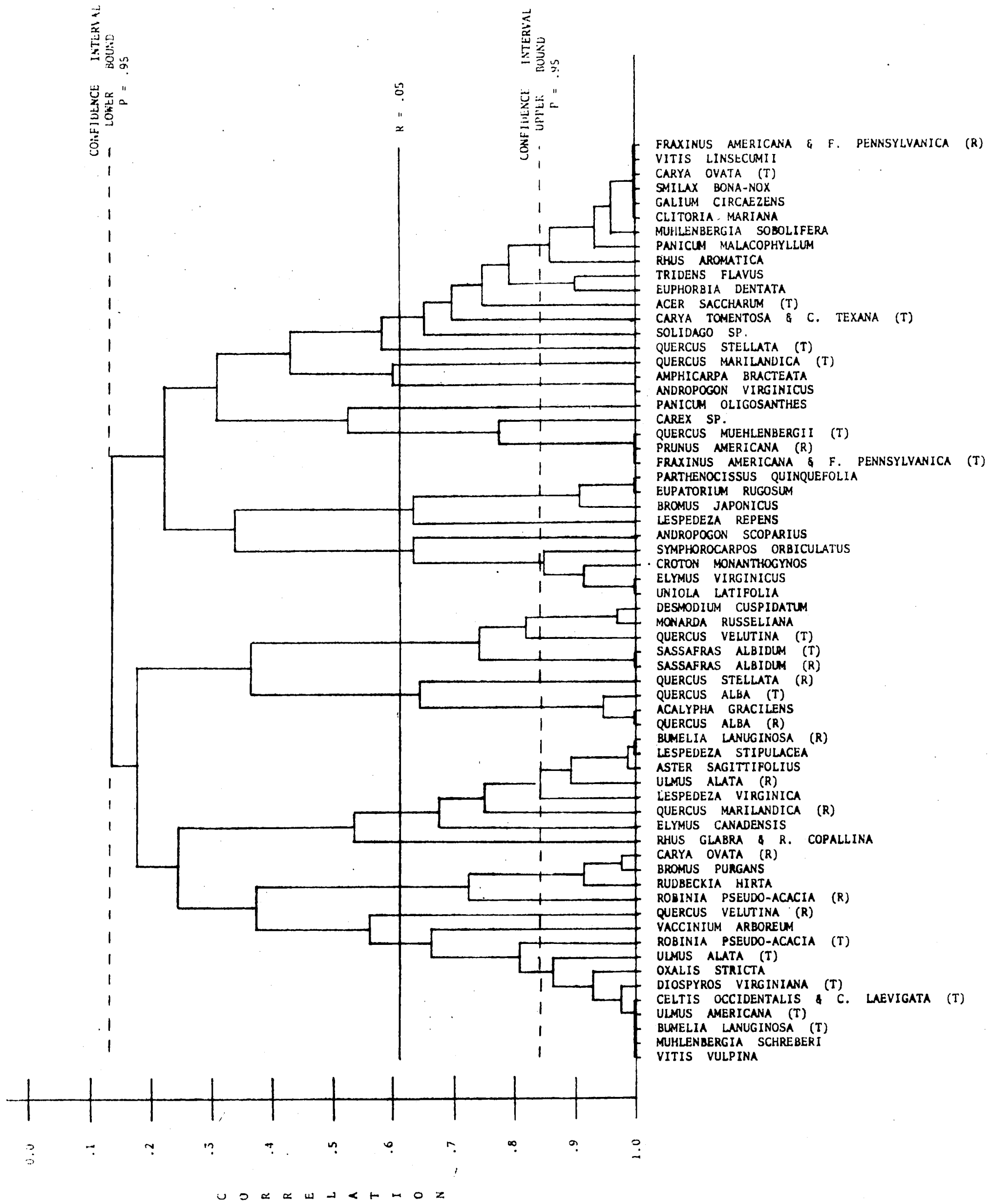

Fig. 56. Clustering dendrogram of 64 species from the Hector ridge-top block

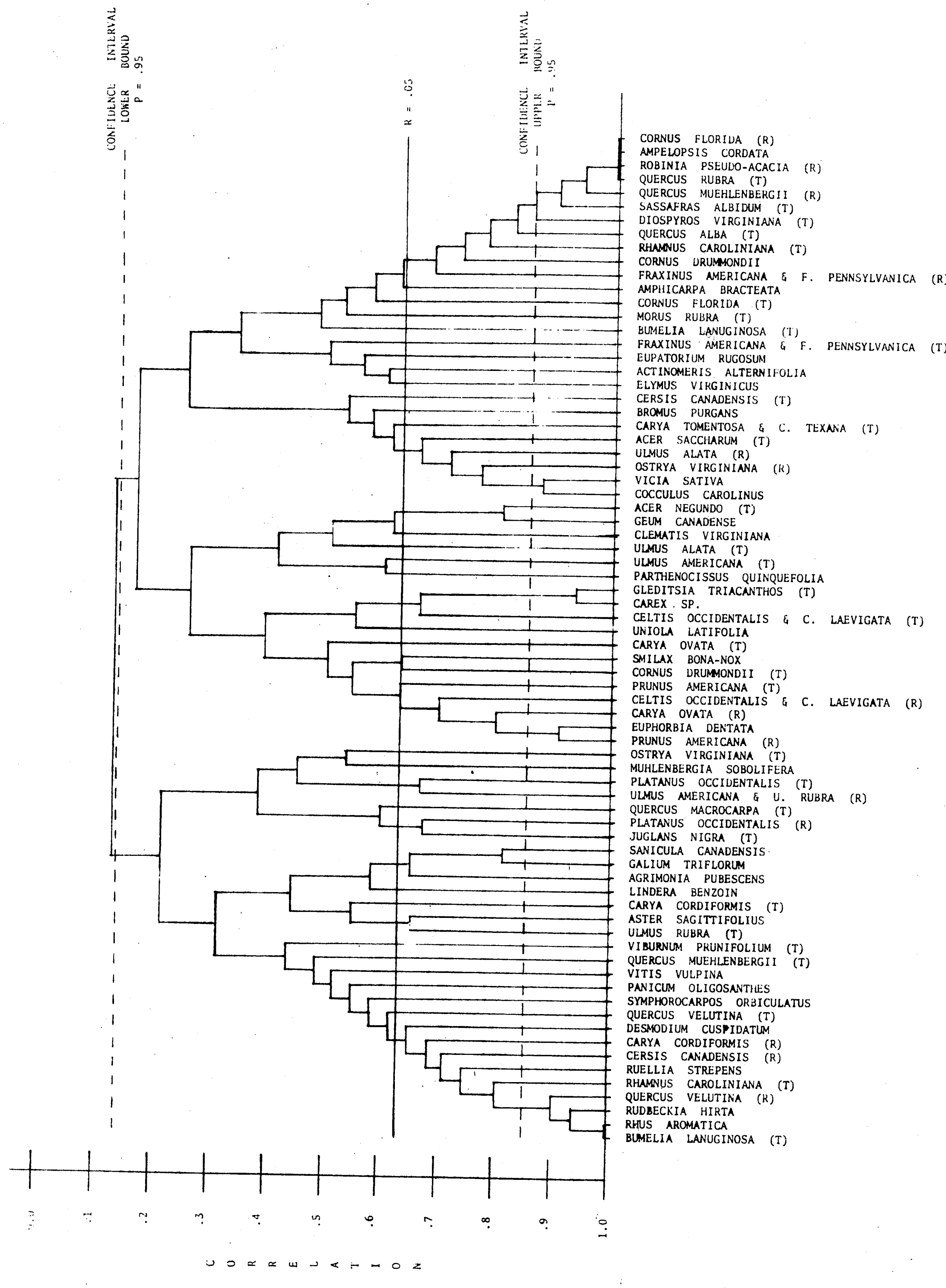

Fig. 57. Clustering dendrogram of 74 species from the Elsah floodplain block over chert bedrock

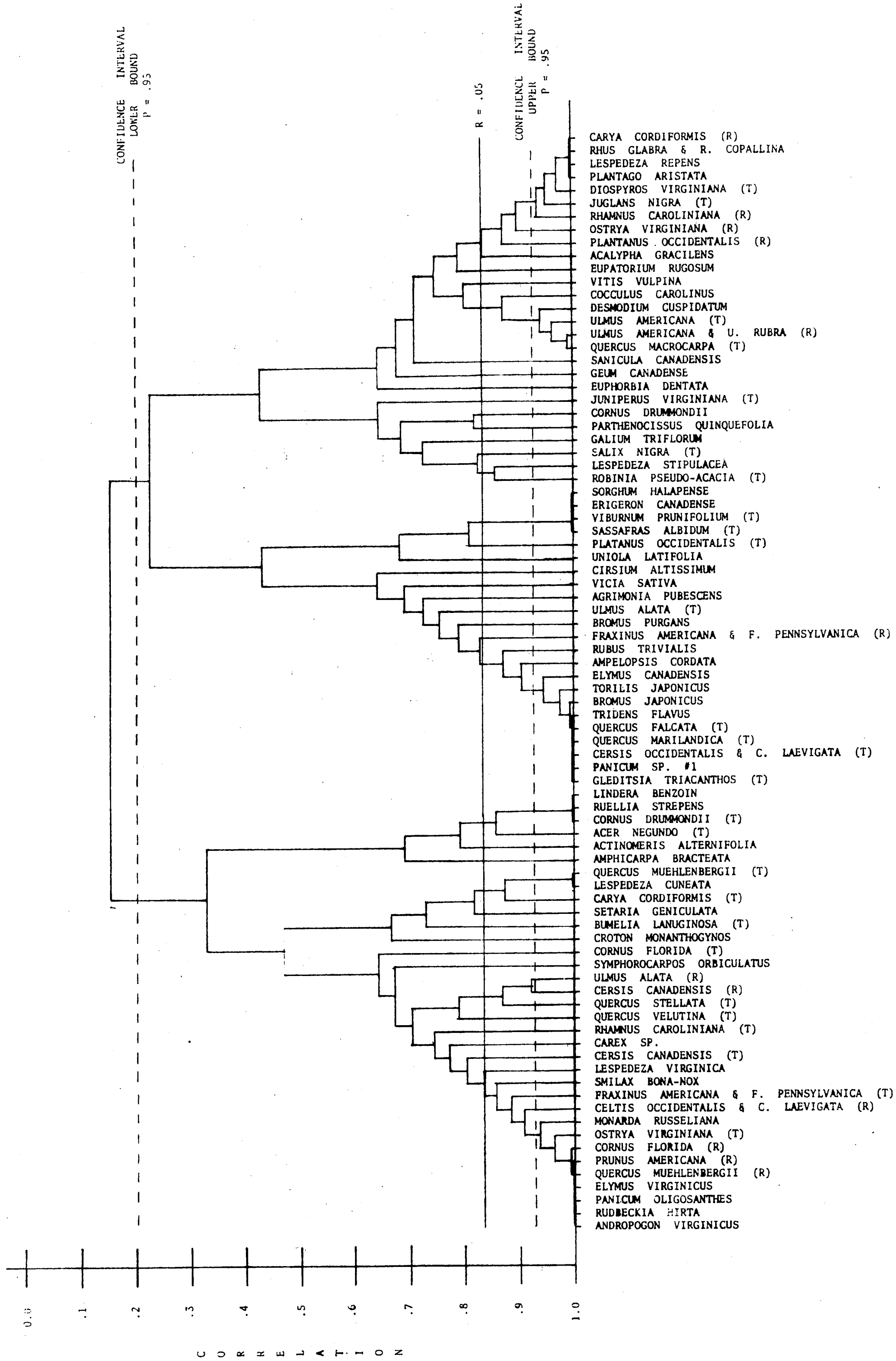

Fig. 58. Clustering dendrogram of 84 species from the Elsah stream-bank block

CHAPTER VII

DISCUSSION

Variation of Present-Day Vegetation on the Refuge

Variation Between Blocks

Variation in vegetative cover between blocks is significant for all classes of vegetation (Table 20), and extremely high F values are calculated for trees and for herbaceous plants. Trees are absent in meadows and tree cover is reduced in the old fields, on the grassland range sites, and along stream banks. Grasses and forbs have the highest cover values in meadows, old fields, and range sites, and are much lower under stands with dense tree cover. Much of the variation between blocks is attributable to this sort of variation, but the variation is also significant between the different forest types on the same soil type and between the same forest type on different soil types. An analysis of two forest types on four blocks (Post Oak-Black Oak on Linker South-to-West Aspect and Clarksville South-to-West Aspect and White Oak Red-Oak Hickory on Linker North-to-East Aspect and Clarksville North-to-East Aspect) showed difference in cover between the blocks significant at .01 (F 12.6 at 3 and 4,700 degrees of freedom).

Variation Between Transects

Variation of cover on transects (ignoring blocks) (Table 20) is not significant for all classes of vegetation. Variation of cover between transects within blocks (Table 21) is significant in 1 block for trees, in 5 blocks for tree reproduction, in 2 blocks for shrubs and vines, and in 9 blocks for grasses and forbs.

The significant variation between lines for trees occurred on the Staser Old-Field block. The significance of the variation may be assumed valid despite the small number of transects. One transect in this block is devoid of trees, another has nearly 100 percent tree cover, and tree cover on the remaining transects ranges from 20 to 80 percent.

For tree reproduction significant variation between transects occurs within the Clarksville North-to-East, Clarksville Ridge-Top, Clarksville South-to-West, Talpa North-to-East, and Elsah Stream-Bank blocks. In the Clarksville blocks much of the variation is due to vigorous coppice growth by top-killed trees on transects in the areas of recent severe fires (1964, 1966, 1967). In areas of older fires such coppice growth had grown large enough to be counted as trees. On Talpa soils stands of trees intermingle with open grassy areas. The Elsah Stream-Bank block is a narrow band of trees on the stream bank adjacent to the open stream bed. This block follows the bends and meanders of the stream on the valley floor. In the Talpa and Elsah Stream-Bank blocks some of the tree reproduction lines crossed the edge between the open areas and stands of trees, other lines were wholly in the open or under trees.

Variation in shrub and vine cover between transects is significant in the White Oak-Red Oak-Hickory type on Sallisaw Terrace block and in the Staser Old-Field block. Variation in the Sallisaw Terrace block is accountable to 98 ft of shrub intercept on one transect and low shrub cover values on the other transects. In the Staser Old-Field block shrub and vine cover is low on the transect without trees and varies inversely with tree cover on the other transects.

Significant variation in cover between transects is present in nine blocks for grasses and forbs. Under forest stands herbaceous cover is inversely related to the density of the tree canopy. South-to-west facing slopes are warmer and dryer than north-to-east facing slopes and the tree canopy is more open than on north-to-east-aspects. The more open nature of the overstory permits more general distribution of forbs and grasses on the forest floor on south-to-west-facing slopes. On north-to-east-facing slopes the dense canopy restricts more herbaceous cover to areas under breaks or openings in the overstory. In Linker, Summit, and Clarksville soils significant variation is present on the north-to-east aspects but not on the south-to-west-facing slopes. The same soil depth-available moisture-tree canopy-ground cover relationship is observed between the Hector Ridge-Top and Clarksville Ridge-Top block. Hector soils are shallow and tree stands are more open than on the deeper Clarksville soils. Ground cover is more evenly distributed under the Post Oak-Black Oak forest on the Hector Ridge-Top block than under the same forest type on the Clarksville Ridge-Top block. The dense tree canopy on Elsah soils in stream bottoms restricts distribution of herbaceous plants in the same manner. In the old field blocks, clumps of trees and shrubs alternate with open areas; density of grasses and forbs is high in the open areas and low under trees and shrubs.

Variation Between Species

Variation in cover between species for all blocks combined (Table 20) is significant for trees and possibly significant for the three other classes of vegetation. With the smaller residual mean square [df = $(r - 1)\Sigma(s - 1)$] the calculated F values are significant at the .01 level for all classes of vegetation. When the conservative residual mean square [df - $\Sigma(s - 1)$] is used to calculate F, only the variation in cover between trees is significant. When variation in cover between species within blocks (Table 21) is examined, blocks with more than 12 transects show significance in variation of cover between species for all classes of vegetation. The Hector North-to-East and Hector South-to-West blocks are unquestionably undersampled, and significance between species in these blocks is not expected because of undersampling. Trees are absent in the Sallisaw Meadow and Summit Meadow blocks and tree reproduction and shrubs and vines are virtually absent in these blocks. No significance in variation in cover is expected for these classes of vegetation in these two blocks. The extreme variation in cover between rare and common species of grasses and forbs in the meadows is significant. The highly variable distribution of tree cover between transects in the Staser Old-Field block, the small number of species present, and few transects in this block make lack of significance of variation in cover between species of trees and tree reproduction expected. The low occurrence of herbaceous species under forest stands on Summit soils and use of only nine transects in the Summit South-to-West block indicate that this block was undersampled for grasses and forbs. Significance between species on adjacent Clarksville, Linker, and Talpa blocks and the similar Summit North-to-East block indicate this. Undersampling may also be true of the Elsah Stream-Bank block for tree reproduction and shrub and vine classes.

Species x Block Interaction and Variation Between Blocks by Species

Interaction between species and blocks is significant for all classes of vegetation when the smaller residual mean square is used [df = $(r - 1)\Sigma(s - 1)$] (Table 20). When the conservative residual mean square [df = $\Sigma(s - 1)$] is used no significant interaction is found.

As the test for interaction is inconclusive, another approach is to examine the variation between blocks for each species (Tables 22, 23, 24, and 25). Overall, 63 percent of the species show significant variation between blocks. By classes, significant variation between blocks is present for 75 percent of the trees, 63 percent of the tree reproduction species, 63 percent of the shrub and vine species, and 59 percent of the herbaceous species. Most species that do not show significance are uncommon or rare and are limited to only one or a few blocks in distribution. The few exceptions that are common and widely distributed are mockernut and black hickory reproduction, winged elm, american plum, persimmon, carolina rose, poverty grass, sand dropseed, *Panicum malacophyllum*, panicled tick-clover, large-bracted tick-clover, cat-claw sensitive-briar, toothed spurge, rose vervain, white snake-root, sticky-head, goldenrod, arrow-leaved daisy, and ox-eye.

The species x block interaction is assumed to be significant. Several factors may be the cause of interaction. All plants must compete for light, moisture, and space. Competition between species is reduced by adaptation to different combinations of environmental variables as optimal by the different species. Such variables are pH, base levels, and moisture in soils, and shading by other plants. Terms to describe adaptations to some of the variables are calciphilic for plants that show an affinity for limestone-derived or base-rich soils and calciphobic for plants that are the opposite (Spurr 1964). Tolerance refers to the ability of plants to withstand shading; tolerant plants can grow under shade or with root composition, while intolerant species cannot withstand shading (Spurr 1964). Demanding species are those that require more moisture than most others that grow in the same community (Spurr 1964).

On the refuge Talpa and Summit series are limestone-derived soils. Linker and Hector soils are derived from sandstone and shale. On a large area of Linker soils developed in sandstone colluvium over limestone trees are able to cycle bases weathered from the underlying limestone. Clarksville soils developed in residual chert left after limestone had been removed by weathering. Elsah, Staser, and Sallisaw soils all developed in alluvium. These soils have moderate to high base levels from continued weathering of the transported parent materials. These soils also receive bases leached from upland soils in runoff and ground water.

Depth and texture affect the moisture-holding capacity of soils. Hector and Talpa soils are too shallow to hold appreciable quantities of water. Linker, Summit, and Staser soils are both deep and fine textured and can store 6 to 7.5 in of water. The effect of texture is seen by comparing Hector and Talpa or Clarksville and Summit soils (Table 3).

The position of a soil also affects the amount of moisture available to plants. Summit soils are downslope from Linker soils and Elsah soils are lower in stream valleys than Sallisaw soils. Each of these pairs is close in moisture holding capacity, but the lower soil in each pair can provide more water for vegetative growth by receiving runoff and lateral seepage of ground water from upslope.

Some examples will illustrate how these variables affect distribution of species. Calciphilic species (bitternut hickory, shagbark hickory, chinquapin oak, blue ash, and frost grape) are restricted to or have their greatest cover values in the limestone-derived or base-rich soils. Calciphobic species (shortleaf pine, blackjack oak, deerberry, and farkleberry) are present only on the Clarksville or Clarksville and Linker soils.

Some species appear to be obligatory tolerants (flowering dogwood, spicebush, the ferns, diarrhena, and some of the sedges). Intolerant species (shortleaf pine, red cedar, black willow, persimmon, and the sumacs) occur in the overstory with little reproduction under the canopy, or they grow in open areas. Moisture-demanding species (scouring rush, diarrhena, black willow, bur oak, eastern hop-hornbeam, spicebush, sycamore, agrimony, boxelder, and carolina buckthorn) are found primarily in Elsah, Sallisaw, and Staser soils. Other species are able to withstand drouthy conditions (<u>Asplenium</u>, winged elm, stonecrop, and prickly-pear). Some species are able to compensate; winged elm and chinquapin oak can grow under shade where adequate moisture is available and can also grow on drouthy sites in the open. As mentioned above, many herbaceous species that grow under the forest canopy are affected in their distribution by openings in the overstory.

Similarity of Vegetation on Environmentally Similar Sites

The analyses discussed above established that cover between blocks and between species does vary significantly. To examine the hypothesis that vegetation on ecologically similar sites is similar requires a technique that can analyze several variables on samples in two or more blocks simultaneously. A discriminant analysis is the multi-variate technique selected to examine this hypothesis. The discriminant analysis uses generalized squared distance to classify transects into blocks at a predetermined level of significance using species cover on the transects as the variables. The level of probability is predetermined for the classifications. No procedure is yet available to test the number of misclassifications of transects from the block of origin (Dr. William Warde, personal communication). As the number of blocks is increased the possibility of misclassification also increases, but increasing the number of variables decreases the probability of misclassification (Winer 1971). In this analysis 123 species are used as variables to classify transects from 16 blocks.

The discriminant analysis is a non statistical test, but because of the number of blocks in the analysis the results of classification performance indicate a high degree of similarity between transects within blocks. Eighty-two and three-tenths percent of the transects in the analysis are classified in the block of origin.

The majority of the misclassifications fall into one of four categories: (a) misclassified into the same forest type on a different soil series, (b) misclassification into a different forest type on a different slope aspect of the same soil series, (c) misclassification of a transect into a block that is adjacent in position to the block of origin, and (d) misclassification into the same type on the same soil in an adjacent block. An examination of the summary-of-classification results (Table 27) show 8 misclassifications fit category (a), 9 misclassifications fit category (b), 8 misclassifications fit category (c), and 9 misclassifications fit in category (d). Eight misclassifications do not fit in any of these categories.

Similarity in soils or adjacent position appears to be the most likely cause of misclassifications. Sixteen of the misclassifications are between different slope aspect or position blocks on the same soil series. Fourteen of the misclassifications are to a different soil that is adjacent to the soil of origin on the same slope. Four misclassifications are between Linker and Summit soils on opposite slope aspects. Linker and Summit soils are similar in moisture holding capacity, and the Linker soils lie over sandstone colluvium that overlies limestone. Calciphilic species can obtain bases weathered from the underlying limestone. Five misclassifications are between the Hector Ridge-Top and Clarksville Ridge-Top or South-to-West Aspect. The same forest type (Post Oak-Black Oak) is found on these three blocks. The two remaining misclassifications are from the Talpa South-to-West block to the Hector

Ridge-Top block. Although dissimilar, grassland types occur in each of these blocks. It is interesting to note that in the four blocks that have more than one vegetation type (Clarksville South-to-West, Hector Ridge-Top, Talpa North-to-East, and Talpa South-to-West) only five transects were misclassified into blocks having different soils. The high percentage of transects that are classified into the block of origin and the similarity of blocks between which most misclassifications occurred indicate that soil series, slope aspect, and slope grade are useful criteria for defining management units.

Species-to-Species Relationships

The analysis of variance established the significance of the variation of plant species between soil series-slope aspect blocks. The cluster analysis demonstrated the similarity of vegetation within soil series-slope aspect blocks, although no test for significance can be made of this. If pairs or groups of species are found to vary in the same direction and magnitude in response to changes in environmental variables, then the performance of one species of the pair or group could be a useful tool to estimate the performance of the other species associated with it.

To find significant relationships between species a multivariate technique that can analyze similarities between all species simultaneously is useful. Cluster analysis uses statistical techniques to find the closest relationships between species or groups of species. The closeness of these relationships can be examined for significance.

Results of cluster analysis show clusters of 9 to 16 species in the 11 blocks to which the technique was applied that are significant at the

.05 level. In the dendrograms (Figures 48 to 58) the most abundant species usually are not closely correlated with other species or clusters of species. Many of the subordinate species do have high correlations with other species. The cause of the loose association of dominant species and close correlation of groups of subordinate species is because the dominant species and commoner species occur on all or most of the transects while the less common species appear on fewer transects in a block. The less abundant species tend to segregate into groups. The dominants are loosely associated with all species present in the block but are not closely associated with any particular group of the lesser species. These groups of the less-abundant species are an expression of environmental variation within the block. The variation expressed is the total effect of variation in light, available moisture, and soil fertility. Factors that influence these variables are crown cover, fire, logging and grazing, grade and aspect of slope, depth and texture of soils, runoff and lateral soil water movement, and parent material of the soil.

Clustering of minor species reveals considerable regrouping of species between blocks. This is consistent with Gleason's (1926) theory of individualistic plant response to environmental variation. Each species is responding to the sum of environmental variables independently of other species. Within a soil series-slope aspect or soil series-position block, environmental variation is minor for most of the variables, and species tend to segregate in response to only one or a few of the variables. In different blocks the environmental variables are combined with different values and a different variable or combination of variables will affect the segregation of species.

Examination of the dendrograms gives striking evidence that species respond independently to variations in the environment. By first examining blocks that have the same forest type, no species pairs are found in all of the blocks in which the forest type appears. The Post Oak-Black Oak type occurs on Linker South-to-West block (Fig. 49), Clarksville Ridge-Top (Fig. 51), Clarksville South-to-West block (Fig. 52), and Hector Ridge-Top block (Fig. 55). The White Oak-Red Oak-Hickory type occurs on Linker North-to-East block (Fig. 48), Clarksville North-to-East block (Fig. 50), and Sallisaw Terrace block (Fig. 58). No species pairs significantly correlated at .05 are found on all three blocks for the Post Oak-Black Oak type or on both blocks for the White Oak-Red Oak-Hickory type. The same is true when different blocks on the same soil are examined. No species pair correlated at .05 are found on both blocks for Linker soil (Figs. 48 and 49), for the three Clarksville soil blocks (Figs. 50, 51, and 52), or for the two blocks on Elsah soils (Figs. 56 and 57).

In view of the close correlation between some species within blocks, indicator species can prove useful within limitations. First, the plant-environment relationships must be defined within a soil series-slope aspect or soil series-position class; second, species used as indicators are more likely to indicate the performance of minor species than of dominant species; and third, the same species will not necessarily indicate the same potential performance of the other species on different soils or on different positions.

Previously Undescribed Forest Types Found on the Refuge

During this study some forest stands were found that differed from descriptions of forest types given by the Society of American Foresters (1954). Two groups of these stands displayed consistent relationships to specific soil-slope aspect or soil-position blocks. These forest stands will be named and described here.

The first group occurs on Summit soils on both north-to-east and south-to-west blocks. This type is named the Black Oak-Sugar Maple forest type for the co-dominant species (Fig. 59). Black oak and sugar maple each make up 22 to 24 percent of the overstory. Leading associate tree species are chinquapin oak with 12 percent, shagbark hickory with 8 to 9 percent, and American and green ash with 7 to 8 percent contribution to the overstory cover. Minor but consistent associate tree species are winged elm with 4 percent, post oak with 3 to 4 percent, mockernut and black hickory with 2.5 percent share of the overstory. Important woody shrub and vine species are saw greenbriar, which contributes 44 percent of the shrub and vine cover; frost grape, with 20 percent, and roughleaf dogwood, with 16 percent share of the shrub and vine cover. Fragrant sumac contributes 10 percent and coralberry contributes 4 percent to shrub and vine cover. Poison ivy, red-berried moonseed, and bristly greenbriar are minor but regular associates in the black oak-sugar maple type. Leading ground-cover species are creeping lespedeza and broad-leaved spike grass, each of which contributes 10 percent to the ground cover. Other important herbaceous species are sedges, Canada brome, few-flowered panic grass,

Fig. 59. Stand of black oak-sugar maple forest type on east-facing slope in Summit soil

Fig. 60. Stand of bitternut hickory-black oak-elm forest type in Elsah soil

Brachyelytrum erectum, and black-eyed susan. Minor but regular associate forbs are *Galium circaezens*, hog-peanut, sand dropseed, Virginia wildrye, and black snakeroot.

In the Black Oak-Sugar Maple type, total tree intercepts range from 223 ft to 463 ft on the transects and average 417.8 ft on the north-to-east block and 344.5 ft on the south-to-west block of Summit soils. On transects from the north-to-east aspect block of Summit soils reproduction intercepts averages 38 ft, shrubs and vines average 33 ft of intercept on a 100-ft line, and grasses and forbs average 16.6 ft on a 50-ft line. On transects from the south-to-west aspect block sum of intercepts for tree reproduction average 22 ft and for shrubs and vines 32.5 ft per 100 ft of line. Grasses and forbs average 15 ft of intercept per 50 ft of line.

The second forest type is named the Bitternut Hickory-Black Oak-Elm type. This type occurs on Elsah soils in the floodplain position blocks (Fig. 60). The dominant species is bitternut hickory which contributes 24 percent of the tree cover. Leading associate species are black oak and winged elm, each of which make up 10 percent of the overstory. The major understory tree is eastern hop-hornbeam which contributes 6 to 7 percent of the tree cover. Other common associate tree species are black walnut, chinquapin oak, shagbark hickory, American ash, American and slippery elm, and hackberry. Each of these species makes up 3 to 6 percent of the overstory. Red bud and Carolina buckthorn are minor but common associates in the tree understory. Frost grape, saw greenbriar, and Virginia creeper are the leading shrub and vine species. Each contributes 20 to 24 percent to the shrub and vine cover. Roughleaf dogwood, spicebush (*Lindera benzoin*), and coralberry each contribute 8 to 10 percent of the shrub and vine cover. Other common but minor shrubs and vines are poison ivy, heart-leaf ampelopsis, and pepper-vine. Broad-leafed spikegrass makes up 26 percent of the herbaceous cover, and hog-peanut contributes 12 percent to the ground cover. Two species of sedge provide 18 to 19 percent of the cover, and Canada brome contributes 8 percent. Black snake-root, Virginia wildrye, few-flowered panic grass, and large-bracted tick-clover each provide 2 to 4 percent of the herbaceous cover. Minor but regular associates are sand dropseed, toothed spurge, and wingstem.

Tree cover intercepted on the transects in the Bitternut Hickory-Black Oak-Elm forest type range from 370.5 ft to 619 ft. The average is 496 ft per line. Tree reproduction averages 25 ft and shrubs and vines average 50.7 ft of intercept per transect. Grasses and forbs average 32.3 ft per transect.

Management Implications

Ideally, units of vegetation selected for management purposes or vegetation studies should be as homogenous as possible. Stands of vegetation on environmentally similar sites regarding geology, soils, and topographic position are also expected to be similar in species composition. They will also be expected to respond in a similar manner to management efforts. In studies on vegetation grouping similar stands reduces variation within a unit (reduces experimental error). In this study it was found that forest stands from sites that are similar in topographic, position, soil series, and underlying geological strata are similar in species composition.

Wildlife managers, foresters, and other resource managers can simplify the task of defining management units by using geological maps, soil surveys, and topographic maps to determine the location and extent of ecologically similar sites. The risk of combining dissimilar sites is reduced and vegetation can be expected to be more homogenous. This in turn will make extrapolation of vegetation response to specific management practices easier within the unit. Similarly, investigators studying biological problems can use soils, geology, and topography to select, over an extensive area, study sites that are similar or that differ in selected characteristics. By use of geological, topographic, and soil survey maps a researcher can reduce preliminary field work by selecting the sites most likely to meet the requirements of his study before venturing into the field.

Other disciplines can also use the knowledge of the vegetation-environment complex. For example, when specific forest type-soil series-geology-topographic position relationships are established for a region soil scientists, geologists, and engineers can use vegetation as a clue to the soils or geology of a specific site within the region.

The use of certain species to serve as indicators for the prediction of the presence, abundance, or rate of growth of other species is to be done with caution in view of the results of this study. It was found that few species were consistent in their pairing from one soil series or slope aspect to a different soil series or slope aspect. Most of the more common species showed little tendency to be closely associated with any other species. If indicator species are to be used it is strongly recommended that their relationships to other species be established separately for each geological-soil-topographic position unit. Extrapolation of a species as an indicator for another species from one type of unit to another is not recommended because of the independent response of species seen in this study.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Summary

Deer are an important wildlife resource in Oklahoma. The Cookson Hills State Game Refuge was established in Cherokee and Adair Counties, Oklahoma, in 1951 to protect the dwindling deer herd and as a source of deer for restocking other areas without deer. A detailed description of vegetation on the refuge is needed for habitat management. Such information about vegetation on the refuge can be useful to several resource-management disciplines.

Relationships of soils to geology and topography are described and discussed. Eight soil series are present on the refuge, and they have definite relationships to underlying rock and topographic position.

Eight previously named and described forest types and three grassland types occur on the refuge. Their relationship to soils and topography are discussed.

The forests on the refuge were oak-hickory and oak-pine prior to settlement by white men. The original inhabitants were Osage Indians. Cherokee Indians moved into the area in the mid-nineteenth century but their farming operations were of limited extent in the present boundaries of the refuge. White men began moving into the area during the last quarter of the nineteenth century; the most significant influence of white settlement came between 1910 and 1920 when the forests were logged.

Vegetation on the refuge was sampled by a stratified randomized block method. Blocks were defined by soil series and topographic position or in a few blocks, by meadow or old-field classes. Stratification of sampling was by date of fires within blocks. A three-component line-intercept transect was devised to sample cover of trees, tree reproduction, shrub and vines, and herbaceous plants as separate classes on the same site.

Two hundred and sixty transects were distributed among 20 blocks. Fifty-two species of trees, 33 species of shrubs and vines, and 225 species of herbaceous plants occurred on the transects.

Analysis of variance was used to test variation of cover between blocks, between species, and for species x block interaction. Significance was found between blocks and between tree species. The tests for shrubs and vines, tree reproduction, grasses and forbs, and species x block interaction were inconclusive, but were assumed to be significant after AOV's of cover between blocks by species and between species within blocks were performed. Variation between species of at least on class of vegetation was found significant in all blocks. Significant variation between blocks was found for 37 tree species, 27 species of tree reproduction, 18 species of shrubs and vines, and 122 species of herbaceous plants.

A discriminant analysis technique was used to examine similarity of species occurrence on transects within blocks. Two hundred thirty-one transects from 16 blocks were used; 190 transects were classified as belonging to the block of origin. Similarity of soils between blocks was discussed as the probable cause for most of the 41 misclassifications.

A cluster-analysis technique was used to examine association of species on 11 blocks. Although species were grouped into clusters at significant levels of correlation within blocks, considerable regrouping of species occurred between blocks. Close correlations were found within blocks for many minor species but few close associations were found for dominant species. No species pairs or groups were found to occur in all blocks with the same soil series or the same forest type.

During the study two previously unnamed forest types were found. They are described and named in this paper.

Conclusions

1. Line-intercepts are the most accurate and rapid method of sampling vegetation when all classes of vegetation are to be sampled.

2. Variation of cover between species is significant within soil series-slope aspect blocks.

3. Variation of cover between blocks is significant for most species.

4. Species vary independently of each other in response to changes in environmental variables.

5. When environmental conditions are similar, as within a soil series-slope aspect block, the assemblage of species on different sites is similar in species present and amount of cover by species.

6. When all species are considered, different forest types that are on the same soil sereis-slope aspect block show a greater resemblance to each other in the minor tree species, shrubs, and herbaceous plants

present than they do to similar forest types on a different soil series-slope aspect block.

7. Similarity of vegetation within blocks supports the conclusion that soil series and topographic position are useful criteria for defining deer management units in northeast Oklahoma.

8. Independent variation of species between blocks restricts the usefulness of a species pair or group for indicator purposes to use in the soil series-topographic position unit in which the pair or group of plants is associated.

9. Indicator species are not likely to be of great value for predicting the performance in growth rate or yield of dominant species. Most close correlations are between uncommon species. Common and dominant species are not usually closely associated with other species.

LITERATURE CITED

Alrich, A.D. 1953. Public lands and your game and fish dollars. Oklahoma Game and Fish News. 9(1):3-4.

Allred, B. M. W., and H. C. Mitchell. 1955. Major plant types of Arkansas, Lousiana, Oklahoma and Texas and their relationship to climate and soils. Texas Jour. Sci. 7:7-19.

Anderson, G. D. and L. M. Talbot. 1965. Soil factors affecting the distribution of the grassland types and their utilization by wild animals on the Sergngeti Plains, Tangayika. Jour. Ecol. 53: 33-56.

Anonymous. 1945. Forest fires damage Cookson Hills Game Land. Oklahoma Game and Fish News. 1(4-5):18.

Anonymous. 1946. Cookson Hills land acquisition approved. Oklahoma Game and Fish News. 2(8):16.

Anonymous. 1954. Guardian of the deer. Oklahoma Game and Fish News. 19(2):11-12.

Arend, J. L. 1950. Influence of fire and soil on distribution of eastern redcedar in the Ozarks. Jour. For. 48:129-130.

Barkham, J. P. and J. M. Norris. 1970. Multivariate procedures in an investigation of vegetation and soil relations of two beech woodlands, Cotsold, England. Ecology. 51:630-639.

Baskett, T. S., R. L. Dunkeson and S. C. Martin. 1957. Responses of forage to timber stand improvement in the Missouri Ozarks. Wildl. Mgmt. 21:121-126.

Bauer, H. L. 1943. The statistical analysis of chaparral and other plant communities by transect samples. Ecology. 24:45-60.

Bolte, J. R., J. A. Hair and J. Fletcher. 1970. White-tailed deer mortality following tissue destruction induced by lone star ticks. J. Wildl. Mgmt. 34:546-552.

Bond, C. H. 1957. An economic study of Oklahoma deer. Oklahoma Wildlife. 13(12):18-19.

Borman, F. 1953. The statistical efficiency of sample plot size and shape in forest ecology. Ecology. 34:474-487.

_______________, T. G. Siccama, G. E. Likens and R. H. Whittaker. 1970. The Hubbard Brook ecosystem study: composition and dynamics of the tree stratum. Jour. Ecol. 40:373-388.

Bourdeau, P. F. 1953. A test of random versus systematic ecological sampling. Ecology. 34:499-512.

Braun, E. L. 1950. Deciduous forests of eastern North America. McGraw-Hill Book Co., New York. 596 pp.

Broadfoot, W. M. 1969. Problems in relating soil to site index for southern hardwoods. For. Sci. 15:354-364.

Brown, R. T. and J. T. Curtis. 1952. The upland conifer-hardwood forests of northern Wisconsin. Ecol. Monogr. 22:217-234.

Buell, M. F., and J. E. Cantlon. 1950. A study of two communities of the New Jersey Pine Barrens and a comparison of two methods. Ecology. 31:567-586.

Buol, S. W., F. D. Hole and R. J. McCracken. 1973. Soil genesis and classification. Iowa State Univ. Press, Ames, Iowa. 360 pp.

Cain, S. A. and G. M. deO. Castro. 1969. Manual of vegetation analysis. Harper. New York. 325 pp.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Jour. For. 39:388-394.

Cantlon, J. E. 1953. Vegetation and microclimate on north and south slopes of Cushetunk Mountain, New Jersey. Ecol. Monogr. 23:241-270.

Carlile, F. 1958. Vegetation study--refuges and outside range. Oklahoma Dept. Wildl. Cons. Federal Aid Proj. W-66-R-3. Job 5 amended. 17 pp.

Clements, F. E. 1916. Plant succession. Carnegie Inst. Washington Publ. 242:1-512.

Cole, E. L. 1970. Soil survey, Cherokee and Delaware Counties, Oklahoma. Soil Cons. Serv., U.S.D.A., Washington, D. C. 74 pp.

Cooperrider, T. S. 1962. The flora of north-facing slopes compared to that of the surrounding area in eastern Iowa. Amer. Midl. Nat. 67:368-372.

Cottam, G. 1949. The phytosociology of an oak woods in southeastern Wisconsin. Ecology. 30:271-287.

Crawford, H. S. 1971. Wildlife habitat changes after intermediate cutting for even-aged oak management. J. Wildl. Mgmt. 35: 275-286.

__________ and W. M. Harrison. 1971. Wildlife food on three Ozark hardwood sites after regeneration cutting. J. Wildl. Mgmt. 35:533-537.

Curtis, O. 1952. Federal aid in Oklahoma wildlife restoration. Oklahoma Game and Fish News. 8(3):3-7.

__________. nd. Deer season report 1967. Okla. Dept. Wildl. Cons., Game Div., Oklahoma City. 14 pp.

Curtis, J. T. and R. P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology. 32:476-496.

Daubenmire, R. F. 1970. Steppe vegetation of Washington. Wash. Agric. Exp. Sta. Tech. Bull. 62. Washington State Univ. 131 pp.

Della-Bianca, L. and F. M. Johnson. 1965. Effects of an intensive clearing on deer-browse production on the southern Appalachians. J. Wildl. Mgmt. 29:729-733.

Dick-Peddie, W. A. and W. H. Moir. 1970. Vegetation of the Oregon Mountains, New Mexico. Range Science Department, Science Series No. 4. Colorado State University, Ft. Collins. 28 pp.

Duck. L. G. and J. B. Fletcher. 1944. A survey of the game and fur-bearing animals of Oklahoma. Okla. Game and Fish Comm. P-R Ser. 2. Oklahoma City. 144 pp.

Dunkison, R. L. 1955. Deer range appraisal for the Missouri Ozarks. J. Wildl. Mgmt. 19:358-364.

Featherly, H. I. 1946. Manual of the grasses of Oklahoma. Oklahoma Agric. and Mech. Coll., Stillwater, Okla. 137 pp.

Fernald, M. L. 1950. Gray's manual of botany. 8th ed. American Book Co., New York. 1632 pp.

Gibson, R. and H. P. Haskbush. 1898. Field notes of the survey of the subdivision lines of Township 14 North, Range 23 East of the Indian Base and Meridian in the Indian Territory. Type-written, n.p.

Gleason, H. A. 1926. The individualistic concept of the plant association. Bull. Torrey Bot. Club. 53:7-26.

Grigal, D. F. and W. F. Arneman. 1970. Quantiative relationships among vegetation and soil classifications from northeastern Minnesota. Can. J. Bot. 48:555-566.

Greig-Smith, P. 1957. Quantitative plant ecology. Academic Press, New York. 198 pp.

Hack, J. T. 1960. Interpretation of erosional topography in humid temperate regions. Am. Jour. Sci. 258:80-97.

Hair, J. A. and D. E. Howell. 1970. Lone star ticks, their biology and control in Ozark recreation areas. Ag. Exp. Sta., Bull. 679, Oklahoma State Univ., Stillwater, Okla. 47 pp.

Harlow, R. F. and J. D. Whelan. 1969. Measuring habitat productivity. pp. 98-108. In White-tailed deer in the southern forest habitat: Proceedings of a symposium. So. For. Exp. Sta., For. Serv., U.S.D.A.; For. Game Comm., The Wildl. Soc.; School of For., Stephen F. Austin State Univ., Nacogdoches, Texas.

Heady, H. F., R. P. Gibbens, and R. W. Powell. 1959. A comparison of the charting, line interception, and line point methods of sampling shrub types of vegetation. Jour. Range Mgmt. 12:180-188.

Hope-Simpson, J. F. 1940. On the errors in the ordinary use of subjective frequency estimations in grassland. Jour. Ecol. 28: 193-209.

Huffman, G. G. 1958. Geology of the flanks of the Ozark uplift. Okla. Geol. Serv. Bull. 77. Norman, Okla. 281 pp.

Humphrey, R. R. 1962. Range ecology. Ronald Press, New York. 234 pp.

Jenny, H. 1941. Factors of soil formation. A system of quantitative pedology. McGraw-Hill, New York. 281 pp.

Johnson, F. M., H. P. Haskbusch and O. Jones. 1898. Field notes of the survey of the subdivision lines of Township 14 North, Range 24 East of the Indian base and Meridian in the Indian Territory. Typewritten, n.p.

Jones, O. and F. Morris. 1898. Field notes of the survey of the subdivision lines of Township 15 North, Range 24 East of the Indian base and Meridian in the Indian Territory. Typewritten, n.p.

Kerner, A. von M. 1863. Das pflanzenleben der Donaulander. (Transl. H. S. Conrad. 1951. The background of plant ecology. Iowa State Coll. Press, Ames, Ia. 238 pp.)

Kershaw, K. A. 1964. Quantitative and dynamic ecology. American Elsevier Publ. Co., Inc., New York. 183 pp.

Kinsinger, F. C., R. E. Eckert and P. O. Currie. 1960. A comparison of the line interception, variable-plot, and loop methods as used to measure shrub-crown cover. J. Range Mgmt. 13:17-21.

Knight, C. B. 1965. Basic concepts of ecology. MacMillan, New York. 468 pp.

Kucera, C. L. and S. C. Martin. 1957. Vegetation and soil relationships in the glade region of the southwestern Missouri Ozarks. Ecology. 38:285-291.

Lindsey, A. A. 1955. Testing the line-strip method against full tallies in diverse forest types. Ecology. 36:485-495.

Lindsey, J. S. 1951. The white-tailed deer in Oklahoma-ecology, management, and production. Ph.D. thesis, Okla. State Coll. Agric. and Mech., Stillwater, Okla. 159 pp.

Marchand, D. E. 1973. Edaphic control of plant distribution in the White Mountains, eastern California. Ecology. 54:233-250.

McCammon, R. B. and G. Wenninger. 1970. The dendrograph. State Geological Surv., Univ. Kansas, Lawrence, Kans. Computer Contribution No. 48.

McIntosh, R. P. 1967. The continuum concept of vegetation. Bot. Rev. 33:130-187.

McLean, A. 1970. Plant communities of the Similkameen Valley, British Columbia, and their relationships to soils. Jour. Ecol. 40:403-423.

McReynolds, E. C., A. Marriott and E. Faulconer. 1961. Oklahoma: the story of its past and present. Univ. Oklahoma Press, Norman, Okla. 463 pp.

Morris, J. W. and E. C. McReynolds. 1965. Historical atlas of Oklahoma. Univ. Oklahoma Press, Norman, Okla. 70 pp. 70 maps.

Murphy, D. A. and H. S. Crawford. 1970. Wildlife foods and understory vegetation in Missouri's national forests. Tech. Bull. No. 4, Mo. Dept. Cons., Jefferson City, Mo. 47 pp.

__________________ and J. J. Ehrenreich. 1965. Fruit producing trees and shrubs in Missouri's Ozark forests. J. Wildl. Mgmt. 29:497-503.

Odum, E. P. 1953. Fundamentals of ecology. Saunders, Philadelphia. 384 pp.

__________________. 1971. Fundamentals of ecology. 3rd ed. Saunders, Philadelphia. 574 pp.

Oklahoma Department of Wildlife Conservation. 1972. Biennial report July 1, 1970 to June 30, 1972. Okla. Dept. Wildl. Cons., Oklahoma City, Okla. 41 pp.

Ohman, L. F. and R. R. Ream. 1971. Wilderness ecology: a method of sampling and summarizing data for plant community classification. U.S.D.A. Forest Service Research Paper NC-49. 14 pp.

Patten, D. T. 1963. Vegetational pattern in relation to environments in the Madison Range, Montana. Ecol. Monogr. 33:375-406.

Peterson, R. T. and M. McKenney. 1968. A field guide to wildflowers of northeastern and north-central North America. Houghton Mifflin, Boston. 420 pp.

Phillips, E. A. 1959. Methods of vegetative study. Holt, New York. 107 pp.

Ragland, C. and J. L. Lancaster. 1971. Environmental factors affecting the lone star tick. Arkansas Farm Research. 20(5):9.

Raynal, D. J. and F. A. Bazzaz. 1973. Establishment of early successional plant populations on forest and prairie soil. Ecology. 54:1335-1341.

Read, R. A. 1952. Tree species occurrence as influenced by geology and soils on an Ozark north slope. Ecology. 33:239-246.

Rice, E. L. 1965. Bottomland forests of north-central Oklahoma. Ecology. 46:708-714.

__________________ and W. T. Penfound. 1959. The upland forests of Oklahoma. Ecology. 40:593-608.

Risser, P. G. and E. L. Rice. 1971. Diversity in tree species in Oklahoma upland forests. Ecology. 52:876-880.

Segelquist, C. A. 1974. Evaluation of wildlife forage clearings for white-tailed deer habital management in a 600-acre Arkansas Ozark enclosure. Ph.D. thesis, Oklahoma State Univ., Stillwater, Okla.

__________________ and W. E. Green. 1968. Deer food yields in four Ozark forest types. J. Wildl. Mgmt. 32:330-337.

__________________ and R. E. Pennington. 1968. Deer browse in the Ouqchita Forest in Oklahoma. J. Wildl. Mgmt. 32:623-626.

Semter, P. J. 1972. Ecology and behavior of the lone star tick. Ph.D. thesis. Oklahoma State Univ., Stillwater, Okla. 91 pp.

Service, J. 1972. A user's guide to the statistical analysis system. Student Supply Stores, North Carolina State Univ., Raleigh, N. C. 260 pp.

Siccama, T. G., F. H. Bormann and G. E. Likens. 1970. The Hubbard Brook ecosystem study: productivity, nutrients, and phytosociology of the herbaceous layer. Jour. Ecol. 49:389-402.

Silker, T. H. 1965. Plant indicators communicate ecological relationships in Gulf Coastal Plain forests. pp. 317-329. In C. T. Youngberg, ed. Forest soil relationships in North America. Proc. 2nd N. Amer. For. Soils Conf. Oregon State Univ. Press, Corvallis, Ore.

Simonson, R. W. 1959. Outline of a generalized theory of soil genesis. Soil Science Proceedings. 23:152-156.

Smith, A. D. 1944. A study of the reliability of range vegetation estimates. Ecology. 25:441-448.

Society of American Foresters. 1954. Forest cover types of North America (Exclusive of Mexico). Committee on Forest Types, Soc. Am. For., Washington, D. C. 67 pp.

Sokal, R. R. and P. H. A. Sneath. 1963. Principles of numerical taxonomy. W. H. Freeman, San Francisco. 359 pp.

Soil Survey Staff. 1960. Soil classification, a comprehensive system, 7th approximation. Soil Cons. Serv., U.S.D.A., Washington, D. C. 265 pp.

Spurr, S. H. 1964. Forest ecology. Ronald Press, New York. 352 pp.

Steel, R. D. G. and J. H. Torrie, 1960. Principles and procedures of statistics. McGraw-Hill, New York. 481 pp.

Steyermark, J. A. 1959. Vegetational history of the Ozark forest. Univ. Mo. Studies. 31:1-138.

_______________. 1963. Flora of Missouri. Iowa State Univ. Press, Ames, Ia. 1725 pp.

Strong, C. W. 1966. An improved method of obtaining density from line transect data. Ecology. 47:311-313.

Stout, G. G. 1973. Physical condition and age structure of deer in Oklahoma. Okla. Dept. Wildl. Cons. Federal Aid Proj. W-109-R-2, Study III, Jobs 2, 3, 5, & 6. 31 pp.

Wahlgren, H. F. 1941. Climate of Okahoma. pp. 1065-1074. In Yearbook Committee. 1941 Yearbook of Agriculture--Climate and Man. U.S.D.A., Washington, D. C. 1284 pp.

Warth, P. and D. J. Polone. 1965. Soil survey, Adair County, Oklahoma. Soil Cons. Serv., U.S.D.A., Washington, D. C. 62 pp.

Waterfall, U. T. 1969. Keys to the flora of Oklahoma. 4th ed. Published by the author. Stillwater, Oklahoma. 246 pp.

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

Wilkinson, W. W., F. M. Johnson and R. McCoy. 1897. Field notes of the survey of the north boundary of Township 14 North, Range 24 East of the Indian base and Meridian in the Indian Territory. Typewritten, n.p.

Winer, B. J. 1971. Statistical principles in experimental design. 2nd ed. McGraw-Hill, New York. 907 pp.

Wint, G. 1971. Oklahoma's general program in federal aid. Oklahoma Game and Fish News. 7(6):2-6.

Wright, M. H. 1957. A guide to the Indian tribes of Oklahoma. Univ. Oklahoma Press, Norman, Okla. 300 pp.

SCIENTIFIC AND COMMON NAMES OF PLANTS ARRANGED IN TAXONOMIC ORDER

Table 28. Scientific and common names of plants arranged in taxonomic order

Scientific Name	Common Name
EQUISETUM HYEMALE L.	Scouring-rush
BOTRICHIUM VIRGINIANUM (L.) Sw.	Rattlesnake-fern
POLYSTICHUM ACROSTICHOIDES (Michx.) Schott	Christmas Fern
ASPLENIUM PLATYNEURON (L.) Oakes	Ebony-spleenwort
PELLAEA ATROPURPUREA (L.) Link	Purple Cliff-brake
NOTHOLAENA DEALBATA (Pursh) Kunze	Cloak-fern
CHILANTHES FEEI Moore	Slender Lip-fern
PINUS ECHINATA Mill.	Shortleaf Pine
JUNIPERUS VIRGINIANA L.	Red Cedar
BROMUS PURGANS L.	Hairy Wood-chess
B. JAPONICUS Thunb.	Japanese Chess
FESTUCA OBTUSA Biehler	Nodding Fescue
ERAGROSTIS CAPILLARIS (L.) Nees	Lace-grass
E. HIRSUTA (Michx.) Nees	Hairy Lace-grass
DIARRHENA AMERICANA Beauv.	
UNIOLA LATIFOLIA Michx.	Broadleaved Spikegrass

Table 28 (Continued)

Scientific Name	Common Name
TRIDENS FLAVUS (L.) Hitchc.	Purpletop
ELYMUS CANADENSIS L.	Nodding Wild-rye
E. VIRGINICUS L.	Virginia Wild-rye
HYSTRIX PATULA Moench	Bottlebrushgrass
DANTHONIA SPICATA (L.) Beauv.	Wild Oatgrass
MUHENBERGIA SCHREBERI J. F. Gmel	Nimblewill
M. CUSPIDATA (Torr.) Nash	Stonyhill Muhly
M. SOBOLIFERA (Muhl.) Trin.	Rock Dropseed
M. BRACHYPHYLLA Bush	Shortleaved Muhly
SPOROBOLUS ASPER (Michx.) Kunth	Tall Dropseed
BRACHYELYTRUM ERECTUM (Schreb.) Beauv.	Bearded Shorthusk
CYNODON DACTYLON (L.) Pers.	Bermudagrass
BOUTELOUA CURTIPENDULA (Michx.) Torr.	Sideoats Grama
DIGITATIA SANGUINALIS (L.) Scop.	Crabgrass
PASPALUM LAEVA Michx.	Field Paspalum
PANICUM OLIGOSANTHES Schultes	Few-flowered Panicgrass
P. MALACOPHYLLUM Nash	Softleaved Panicgrass
P. CAPILLARE L.	Common Witchgrass
SETARIA GENICULATA (Lam.) Beauv.	Perennial Foxtail
S. GLAUCA (L.) Beauv.	Foxtail
ANDROPOGON SCOPARIUS Michx.	Little Bluestem
A. VIRGINICUS L.	Broomsedge
A. GERARDII Vitmin	Big Bluestem

Table 28 (Continued)

Scientific Name	Common Name
SORGHUM HALAPENSE (L.) Pers.	Johnsongrass
SORGHASTRUM NUTANS (L.) Nash	Indiangrass
TRIPSACUM DACTYLOIDES L.	Gamagrass
CYPERUS sp.	Umbrella-sedge
CAREX CEPHALOPHORA Muhl.	Sedge
COMMELINA ERECTA L.	Dayflower
JUNCUS sp.	Rush
SMILAX TAMNOIDES L.	Bristly Greenbriar
S. BONA-NOX L.	Catclaw Greenbriar
ALLIUM CANADENSE L.	Wild Garlic
A. DRUMMONDII Regel	Wild Onion
DIOSCOREA QUATERNATA (Walt.) Gmel.	Wild Yam
D. VILLOSA L.	Wild Yam
SALIX NIGRA Marsh.	Black Willow
JUGLANS NIGRA L.	Black Walnut
CARYA CORDIFORMIS (Wang.) K. Koch	Bitternut Hickory
C. OVATA (Mill.) K. Koch	Shagbark Hickory
C. TOMENTOSA (Poir.) Nutt.	Mockernut Hickory
C. TEXANA Buckl.	Black Hickory
OSTRYA VIRGINIANA (Mill.) K. Koch	Eastern Hop-hornbeam
CASTANEA OZARKENSIS Ashe	Ozark Chinquapin
QUERCUS ALBA L.	White Oak
Q. MACROCARPA Michx.	Burr Oak
Q. STELLATA Wang.	Post Oak

Table 28 (Continued)

Scientific Name	Common Name
Q. MUEHLENBERGII Engelm.	Chinquapin Oak
Q. RUBRA L.	Northern Red Oak
Q. VELUTINA Lam.	Black Oak
Q. FALCATA Michx.	Southern Red Oak
Q. MARILANDICA Muenchh.	Blackjack Oak
ULMUS RUBRA Muhl.	Slippery Elm
U. AMERICANA L.	American Elm
U. ALATA Michx.	Winged Elm
CELTIS OCCIDENTALIS Pursh.	Hackberry
C. LAEVIGATA Willd.	Sugarberry
MORUS RUBRA L.	Red Mulberry
BOEHMERIA CYLINDRICA (L.) Sw.	Bog-hemp
ERIGONUM LONGIFOLIUM Nutt.	Umbrella-plant
RUMEX sp.	Dock
POLYGONUM COCCINIUM Muhl.	Smartweed
P. SCANDENS L.	Climbing False Buckwheat
CHENOPODIUM ALBUM L.	Lamb's-quarters
RANUNCULUS sp.	Buttercup
ANEMONELLA THALICTROIDES (L.) Spach	Rue-anemone
CLEMATIS VIRGINIANA L.	Virgin's-bower
COCCULUS CAROLINUS (L.) DC.	Red-berried Moonseed
SASSAFRAS ALBIDUM (Nutt.) Nees	Sassafras
LINDERA BENZOIN (L.) Blume	Spicebush
LEPIDIUM VIRGINIANUM (L.)	Poor-man's-pepper

Table 28 (Continued)

Scientific Name	Common Name
ARABIS CANADENSIS L.	Sickle-pod
SEDUM PULCHELLUM Michx.	Rock-moss
PHILADELPHUS PUBESCENS Loiseleur	Downy Mock-orange
PLATANUS OCCIDENTALIS L.	Sycamore
PRUNUS SEROTINA Ehrh.	Black Cherry
P. AMERICANA Marsh.	Wild Plum
RUBUS TRIVIALIS Michx.	Southern Dewberry
R. ABORIGINUM Rydb.	Northern Dewberry
R. OZARKENSIS Bailey	Blackberry
R. OCCIDENTALIS L.	Black Raspberry
ROSA SETIGERIA Michx.	Climbing Rose
R. CAROLINA L.	Pasture Rose
AMELANCHIER ARBOREA (Michx. f.) Fern.	Downy Serviceberry
CRATAEGUS ENGELMANNII Sarg.	Hawthron
C. MOLLIS Scheele	Red Haw
POTENTILLA SIMPLEX Michx.	Old-field Cinquefoil
GEUM CANADENSE Jacq.	White Avens
AGRIMONIA PUBESCENS Wallr.	Agrimony
DESMANTHUS ILLINOENSIS (Michx.) MacM.	Illinois Bundleflower
SCHRANKIA UNCINATA Willd.	Cat-claw Sensitive Briar
CERSIS CANADENSIS L.	Redbud
GYMNOCLADUS DIOICA (L.) K. Koch	Kentucky Coffee-tree
GLEDITSIA TRIACANTHOS L.	Honey-locust
CASSIA MARILANDICA L.	Wild Senna

Table 28 (Continued)

Scientific Name	Common Name
C. FASCICULATA Michx.	Partridge-pea
BAPTISIA LEUCOPHAEA Nutt.	Cream-colored False-indigo
TRIFOLIUM PRATENSE L.	Red Clover
T. REPENS L.	White Clover
T. CAMPESTRE Schreb.	Hop-clover
STYLOSANTHES BIFLORA (L.) BSP.	Pencil-flower
PSORALEA PSORALIOIDES (Walt.) Cory	Sampson's Snakeroot
ROBINIA PSEUDO-ACACIA L.	Black Locust
TEPHROSIA VIRGINIANA (L.) Pers.	Goat's-rue
DESMODIUM NUDIFLORUM (L.) DC.	Naked-flowered Tick-trefoil
D. GLUTINOSUM (Muhl.) Wood	Pointed-leaved Tick-trefoil
D. ROTUNDIFOLIUM (Michx.) DC.	Prostrate Tick-trefoil
D. CUSPIDATUM (Muhl.) Loud.	Large-bracted Tick-trefoil
D. PANICULATUM (L.) DC.	Panicled Tick-trefoil
D. RIGIDUM (L.) DC.	Stiff Tick-trefoil
LESPEDEZA PROCUMBENS Michx.	Trailing Bush-clover
L. REPENS (L.) Hornem.	Creeping Bush-clover
L. VIOLACEA (L.) Pers.	Bush-clover
L. VIRGINIACA (L.) Britt.	Slender Bush-clover
L. STUEVEI Nutt.	Stueve's Bush-clover
L. HIRTA (L.) Hornem.	Hairy Bush-clover
L. CUNEATA (Dumont) G. Don	Sericea Lespedeza
L. STIPULACEA Maxim.	Korean Lespedeza
CLITORIA MARIANA L.	Butterfly-pea

Table 28 (Continued)

Scientific Name	Common Name
STROPHOSTYLES HELVOLA (L.) Ell.	Wild Bean
AMPHICARPA BRACTEATA (L.) Fern.	Hog-peanut
GALACTIA VOLUBILIS (L.) Britt.	Milk-pea
VICIA MINUTIFLORA Dietr.	Tiny-flowered Vetch
V. SATVIA L.	Spring Vetch
OXALIS STRICTA L.	Yellow Wood-sorrel
GERANIUM CAROLINIANUM L.	Carolina Cranesbill
PHYLLANTHUS CAROLINIENSIS Walter	Carolina Phyllanthus
TRAGIA BETONICIFOLIA Nutt.	Nettle-leaved Tragia
CROTON MONANTHOGYNOS Michx.	Prairie-tea
CROTONOPSIS ELLIPTICA Willd.	Rushfoil
ACALYPHA GRACILENS Gray	Copperleaf
EUPHORBIA DENTATA Michx.	Toothed Spurge
E. HETEROPHYLLA L.	Painted-leaf
E. COROLLATA L.	Flowering Spurge
E. SUPINA Raf.	Milk-purslane
RHUS GLABRA L.	Smooth Sumac
R. COPALLINA L.	Winged Sumac
R. AROMATICA Ait.	Fragrant Sumac
R. RADICANS L.	Poison Ivy
ILEX DECIDUA Walt.	Possum-haw
ACER NEGUNDO L.	Box-elder
A. RUBRUM L.	Red Maple
A. SACCHARUM Marsh.	Sugar Maple

Table 28 (Continued)

Scientific Name	Common Name
SAPINDUS DRUMMONDII H. & A.	Soapberry
BERCHEMIA SCANDENS (Hill.) K. Koch	Supple-jack
RHAMNUS CAROLINIANA L.	Carolina Buckthorn
CEANOTHUS AMERICANUS L.	New Jersey Tea
CISSUS INCISA (Nutt.) Des Moulins	Marine-vine
PARTHENOCISSUS QUINYQUEFOLIA (L.) Planch.	Virginia Creeper
AMPELOPSIS ARBOREA (L.) Koehne	Pepper-vine
A. CORDATA Michx.	Heart-leaved Ampelopsis
VITIS LINSECUMII Buckley	Post-oak-grape
V. VULPINA L.	Frost-grape
TULIA AMERICANA L.	Basswood
HYPERICUM STRAGALUM Adams & Robson	St. Andrew's Cross
H. PUNCTATUM Lam.	Spotted St. John's-wort
LECHIA TENUIFOLIA Michx.	Slender-leaved Pinweed
VIOLA PEDATA L.	Pansy-violet
V. VIARUM Pollard	Violet
V. RAFINESQUII Greene	Field-pansy
PASSIFLORA INCARNATA L.	Apricot-vine
P. LUTEA L.	Passion-flower
OPUNTIA COMPRESSA (Salisb.) Macbr.	Prickly Pear
CUPHEA PETIOLATA (L.) Koehne	Clammy Cuphea
NYSSA SYLVATICA Marsh.	Black Gum
SANICULA CANADENSIS L.	Black Snakeroot

Table 28 (Continued)

Scientific Name	Common Name
TORILIS ARVENSIS (Huds.) Link	Hedge-parsley
CHAEROPHYLLUM PROCUMBENS (L.) Grantz	Chervil
ZIZIA AUREA (L.) Kock	Golden Alexanders
CORNUS FLORIDA L.	Flowering Dogwood
C. DRUMMONDII Meyer	Roughleaf Dogwood
VACCINIUM ARBOREUM Marsh.	Farkleberry
V. STAMINEUM L.	Deerberry
BUMELIA LANUGINOSA (Michx.) Pers.	Chittamwood
DIOSPYROS VIRGINIANA L.	Persimmon
FRAXINUS QUADRANGULATA Michx.	Blue Ash
F. AMERICANA L.	White Ash
F. PENNSYLVANICA Marsh.	Green Ash
CHIOANTHUS VIRGINICUS L.	Fringetree
APOCYNUM CANNABINUM L.	Indian Hemp
ASCLEPIAS HIRTELLA (Pennell) Woodwon	Milkweed
CYNANCHUM LAEVE (Michx.) Pers.	Anglepod
IPOMOEA PANDURATA (L.) C. F. W. Mey	Wild Potato-vine
HELIOTROPUM TENELLUM (Nutt.) Torr.	Heliotrope
LITHOSPERMUM CANESCENS (Michx.) Lehm.	Hoary Puccoon
VERBENA CANADENSIS (L.) Britt.	Rose-vervain
V. URTRICIFOLIA L.	White Vervain
PRUNELLA VULGARIS L.	Heal-all
SALVIA AZUREA Lam.	Blue Sage
CUNILA ORIGANOIDES (L.) Britt.	Dittany

Table 28 (Continued)

Scientific Name	Common Name
MONARDA RUSSELIANA Nutt.	Horsemint
M. CITRIODORA Cerv.	Lemon-mint
SOLANUM CAROLINENSE L.	Horse-nettle
VERBASCUM THAPSUS L.	Common Mullein
SCROPHULARIA MARILANDICA L.	Carpenter's-square
GERARDIA PECTINATA (Nutt.) Benth.	False Foxglove
CAMPSIS RADICANS (L.) Seem.	Trumpet-creeper
RUELLIA STREPENS L.	Smooth Ruellia
PLANTAGO ARISTATA Michx.	Bracted Plantain
P. VIRGINICA L.	Hoary Plantain
GALIUM TRIFOLORUM Michx.	Sweet-scented Bedstraw
G. CIRCAEZENS Michx.	Wild Licorice
G. ARKANSANUM Gray	Wheatstraw
SYMPHOROCARPOS ORBICULATUS Moench	Coralberry
VIBURNUM PRUNIFOLIUM L.	Black-haw
SPECULARIA PERFOLIATA (L.) A. DC.	Venus's Looking-glass
S. LAMPROSPERMA (McVaugh) Fern.	Venus's Looking-glass
VERNONIA ALTISSIMA Raf.	Tall Ironweed
ELEPHANTOPUS CAROLINIANUS Willd.	Elephant's-foot
EUPATORIUM ALTISSIMUM L.	Upland Boneset
E. RUGOSUM Houtt.	White Snakeroot
E. COELESTINUM L.	Blue Boneset
KUHNIA EUPATORIOIDES L.	False Boneset
LIATRIS SQUARROSA (L.) Michx.	Blazing-star

Table 28 (Continued)

Scientific Name	Common Name
GRINDELIA LANCEOLATA Nutt.	Gumweed
GUTIERREZIA DRACUNCULOIDES (DC.) Blake	Annual Broomweed
SOLIDAGO sp.	Goldenrod
ASTER AZUREUS Lindl.	Blue Aster
A. SAGITTIFOLIUS Wedemeyer	Arrow-Leaved Aster
A. PATENS Ait.	Late Purple Aster
ERIGERON STRIGOSUS Muhl.	Daisy-fleabane
CONYZA CANADENSIS (L.) Cronq.	Horse-weed
ANTENNARIA PLANTAGINIFOLIA (L.) Richards	Plantain-leaved Pussy's-toes
HELIOPSIS HELIANTHOIDES (L.) Sweet	Ox-eye
REDBECKIA HIRTA L.	Black-eyed Susan
ECHINACEA PALLIDA Nutt.	Purple Coneflower
HELIANTHUS HIRSUTUS Raf.	Stiff-haired Sunflower
ACTINOMERIS ALTERNIFOLIA (L.) DC.	Wing-stem
VERBESINA VIRGINICA L.	Frostweed
COREOPSIS GRANDIFLORA Hogg	Large-flowered Coreopsis
C. TINCTORA Nutt.	Garden Coreopsis
BIDENS BIPINNATA L.	Spanish-needles
AMBROSIA ARTEMISIIFOLIA L.	Common Ragweed
HELENIUM AMARUM Raf.	Sneezeweed
ACHILLEA LANULOSA Nutt.	Western Yarrow
ARTEMISIA LUDOVICIANA Nutt.	White Sage
CIRSIUM ALTISSIMUM (L.) Spreng	Tall Thistle

Table 28 (Continued)

Scientific Name	Common Name
SONCHUS ASPER (L.) Hill	Spiny-leaved Sow-thistle
LACTUCA CANADENSIS L.	Wild Lettuce
HIERACIUM GRONOVII L.	Hairy Hawkweed

VITA

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