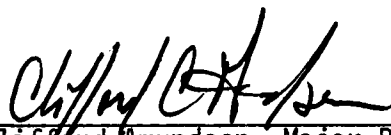
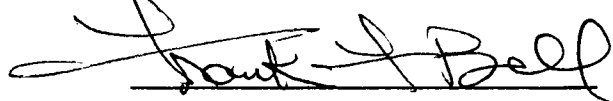


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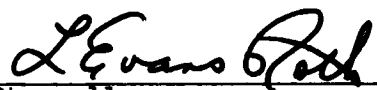
I am submitting herewith a thesis written by Katherine Turner Fuller entitled "The Relationship Between Soil Fertility and Deer Browse Nutritive Quality in Nathan Bedford Forrest State Park." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology.


Clifford Amundsen, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

THE RELATIONSHIP BETWEEN SOIL FERTILITY
AND DEER BROWSE NUTRITIVE QUALITY IN
NATHAN BEDFORD FORREST STATE PARK

A Thesis

Presented for the

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Katherine Turner Fuller

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ABSTRACT

Habitats with infertile soils produce plants with low nutritional quality while fertile soils produce plants with high nutritional quality. Both types of habitat are found in Nathan Bedford Forrest State Park, Benton County, Tennessee and both contribute to the carrying capacity of the present over-stocked white-tailed deer (Odocoileus virginianus, Zimmerman) population in the park.

Soil samples (topsoil and subsoil) and preferred browse species were collected from ten permanent two hectare sites during the period, June 1977 through May 1978. Analysis of the soils and forage indicate differences in nutrient levels in plants growing on different soils and annual seasonal variations in soil fertility and forage nutrient quality.

The following patterns of soil fertility were found. Soil pH was less acidic in the winter months than the summer months. Soil phosphorus dropped significantly in the winter months. Soil potassium increased significantly in the winter months from the summer months. Much of the seasonal variation in soil fertility may be explained by variation in microbial activity with temperature. Increased decomposition rates in the summer months induce lower soil pH through the release of organic acids and releases more available phosphorus from organic phosphorus. Potassium is a highly mobile cation which is cycled quickly through the environment by precipitation and leaching so that soil potassium levels are highest in winter.

A soil fertility and forage nutrient quality gradient exists corresponding to a classification of sites by moisture criteria and physiographic position. The xeric sites (uplands) had the lowest soil phosphorus and the lowest plant phosphorus and plant protein values. The mesic sites represented by alluvial lowland sites and an island had higher soil fertility and the better forage quality.

Browse is only one of many foods available to deer in this habitat. A browse survey is one index utilized by range managers to evaluate the carrying capacity of a habitat. These results indicate that alluvial bottomlands are a very important part of the habitat for a deer population. Thus the maintenance of mesic sites should be stressed in future developments within multi-purpose management areas such as Nathan Bedford Forrest State Park.

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CHAPTER I

INTRODUCTION

The objective of this study is to investigate the relationship between soil fertility and the nutritional quality of plants as deer browse at Nathan Bedford Forrest State Park, Benton County, Tennessee. This multi-purpose park facility supports at present an over-stocked deer population (Paul Reitz, park superintendent, 1978). Many studies in the past have documented the relationships between soil fertility, plant nutritive quality and their effect upon the dependent wildlife populations (Denny, 1944; Crawford, 1950; Murphy and Porath, 1968; Hill, 1972). The following review discusses soil fertility in the Southeast, forage quality of the habitat, and the nutrition and physiology of the white-tailed deer. In sum, the review indicates browse plants are nutritionally affected by the nature of the soil on which they grow and this controls the ability of the habitat to adequately support populations of deer.

Soil Fertility in the Southeast

Soils in the Southeast generally are described as being nutrient poor and especially low in phosphorus (Campbell et al., 1954; Lay, 1957; Short, 1969; Short et al., 1973). It is hypothesized the heavier annual rainfall for the region increases leaching of soil nutrients (Nagy and Wallmo, 1971). These highly leached soils are moderately to strongly acid and have high aluminum and iron oxide contents with a low reserve of organic matter and soil nutrients

(Short, 1969). Phosphorus deficiency in forage is chronic in the Southeast due to the soil deficiency (Halls, 1969).

Browse as an Indicator of Forage Quality

Browse, defined as the current year's growth of woody twigs or stems with leaves, is important as an indicator of yearly forage quality since it can compose the diet of deer throughout the year (Bobik, 1972). Browse availability is important because it lends itself to measurements, is present throughout the year, and serves as an indicator of the degree of pressure (Lay, 1969). Nutritional levels within browse vary according to the position of the nutrients in the stem and the time of year. Nutrients are concentrated primarily in the young meristematic tissues of the bud and first inch of stem tissue (Bailey, 1967; Blair and Epps, 1967) which is more succulent and thus more palatable than older tissues (Oelberg, 1956). Nutrients are found in higher concentrations in leaf tissues as compared to stems (Dietz, 1965; Halls and Epps, 1969).

Leaves and twigs are most nutritious during the growth flush which occurs in spring when browse is the most succulent. The natural maturing of forage throughout the year reduces the nutrient content of the forage (Oelberg, 1956). In a study by Short et al. (1973) digestibility of twigs was related to changes in lignin concentration during the growing season. Lignin is the main non-carbohydrate component of plant fiber and is not digestible by ruminants (Van Soest, 1977). Composite samples of the terminal two inches of twigs with attached leaves may be 57 to 61 percent digestible (percent non-lignin) in the spring and early summer. Digestibility of forage diminishes in

the fall after leaf drop to 42 percent. Green leaves of woody plants are 64 to 67 percent digestible, while dead leaves after nutrients leach out are only 39 percent digestible due to the lignin content (Van Soest, 1973; Van Soest and Mertens, 1974). Thus there appears to be a relationship between time of year, forage succulence, nutritional quality and digestibility (Oelberg, 1956).

Protein and phosphorus concentrations both accumulate in the active meristematic tissues of plants during spring and early summer. A decline in nutrients occurs during senescence with translocation of nutrients from leaves into stems and a decline in palatability and digestibility for animals (Short et al., 1969; Blair and Epps, 1967). Poor forage quality adversely affects wildlife in several ways. Insufficient energy is provided and reduced protein and phosphorus levels may be inadequate for efficient use of available energy. Even in spring, range animals can be affected adversely by the consumption of excessive quantities of watery green forage with reduced protein concentrations due to the high water composition (Bissel et al., 1955; Dietz, 1969).

Crude Protein and Phosphorus

The term crude protein represents both protein and nonprotein nitrogen. A liberal, continuous supply is essential for body maintenance and for the production of new cells throughout life. The protein requirement found optimal for growth in deer is 16 percent by weight of the forage intake per day (McEwen, 1957). If protein levels fall below a minimal level of intake, 6 to 7 percent, then rumen functions become severely impaired (Dietz, 1965; Halls, 1969). Kay (1963) found

ruminants may be able to recycle nitrogen from the urine to prevent loss of protein during stress conditions.

Phosphorus is an essential mineral, vital to many body processes. It is a primary component of the skeleton, intracellular fluids, and compounds such as nucleoproteins and phospholipids. It also is necessary in the production of muscle energy through the metabolic expenditure of adenosine triphosphate (ATP). A wide ratio between calcium and phosphorus will result in a phosphorus deficiency due to improper absorption of the mineral from the intestine (Maynard and Loosli, 1956; Torgerson and Pfander, 1971). McEwen (1957) found minimal phosphorus standards for deer to be 0.25 percent of the dry forage intake to maintain body weight.

The ingestion of quality forage with adequate levels of protein and essential minerals such as phosphorus are mandatory for metabolic maintenance as well as growth. Adequate nutrition levels are important for partuition, lactation, fawn growth, and survival of adult deer under stress conditions (Verme, 1963; Ullrey et al., 1967; Nagy et al., 1969). The optimum level of phosphorus for growth is 0.56 percent of the forage intake (McEwen et al., 1957). Murphy and Coates (1966) list the dietary requirements of deer as 13 to 14 percent crude protein and 0.40 percent phosphorus. Inadequate nutrition seldom causes mortality by starvation but malnutrition increases susceptibility to incidence of parasitism and disease (Hayes and Prestwood, 1969).

The White-Tailed Deer

White-tailed deer find their best habitat along forest edges where vegetation is plentiful within the 5-meter average feeding range

(Leopold, 1950). Studies by Lay (1964), Stiteler and Shaw (1966) and Torgerson and Pfander (1971) indicate the variety in preference of forage plants allows white-tailed deer to accumulate nutrition from a number of sources. Selectivity by the animal may result in a diet with 66 percent more protein than randomly collected material of a same species (Bissel, 1959; Wilson, 1969). Deer vary the quantity of food intake during the year. Consumption of forage reaches a low point in the winter months when preferred forage is scarce, while increasing significantly in the spring (McEwen et al., 1957; Long et al., 1965; Short et al., 1969; Ozoga and Verme, 1970).

In spring, deer require higher nutritional levels from forage to recover from winter weight loss, allow antler genesis, growth, gestation, and lactation. High intake of food and greater digestibility of spring forage allows rapid passage and ingestion of foods through the animal. In late summer and autumn, demands above maintenance requirements have lessened, allowing fat deposition for the winter months. During winter, deer especially are affected by decreased nutritional forage quality. Range animals must travel extensively in the course of a day to obtain better quality forage with the extended feeding schedule (Stoddart and Smith, 1955; Short, 1975).

On southern ranges during most of the year, protein content of browse is below the acceptable standard levels suggested for herbivore growth (Halls et al., 1957; Blair and Halls, 1967). Phosphorus concentrations in forage are also lower than the minimal maintenance requirement. Browse materials may contain various amounts of potential inhibitors to rumen organisms. But deer have achieved an adaptation against plant protective mechanisms by selective browsing of many

different plant species so that no significant amount of any one inhibitor is consumed (Van Soest and Robertson, 1976). Even though grasses, forbs, and browse achieve high nutritional levels in the spring and summer months, it appears deer are existing on ranges where the major yearly food sources rank below the recommended nutritional standards (Campbell et al., 1954; Halls, 1969). The white-tailed deer is a highly adaptable animal with a good breeding potential, making them capable of adjusting to environmental stress (Carhart, 1946; Severinghaus and Cheatum, 1956; Robertson, 1969).

The Relationship of Past Studies to the Present Study

The first investigations into the interactions between soil fertility, plant nutrition, and animal populations concerned the yield and quality of forage crops for livestock (Hall, 1905; Cooper et al., 1927; Midgley, 1937; Albrecht and Smith, 1941; Denny, 1944). The results from these investigations emphasized the intimate association between soil fertility and the dependent animal populations.

During the 1940's several investigations studied soils in relation to wildlife populations (Denny, 1944; Crawford, 1950; Albrecht, 1952). Crawford (1950) found a significant correlation between animal weights and bone strengths to quality of their range. The study performed in Missouri in the late 1940's plotted county average weights of animals against county soil fertility ratings. Based on data accumulated from 39,000 raccoons taken in the counties, the fewest and smallest raccoons occurred in the counties showing the lowest soil fertility ratings. In the same study, rabbits collected from the better soil regions, produced leg bones which were larger and

thicker than the bones of rabbits from soil regions of poorer fertility (Crawford, 1950).

In a more recent study utilizing white-tailed deer, Murphy and Porath (1968) showed variations in body weights of animals taken from different soil regions in Missouri. When the body weights of fawns were superimposed on a soils map of the state, the weights fell into three general classes corresponding to southern, central, and northern Missouri. Antler development in the males and female fertility followed the same soil class pattern.

Several past studies suggested methods and objectives for the present study. Hundley (1959) studied nutrient composition in selected deer browse species growing on different soils in Virginia. Hundley's objectives were:

- (1) To determine the differences in available nutrients in the twigs of five deer browse species growing on different soils.
- (2) To investigate the variations in available soil nutrients as they may relate to the chemical compositions of these twigs.
- (3) To determine the variations in the nutrients of these twigs during different seasons of the year.

Thorsland (1966) sampled soils and associated plant species for mineral contents in South Carolina. The mineral analysis of the browse samples and the analysis of the soil samples showed a relationship between soil fertility and plant mineral content. A direct relationship was indicated between phosphorus content of browse samples and the phosphorus content of the soils.

A similar study by Kruger and Donant (1974) in California utilizing mule deer obtained results positively correlating forage nutrient quality with soil fertility levels.

The objectives of the present study were to ascertain the relationship between soil fertility, time of year, and the nutritive quality of deer browse during the period June 1977 through May 1978 in Nathan Bedford Forrest State Park, Benton County, Tennessee. The analysis of collected materials, soils and forage, was intended to indicate:

- (1) Differences in protein and phosphorus levels in preferred browse species growing on different soils.
- (2) Variations in available soil nutrients related to browse chemical composition.
- (3) Annual seasonal variations in forage nutrient quality.
- (4) The variations in soil fertility occurring between the two seasonal sampling dates.
- (5) Variation in terms of location within the stem tissue of nutrients.

CHAPTER II

METHODS AND MATERIALS

Study Area

In 1929 a memorial park honoring Confederate war general Nathan Bedford Forrest was set aside in remembrance of the river battle at Johnsonville, Tennessee, which occurred on November 4, 1864. The state of Tennessee appropriated \$5,000 and nearly 162 hectares of land to the Benton County Historical Society to construct the park (TN Hist. Quart., 1963). The Tennessee Valley Authority bought much of the property adjacent to the park property associated with the construction of a dam on the Tennessee River at Gilbertsville, Kentucky. The resulting creation of Kentucky Lake in 1944 inundated the old town of Johnsonville as well as most of the battlefield.

Today, Nathan Bedford Forrest State Park includes land tracts on both sides of the lake. The area is located approximately 15 kilometers northeast of Camden, the county seat of Benton County. The western bank is dominated chiefly by Pilot's Knob, one of the highest points in West Tennessee at 203 meters above sea level. Presently the park has expanded to include nearly 1,619 hectares which are under supervision of the state of Tennessee and the Tennessee Valley Authority (Pers. Comm., Paul Reitz, 1978). Logging practices are permitted only to salvage damaged timber and no other commercial logging is allowed. According to state wildlife reports (TN Wild. Res. Ag., 1976-1977) and from personal correspondence with Paul Reitz, park superintendent

(1978), the present deer population is over-stocked and both buck and doe hunts are being used as control measures.

Climate

The climate of Benton County is of the humid continental type. Mild winters, with only an occasional extreme cold spell, hot summers, and an average precipitation of about 127 centimeters are characteristic. The county has an average frost-free period of 192 days, from April 11 to October 21. The annual rainfall of 132 centimeters is fairly well distributed throughout the year with the least precipitation occurring in the summer. Droughts are not very common but lack of rain in months such as July and August can produce drought conditions on certain soil types. Evapotranspiration is greatest during these months (Benton Co. Soil Survey, 1953).

Between June 1977 and May 1978 rainfall was slightly higher than the average with 150 centimeters. July, August, and February were the months with the lowest rainfall. June, July, and August were the months with the highest temperatures (Climatological Data, Tennessee, 1977-1978).

Site Characteristics

Ten sites, each two hectares in size, were selected utilizing topographic maps and aerial photographs obtained from the Tennessee Valley Authority. Trail and hunt maps provided by the Tennessee Park Service of the park area were utilized also. Sites 1 and 2 were selected because each represented old field sites with vegetation suitable for deer foraging. Sites 3, 4, 5, and 6 were located off of the principal ridge in the park, Pilot's Knob Ridge. All sites had

similar slopes ranging from 50 to 60 percent but site 3 faced northward, site 4 faced westward, site 5 faced eastward and site 6 faced southward. Sites 7 and 8 were located in a bottomland area called Chester Hollow and were chosen because of their alluvial parent material, due to proximity to the river and the dissection of the hollow by tributary streams coming from the surrounding ridges. Site 9, an island in Kentucky Lake located at a distance of 100 meters from shore, was chosen specifically to provide results from an area displaying more fertile soils. Site 10, referred to as Beech Hollow, was recommended as a known deer foraging habitat.

Soils

The Benton County Soil Survey was published in 1953. This publication provided by the United States Department of Agriculture and the Tennessee Valley Authority was used as the source for the following information on the soils in the study area.

Mountview Series

Mountview soils are classified as well-drained soils with a thin layer of loess developed over cherty limestone residuum. Chert fragments may be found in varying concentrations throughout the soil profile. The soils are permeable to air, roots, and water. Mountview soils are low in organic matter, plant nutrients, available water holding capacity and are strong to very strongly acid. Soils from this series were found only in site 1.

Ennis Series

Well-drained Ennis soils are found on first bottoms formed from young alluvium washed chiefly from upland soils underlain by cherty limestone. The soil profile may have varying concentrations of chert fragments. Soils are medium to strongly acid and moderate in organic matter concentration. Plant nutrients are not in plentiful supply and the moisture supplying capacity is dependent upon the amount of chert in the soil. Soils from this series were found in site 2.

Bodine Series

Soils from the Bodine Series dominate many of the ridge areas in this region of Tennessee. The soils developed from residuum of highly cherty limestone. Sharp and angular chert fragments varying in size are found throughout the soil profile. The soils are characterized by low organic matter content, low available plant nutrients, low available water holding capacity, and rapid internal and external drainage. Soils are strong to very strongly acid. Soils from this series were found in sites 1, 3, 4, 5, and 6.

Robertsville Series

The poorly drained gray soils of the Robertsville series are confined to the terraces of the Tennessee River or to the terraces along tributary streams. The soils are very strongly acid, low in organic matter, and low in plant nutrients. Mottling occurs within the profile, an indication of poor drainage and low aeration. Soil permeability is controlled by the height of the water table. The soil profile contains water-worn chert and gravel. Soils from this series were found in site 7 and site 10.

Greendale Series

Well-drained Greendale soils form from local alluvium at the foot of slopes. The soils are young, not showing a well-developed textural profile. The parent material is from upland soils derived from cherty limestone. Soils are medium to strongly acid, low in organic matter, permeable, and contain numerous chert fragments. Soils from this series were found in site 8.

Lindside Series

Lindside soils are young soils formed from alluvial parent material. The soils receive a yearly influx of silt distributed by the spring inundation from reservoir waters. Soils have medium acidity, high organic matter content, high available plant nutrients, and high water-holding capacity. Soils from this series were found in site 9, the island.

Humphreys Series

Humphreys soils are well-drained cherty soils of low terraces which have developed from alluvium from upland streams. Soils are strongly to very strongly acid, medium in organic matter and available plant nutrients. Soils from this series were found in site 10.

Soil Collection and Analysis

Soil samples were collected from each site twice during the year. The first samples were taken in July of 1977 and the second collection in December of 1977. One organic sample, three topsoil samples representing 0 to 13 centimeters and three subsoil samples representing 30 to 42 centimeters were taken from a soil profile.

Seven soil samples per site were collected each date. The samples were chosen at random over the site areas, but a distinct change in topography normally dictated the taking of a soil core. In the ridge sites, samples were collected along the ridge border, at a point midway in the site and along the bottom border. This sampling procedure was designed to reflect within site variation of soil fertility. Samples were collected utilizing a bucket auger.

After collection, samples were taken to a lab and weighed. They were sieved to remove chert fragments, and spread out on trays to allow air drying. Wet weights, dry weights, percentage water loss, and percentage chert concentration were recorded.

Soils were analyzed by the Soils Testing Lab, The University of Tennessee, Knoxville and the Agricultural Extension Service in Nashville, Tennessee. Their standard procedures are: Soil nutrients were extracted using 1 percent $(\text{NH}_4)_2\text{SO}_4$ in .05 N H_2SO_4 . Phosphorus was determined colormetrically using the 1, 2, 4-aminonaphthalsulfonic-reduced molybdophosphoric blue method (Jackson, 1965). Potassium was determined using atomic absorption spectrophotometry. Soil pH was determined in a 1:1 (wt. soil:v. H_2O) suspension using a glass electrode.

Preferred Browse

Preferred browse species are the plant species most likely to be consumed by deer. Moore and Strode (1966) refer to such forage as delicacies or candy species which are normally high in nutritive value. Various habitat appraisals have produced different lists of preferred browse species for states in the eastern United States.

From studies in North and South Carolina, Arkansas, Virginia, and Georgia, smilax (Smilax sp. L.), honeysuckle (Lonicera japonica Thumb.), flowering dogwood (Cornus florida L.), wild grape (Vitis sp. Michx.), red maple (Acer rubrum L.), blackberry (Rubus sp. L.), sassafras (Sassafras albidum Nees), and strawberry bush (Euonymus americanus L.), are the species of plants listed most often as either preferred or staple deer browse plants (Hammerstrom and Blake, 1939; Hundley, 1959; Ripley and McClure, 1963; Halls and Alcani, 1965; Stiteler and Shaw, 1966; Nixon et al., 1970; Segelquist et al., 1972; Sossaman and Weber, 1973; Sheldon and Causey, 1973).

The browse species collected for the present study included: smilax, honeysuckle, red maple, flowering dogwood, wild grape, sassafras, blackberry, buttonbush (Cephalanthus occidentalis L.), and farkleberry (Vaccinium arboreum Marxh.).

Smilax

Smilax was the only plant collected from all the sites regularly during the year. Therefore, it provides an indicator and common denominator for comparing forage quality between sites. It was the browse species analyzed most extensively for phosphorus content and to indicate position of nutrient concentration within plants.

Smilax are thorny, evergreen, woody vines, with small lance-shaped leaves. Five species are found commonly across the South and are widely distributed in forests, cutovers, swamps, abandoned fields and along fence rows. Maximum growth is achieved by plants growing in the open. Fruits are utilized by many species of wildlife. The fast-growing green canes and tender shoots are very palatable. Smilax

is consumed by deer year around (Halls and Alcani, 1965; Goodrum, 1977).

Japanese Honeysuckle

Honeysuckle, an introduced Asian species (1906) grows throughout the South along fence rows, borders of woods, and on low moist ground along streams. The plant can provide a dense network of forage available as browse year round. Fruits persist on honeysuckle plants throughout winter and are low in crude fiber, high in nitrogen, and moderate to high in phosphorus (Sheldon and Causey, 1973; Halls, 1977a). Honeysuckle was collected from the old field sites, 1 and 2.

Flowering Dogwood

Flowering dogwood is a shade tolerant understory species, which may exist on drier upland sites or in mesic valleys and hollows. The browse and fruits which are utilized by many species of game animals are low in crude protein and phosphorus. The litter decomposes rapidly, enhancing the recycling of nutrients (Halls, 1977b). Dogwood was collected from the ridge sites, 3 and 6 and from the hollow sites, 7, 8, and 10.

Red Maple

Red maple is a highly shade tolerant small tree which thrives in the more mesic sites. It is rated as medium to high in palatability and can sustain heavy browsing. The leaves and twigs collectively contain 3 to 6 percent crude protein. In southern coastal regions during the spring, mineral content of leaves and twigs has been

analyzed as 0.17 percent phosphorus (Bonner, 1974). Red maple was collected from the four mesic sites, 7, 8, 9, and 10.

Wild Grape

Wild grapes are shade intolerant climbing vines which grow best in moist fertile soils. Fruits, young canes and dried leaves are consumed by deer during various seasons of the year. Fruits are low to moderate in crude protein and moderate in phosphorus (Halls, 1977c). Wild grape was collected from the ridge sites, 3 and 5, and from the mesic sites, 8, 9, and 10.

Sassafras

Sassafras achieves its best growth in open sites on moist, well-drained sandy loam soils. In forest openings it will grow rapidly with its palatable browse growing out of reach of deer unless the stand is periodically cut back. Seeds are high in crude protein and moderate in phosphorus (Leonard, 1977). Sassafras was collected from the four ridge sites, 3, 4, 5, and 6.

Blackberry

The genus Rubus includes many semiwoody, thorny shrubs available as wildlife forage. Blackberry is a typical member of the genus producing an abundance of spiny stems meshing into dense thickets and having large, black aggregate fruits. Growing best in open stands, blackberry remains palatable through the summer and is often utilized as forage in fall and winter (Lay, 1977). Blackberry was collected from the old field sites, 1 and 2.

Strawberry Bush

Strawberry bush is a shade-tolerant shrub which grows best in rich moist soils. Its leaves are persistent through winter in the southern range. The leaves and stems are highly preferred by deer (Halls and Alcani, 1968). Strawberry bush was collected from the mesic sites 7, 8, and 10.

Buttonbush

Buttonbush is a water tolerant species found along stream borders or in fresh-water swamps. It is utilized as a staple browse by deer, with its leaves and twigs browsed especially in summer and fall. Buttonbush is considered unpalatable for livestock. The bitter leaves contain two toxic glucosides, cephalanthin and cephalin (Martin et al., 1961). Buttonbush was collected only from site 9, the island.

Farkleberry

Farkleberry is a species of blueberry. It is found in pure stands growing on well-drained soils in open oak woods and along rocky ledges. Fruits are low in crude protein and phosphorus (Dale and Hughes, 1977). Farkleberry was collected from the ridge sites, 4, 5, and 6.

Collection Procedure

Short (1968) utilized four collection criteria which were followed in the present study:

- (1) Plants should duplicate food items ingested.
- (2) Forage collection should follow specific times of day and rate of sampling through the collection period.

- (3) Collected materials must be processed quickly to kill biological activity, minimizing chemical degradation.
- (4) Careful measure should be taken to assess forage quality to the animal.

Permanent sites were established as 60 meter by 96 meter rectangular sites which enclosed an area approximately two hectares in size. The corners of the permanent sites and the borders surrounding the sites were distinguished by the tacking of colored tape on trees along the border lines.

Aldous (1944) recommended the surveying of 0.01 acre plots and the utilization of circular quadrats for deer habitat appraisals. Utilizing methods discussed by DeVos and Mosby (1969), circular plots with a radius of 3.57 meters were used as the collection plots. The circular collection plots were selected at random from each 2 hectare permanent sites each month. The size of the plot was designed to provide a sampling area amounting to 1 percent of the permanent site sampled per month or 12 percent total sampled over the year.

Monthly browse collection was based on the (Browse Clip and Weigh) method used by Schwan and Swift (1941). Briefly the method includes collection of twigs with leaves, recording of wet weight, drying, and recording of the dry weights of the stem and leaf tissue collectively. Studies by Short and Harrell (1969), Blair and Epps (1969), and Segelquist et al. (1972), indicated browse samples should be collected within a height zone from ground level up to 1.5 meters. With deciduous browse species, 15 centimeters of the annual growth was clipped per browse sample. From vine samples 26 centimeters of the annual growth was clipped. A routine collection route

was followed each month to insure plant specimens were collected at approximately the same time of the day each month (Short, 1968).

Forage Analysis and Lab Procedures

Plants collected during the spring and summer months included leaf and stem tissues. Analysis on forage material from the fall and winter months was conducted on stem tissue only. Each plant specimen was oven dried at 45°C for 24 to 48 hours. Van Soest (1967) recommended this procedure because oven-drying above 50°C will increase the yield of lignin and fiber and cause some degradation of protein.

Samples designated for chemical analysis were ground through a 30 mesh screen in a Wiley Mill and stored in glass scintillation vials. Sample weights were reduced to 100 mg dry weight per vial. Five ml of concentrated sulfuric acid was added to each vial. This was followed by the addition of two ml of 30 percent hydrogen peroxide. The vials were capped tightly and shaken. Caps were loosened on each vial and were placed in an autoclave for 45 minutes at 121°C and 18 pounds of pressure. The vials were removed from the autoclave and placed under a ventilated hood. Ten ml of distilled water was added to each vial (Lowendorf and Dominski procedure, unpublished, modified by Richardson, pers. comm. C. J. Richardson).

Nitrogen and phosphorus were determined colorimetrically in a Bausch and Lomb Spectronic 20 spectrophotometer. For nitrogen, 0.3 ml of digest was added to 7.35 ml of distilled water and then 7.35 ml of Nessler's reagent was added. Samples were read at 415 nm after a 20 minute time interval.

Phosphorus was determined according to a procedure from Jackson (1965). An equal volume of molybdovanadate solution was mixed with 7.5 ml of the digest. Samples were read at 400 nm after a 10 minute time interval.

Nitrogen and phosphorus standards were produced in 1.8 normal sulfuric acid. Sample concentrations were calculated by linear interpolation of the standards. Procedures also were conducted on standard reference, orchard leaves (Standard Reference Material 1571, U.S. National Bureau of Standards, Washington, D.C. 20234).

Statistics

Data were analyzed using analysis of variance, Duncan's multiple range test, and simple correlation, using the statistical analysis subroutine (SAS, 1979) on the IBM 360 computer at The University of Tennessee, Knoxville.

CHAPTER III

RESULTS

The two permanent sites were subdivided into four classes reflecting similarities in soil type, soil fertility, soil moisture, plant cover, species composition, and plant nutrition. The four ridge sites, 3, 4, 5, and 6 composed the xeric classification. Two old field sites, 1 and 2, were classified as sub-xeric. Three sites composed of various alluvial soils were included under the mesic classification. The island, site 9, was placed in a separate category since it was distinguished from all other sites by soil type, plant species, periodic inundation, and accessibility by deer.

Xeric Sites

The xeric sites, 3, 4, 5, and 6 were very similar except for differences in the cardinal aspects. All four sites had a similar canopy dominated by oaks and hickories, although differences occurred in the shrub layer.

Results show a general increase in soil pH from July to December, Figure 1. Both the topsoil horizon and the subsoil horizon exhibited this increase. Soil phosphorus declined from summer to winter. The average concentration of soil phosphorus in December was only one part per million, Figure 2. Soil potassium was higher in December than in July, a pattern similar to pH, Figure 3.

Pearson product-moment correlations (SAS, 1979) showed a significant negative correlation between soil pH and soil phosphorus

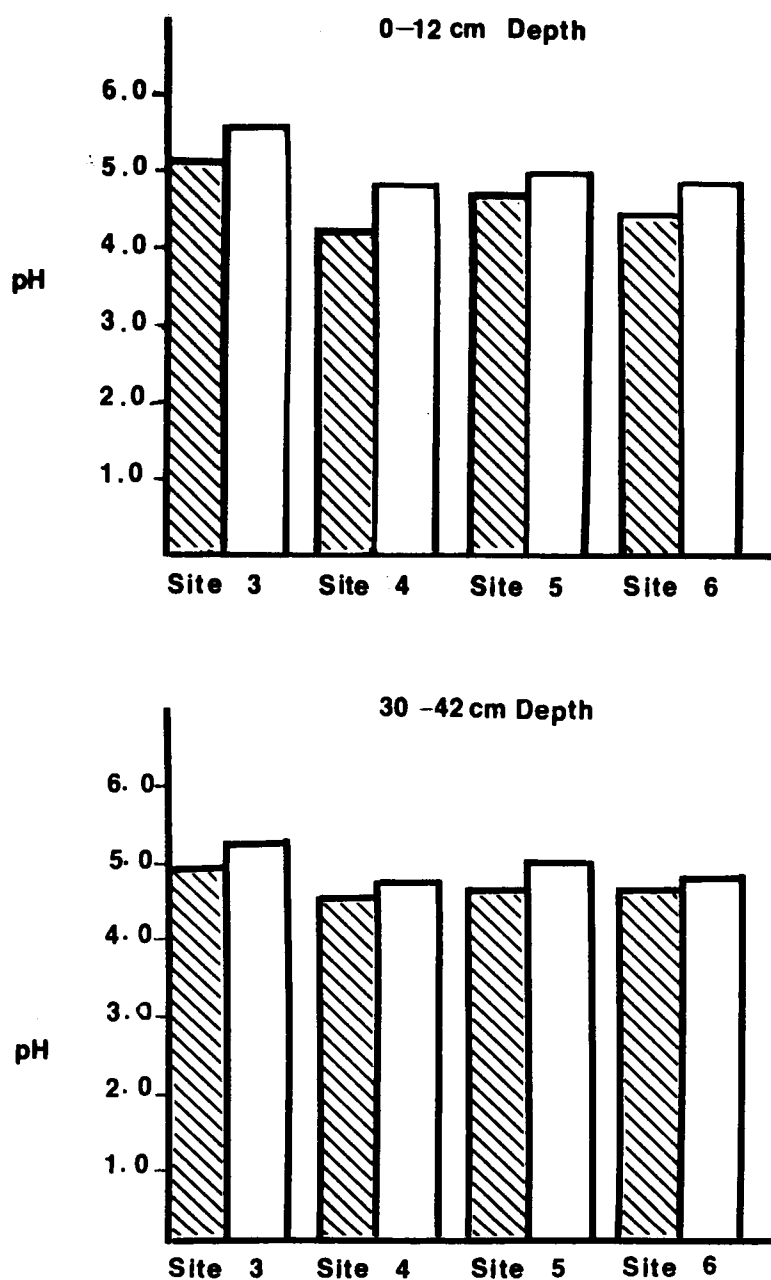


Figure 1. Average soil pH for xeric sites at the 0-12 cm depth (above) and 30-42 cm depth (below). July designated by striping and December by plain bars.

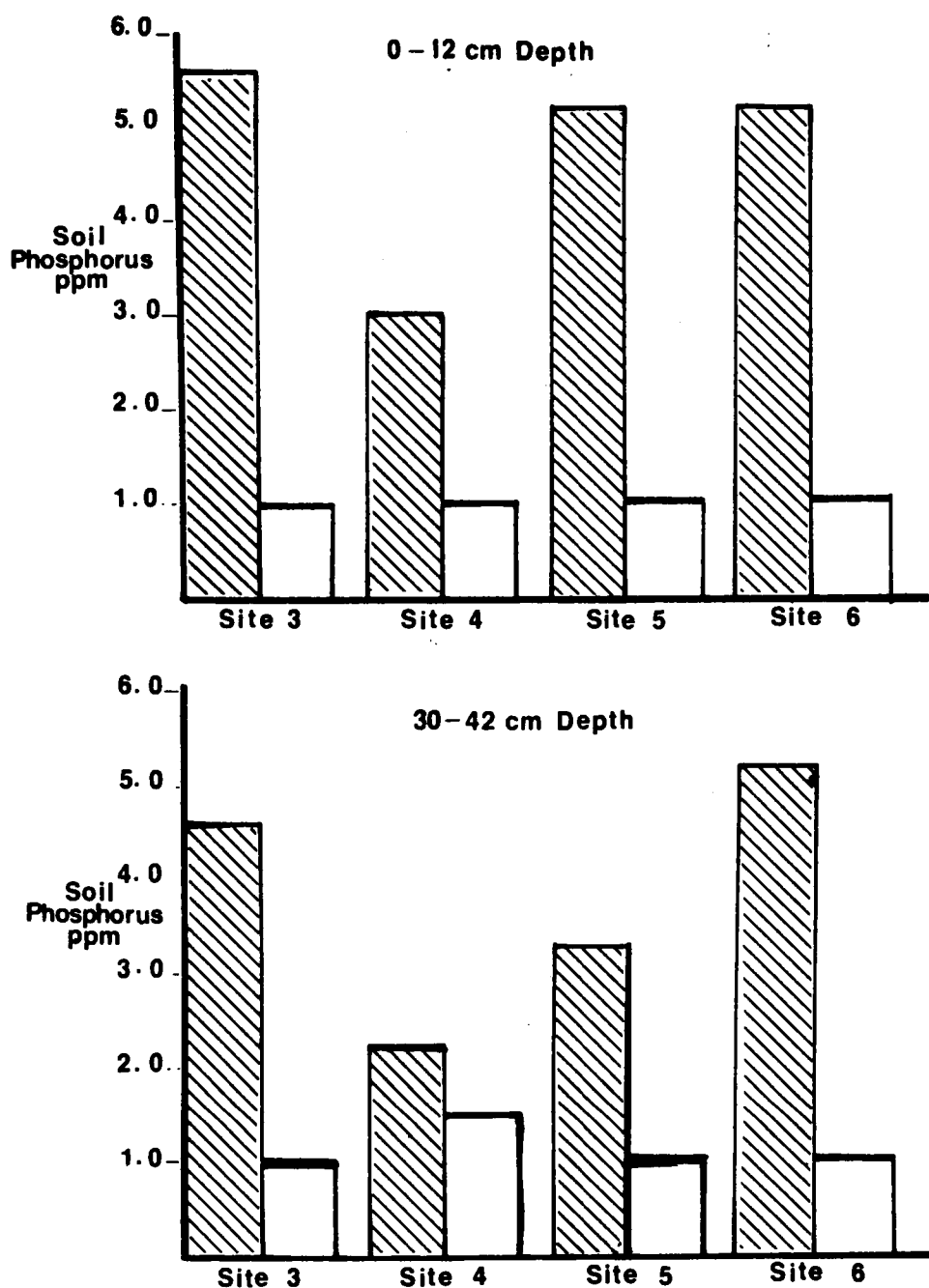


Figure 2. Average soil phosphorus values for xeric sites at the 0-12 cm depth (above) and 30-42 cm depth (below). July designated by striping and December by plain bars.

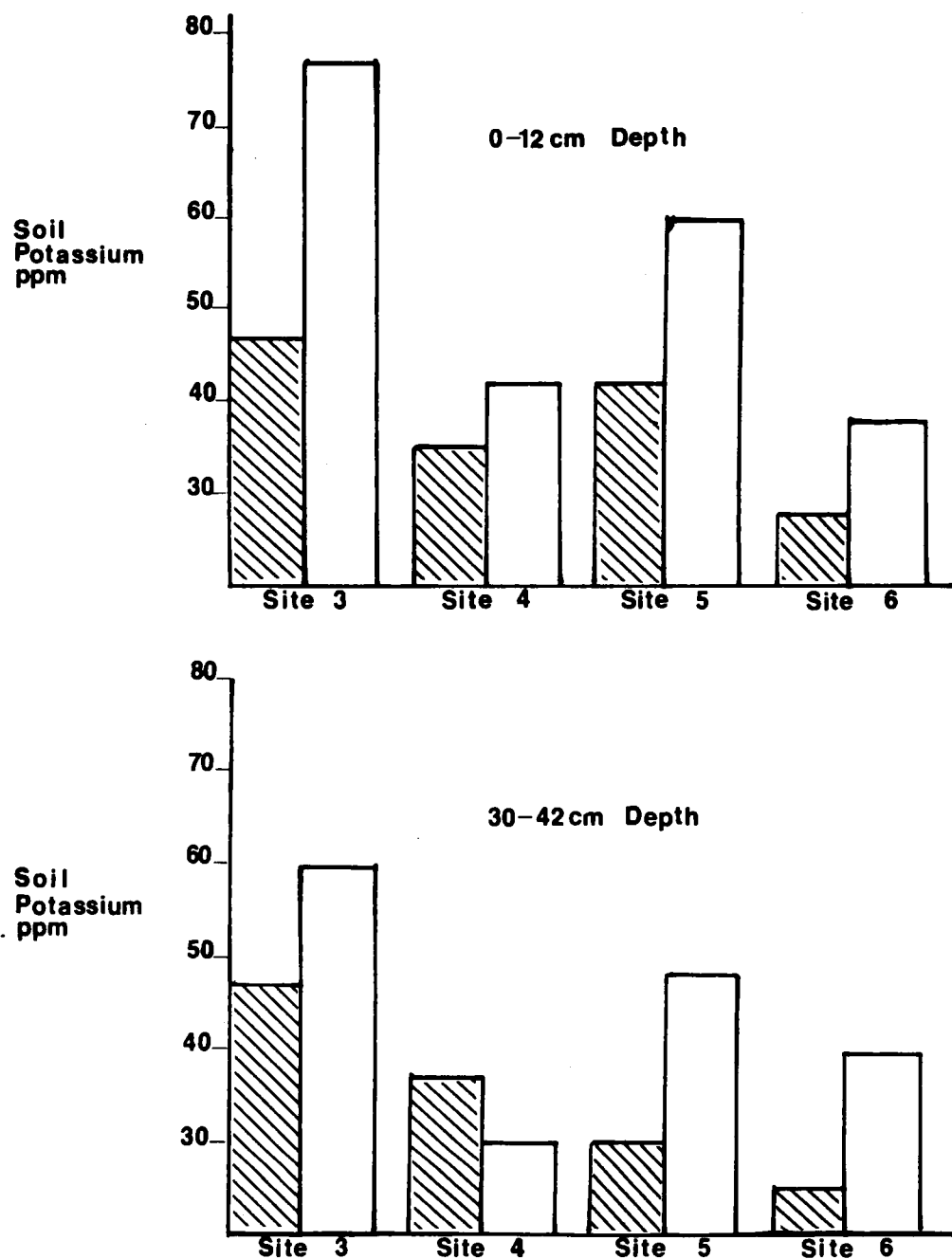


Figure 3. Average soil potassium values for xeric sites at the 0-12 cm depth (above) and 30-42 cm depth (below). July designated by striping and December by plain bars.

and between soil potassium and soil phosphorus. Soil pH was positively correlated with soil potassium, Table I. The fertility means for all xeric sites are similar. Duncan's multiple range test indicated significant differences between the four sites. In general the less xeric sites, sites 3 and 5 (North and East slopes) had higher fertility than the more xeric sites, sites 4 and 6 (West and South slopes), Table II.

Sub-xeric Sites

Sites 1 and 2 were included in the sub-xeric class. The sites were designated as sub-xeric due to the presence of shrub species characteristic of secondary succession and due to similarities in topography and drainage.

There were no extreme differences in soil pH between the sub-xeric sites or between the two soil collection dates, Figure 4. Figure 5 shows a similar pattern between the two sites for soil potassium; however, December potassium concentrations were higher than those in July. The soil phosphorus results show a definite separation between the sites. Figure 6 shows a much higher phosphorus concentration in site 2 during July. Soil fertility trends in the two sites are viewed best utilizing Table III. Soil pH means and potassium means are not significantly different but soil phosphorus means are grouped separately.

Mesic Sites

The mesic class included sites 7, 8, and 10. The sites were characterized by flat, lowland topography, similar water-tolerant

TABLE I
CORRELATIONS OF SOILS DATA FOR
XERIC SITES ONLY

Correlated Pair	Corr. Coef.	Sign. Level
Soil pH x Soil Phos.	- 0. 31993	*0.0266
Soil pH x Soil K	0. 60806	0.0001
Soil Phos. x Soil K	-0. 30610	*0.0344

*Significance probability of the correlation.

TABLE II
XERIC SITE MEANS FOR SOIL pH, SOIL
PHOSPHORUS, AND SOIL POTASSIUM

	Site 3 North	Site 4 West	Site 5 East	Site 6 South
pH	5.21 ^a	4.57 ^c	4.81 ^b	4.68 ^{bc}
Phosphorus	3.10ppm ^a	1.90ppm ^b	3.00ppm ^a	2.60ppm ^{ab}
Potassium	57.50ppm ^a	35.80ppm ^b	45.00ppm ^{ab}	32.90ppm ^b

Means designated with different superscripts show that the means are significantly different at the .05 level (Duncan's multiple range test).

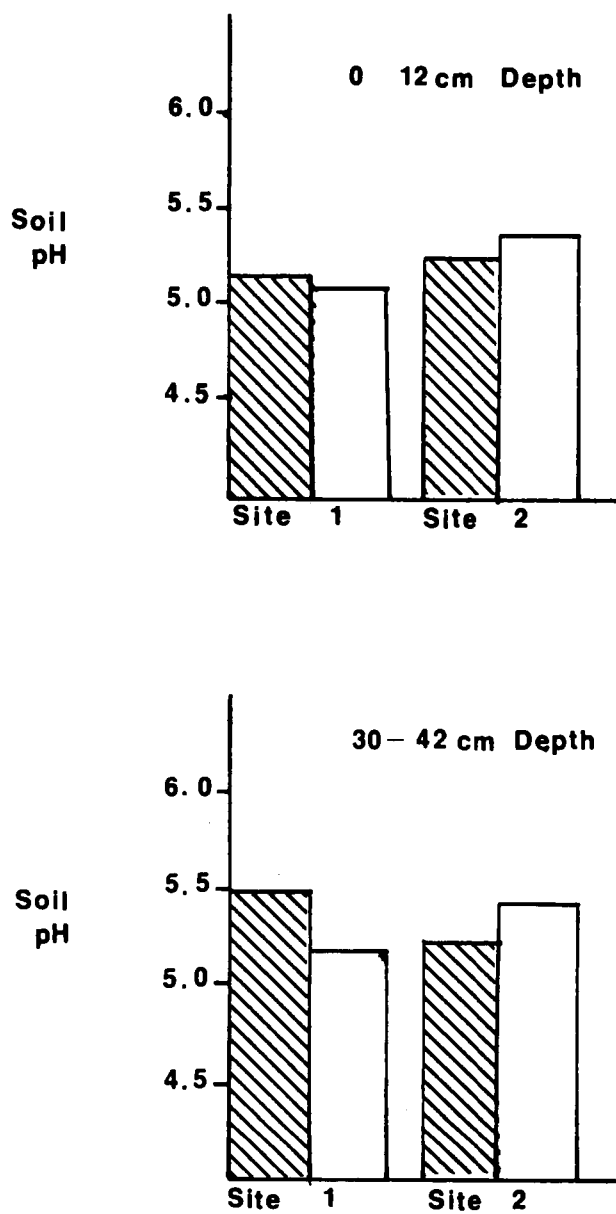


Figure 4. Average soil pH for sub-xeric sites at 0-12 cm depth (above) and 30-42 cm depth (below). July designated by striping and December by plain bars.

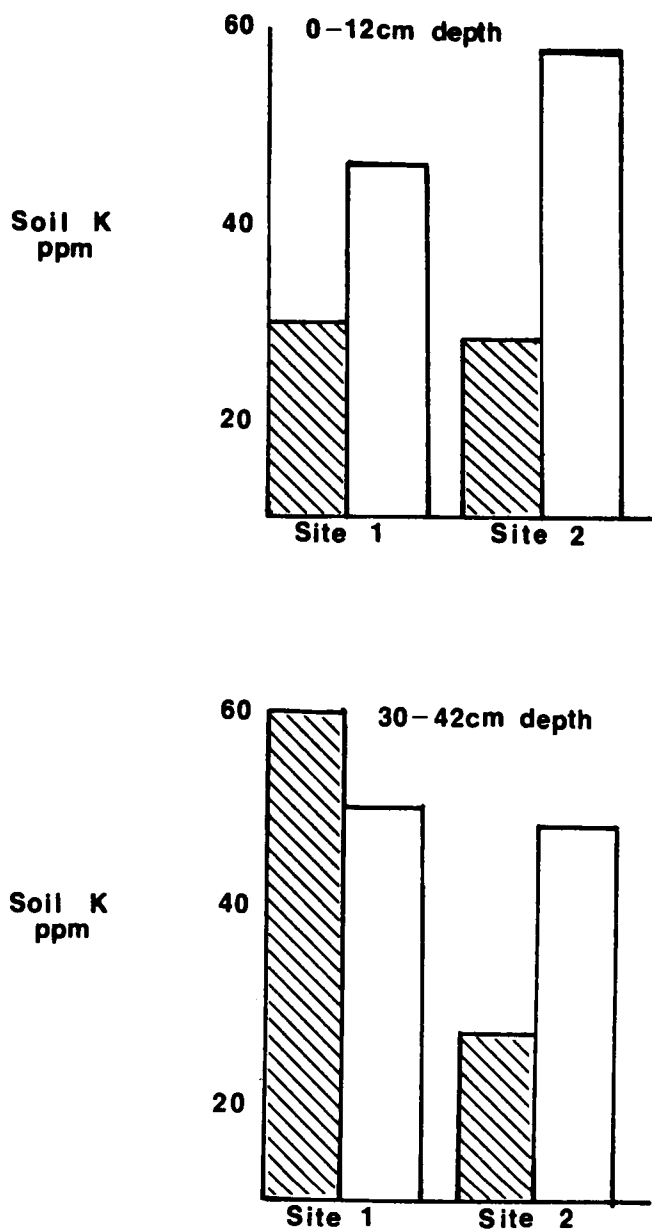


Figure 5. Average soil potassium for sub-xeric sites at the 0-12 cm depth (above) and 30-42 cm depth (below). July samples indicated by striping and December samples by plain bars.

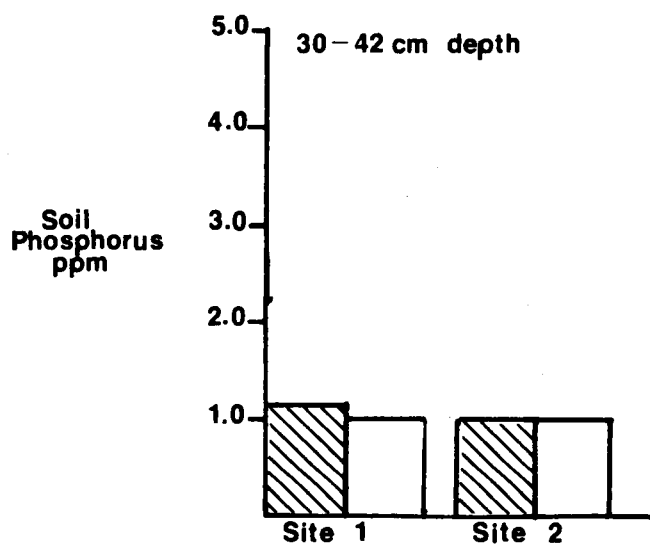
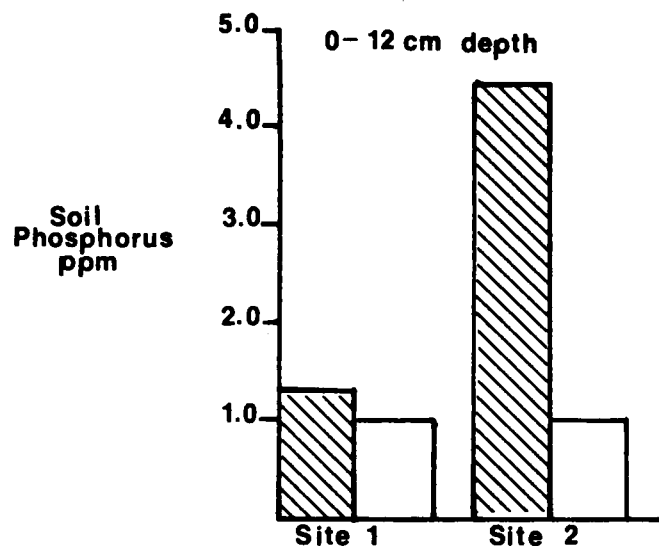


Figure 6. Average soil phosphorus for sub-xeric sites at the 0-12 cm depth (above), and the 30-42 cm depth (below). July samples are indicated by striping and December samples by plain bars.

TABLE III
SUB-XERIC SITES' MEANS FOR SOIL pH, SOIL PHOSPHORUS,
AND SOIL POTASSIUM

	Site 1	Site 2
pH	5.2 ^a	5.3 ^a
Phosphorus	1.1ppm ^a	2.6ppm ^b
Potassium	46.7ppm ^a	40.4ppm ^a

Means designated with different superscripts show that the means are significantly different at the .05 level (Duncan's multiple range test).

vegetation, the presence of transecting creeks, and similar alluvial soils.

Table IV shows mean concentrations for potassium, phosphorus and soil pH. Site 8 had a significantly lower pH than the other two sites as well as lower potassium content. Soil phosphorus varied significantly between both sites and sampling dates using analysis of variance. Site 7 had a significantly higher phosphorus concentration, due largely to the July average concentration of 5.0 ppm which was 300 percent higher than the December concentration.

The mesic sites can be separated into a definite fertility gradient utilizing a graph plotting soil phosphorus versus soil potassium from the 0-12 cm depth, Figure 7. This gradient was consistent for the summer as well as the winter.

Island

An island site, 9, was investigated for several important reasons. Deer prefer secluded areas and the island is located 100 meters from the mainland. Several species of water tolerant plants present are listed as preferred deer browse. Deer have been commonly observed on the island (pers. comm., Paul Reitz).

Site 9 exhibited less acid soils with a pH value of 5.3. The island soil samples averaged three to eight times more soil phosphorus than values from all other sites, Table V. Soil potassium values for the island were intermediate in relation to the other sites.

Collective Soils Data

Table V presents all the soils results collectively. These results indicate that the island site ranks well ahead of all other

TABLE IV
MESIC SITE MEANS FOR SOIL pH, SOIL
PHOSPHORUS, AND SOIL POTASSIUM

	Site 7	Site 8	Site 10
J/pH	4.7	4.5	4.6
J/Phosphorus	5.0ppm	2.3ppm	3.7ppm
J/Potassium	41.7ppm	27.7ppm	35.0ppm
D/pH	4.9	4.8	4.8
D/Phosphorus	2.6ppm	1.0ppm	1.0ppm
D/Potassium	26.0ppm	26.0ppm	26.0ppm

J/July means, 0-12 cm depth and D/December means, 0-12 cm depth.

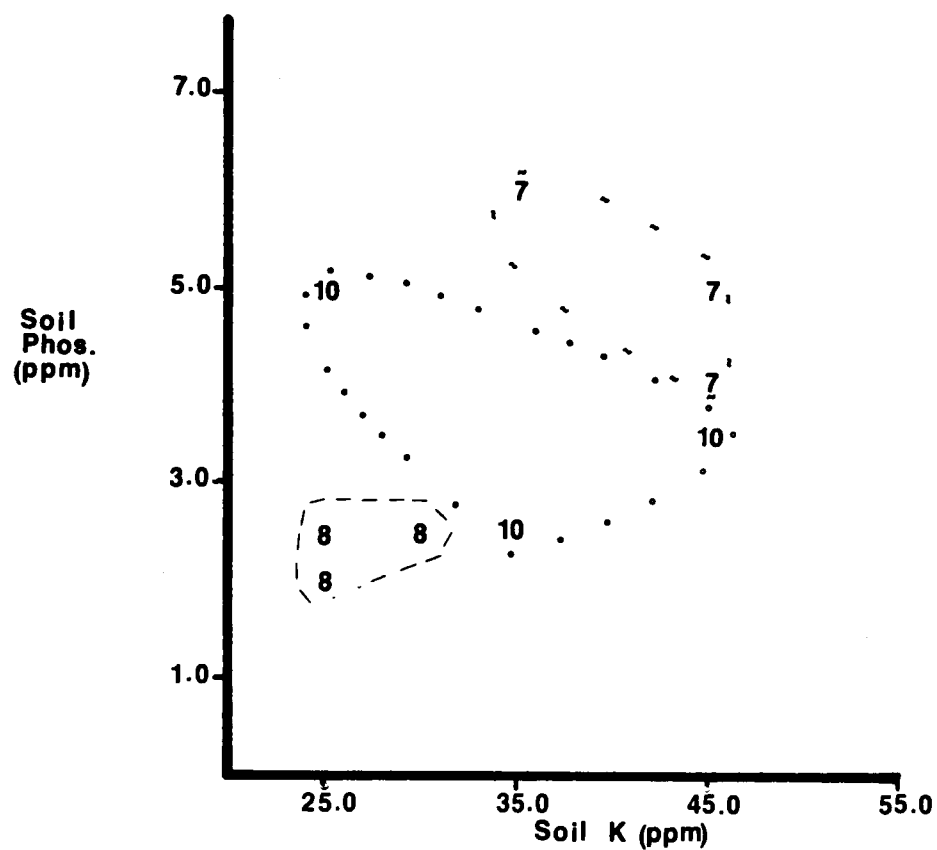


TABLE V
MEANS FOR SOIL pH, SOIL PHOSPHORUS, AND SOIL
POTASSIUM FROM ALL SITES

Site	Class	pH Mean	Phos. (ppm)	K (ppm)
3	Xeric	5.2 ^a	3.0 ^b	57.5 ^a
4	Xeric	4.8 ^{bc}	2.6 ^{bc}	45.0 ^{abc}
5	Xeric	4.7 ^{bc}	3.1 ^b	32.9 ^{bcd}
6	Xeric	4.6 ^c	1.9 ^{cd}	35.8 ^{cd}
1	Sub-xeric	5.3 ^a	1.2 ^{bc}	47.0 ^{ab}
2	Sub-xeric	5.2 ^a	2.6 ^d	44.0 ^{bcd}
7	Mesic	4.8 ^b	3.0 ^b	31.7 ^{cd}
8	Mesic	4.8 ^{bc}	1.9 ^{cd}	32.1 ^{bcd}
10	Mesic	4.6 ^{bc}	1.7 ^{cd}	27.3 ^d
9	Island	5.3 ^a	8.8 ^a	39.6 ^{bcd}

Different superscripts indicate the means are significantly different at the .05 level (Duncan's multiple range test).

sites in soil phosphorus. Moreover soil pH for this site is the most favorable of those sampled for optimum plant growth (Brady, 1974). Soil phosphorus varied statistically between date, horizon, and site. Generally as soil pH values became more basic, soil potassium values increased. A positive correlation does exist between soil potassium and soil pH with an "r" value of 0.48. Sites 9, 3, and 2 showed higher soil pH values and exhibited high phosphorus values; however, a correlation does not exist between the variables.

Plant Data

Plant results are presented utilizing the same site grouping, to determine if common site variables have predictive value for browse quality. Plants were analyzed for total nitrogen which then was converted into a crude protein value by multiplying by 6.25 (Dietz, 1965). Plant analysis also included evaluation of plant phosphorus and percent moisture.

Using analysis of variance, season was the only variable found significant for protein analysis in Smilax. Duncan's multiple range test exhibited two separations for plant protein. Smilax analyzed from the island had the highest plant protein value and was grouped separately from all other sites, Table VI. Plant protein averaged 13.1 percent for the island over the year. Other sites showing high protein averages for the year had high values occurring in certain spring months. Site 2 with a 12.8 percent yearly average had the highest monthly protein value with 17.6 percent protein in April.

Table VI also shows the plant phosphorus analysis for Smilax. Site 9 had significantly higher plant phosphorus than all other sites

TABLE VI
YEARLY MEAN PERCENTAGES FOR SMILAX PHOSPHORUS,
PROTEIN, AND MOISTURE BY SITE AND CLASS

Site	Class	% Phosphorus	% Protein	% Moisture
3	Xeric	0.12 ^{ab}	11.0 ^a	60.0 ^{ab}
4	Xeric	0.17 ^{ab}	12.5 ^a	59.1 ^{ab}
5	Xeric	0.16 ^{ab}	11.5 ^a	44.0 ^b
6	Xeric	0.12 ^b	11.6 ^a	62.8 ^a
1	Sub-xeric	0.12 ^b	11.7 ^a	52.2 ^{ab}
2	Sub-xeric	0.15 ^{ab}	12.8 ^a	59.9 ^{ab}
7	Mesic	0.17 ^{ab}	12.9 ^a	50.0 ^{ab}
8	Mesic	0.17 ^{ab}	12.0 ^a	58.8 ^{ab}
10	Mesic	0.16 ^{ab}	11.7 ^a	50.0 ^{ab}
9	Island	0.26 ^a	13.1 ^a	49.8 ^b

Different superscripts indicate the means are significantly different at the .05 level (Duncan's multiple range test).

(0.26 percent). Sites 7, 8, and 10 (Mesic), sites 5 and 6 (Xeric) and site 2 (Sub-xeric) occupied a medium range for plant phosphorus. All the mesic site soils are included in this medium range.

Table VI also includes plant moisture content data for each site. Plant moisture was a variable tested to indicate more palatable, succulent, and nutritional forage. For Smilax only, analysis of variance showed that plant moisture was not significant for site at the .05 level. The three sites showing highest plant moisture were sites 4, 5, and 3 in the xeric soil class.

Table VII shows the influence of season on plant nutrient content. Season one (March-June) showed the highest plant nutrient values for phosphorus and protein, although there was not a great range displayed in protein values. Season two (July-October) showed a smaller percentage of phosphorus and protein in the plants while plant moisture remained the same. The winter season reflects the loss of succulent and nutritious foliage.

Even though Smilax was the principal browse species collected, its collection in some sites was limited to two or three months. Consequently all browse species data collected and analyzed are presented in Figure 8. A positive correlation with an "r" value of .82 occurs between plant protein and plant phosphorus. As expected, site 9 ranked high in both plant protein and plant phosphorus. The mesic group (Sites 7, 8, and 10) had medium to high plant protein and phosphorus values. The old field sites, 1 and 2, were low in plant phosphorus. The xeric sites, 3, 4, 5, and 6, had low to medium values for plant nutrients. Site 3, even though showing high soil fertility (Table V, page 36) had the lowest plant nutrient concentrations.

TABLE VII
SEASONAL MEANS OF SMILAX PHOSPHORUS, PROTEIN, AND
MOISTURE

Season	Period	% Phosphorus ^{**}	% Protein	% Moisture
-1/	Spring-Growth	0.21 ^a	12.7 ^a	59.1 ^a
-2/	Summer-Maintenance	0.14 ^b	11.8 ^b	60.7 ^a
-3/	Winter-Senescence	0.13 ^b	11.3 ^b	39.6 ^b

-For purposes of comparison, Spring includes March-June; Summer includes July-October; Winter includes November-February.

**Significant seasonal effects at the .10 level, protein and moisture significant at the .05 level (analysis of variance).

Different superscripts indicate the means are significantly different at the .05 level (Duncan's multiple range test).

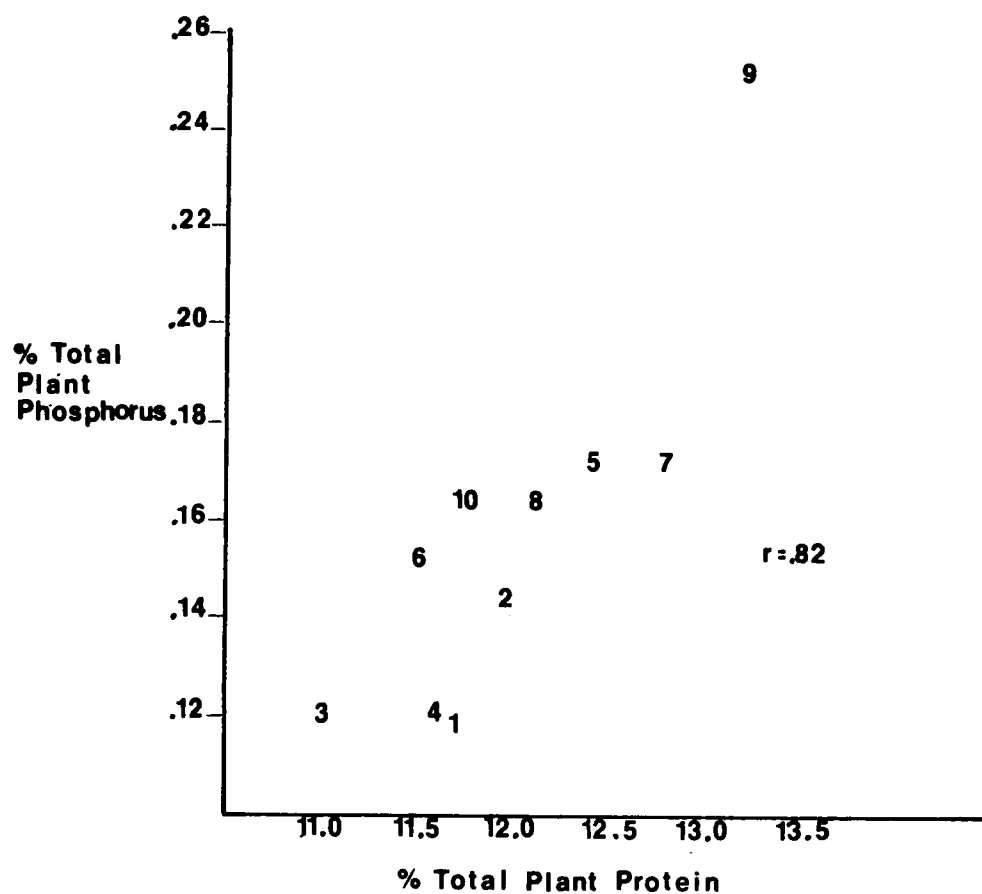


Figure 8. Yearly means of total plant phosphorus versus plant protein for all species by site. Sites are identified by numerals 1-10.

Plant and Soils Data Collectively

In an attempt to determine if relationships existed between soil and plant variables, the two data sets were combined and correlation analysis was used. Originally the seasons were divided into three. Season one or the growing season included the months, March, April, May, and June. Season two or the maintenance season included July, August, September, and October. Season three or the senescent season included November through February. Since the two soil collections represented summer (July) and winter (December), plant seasons one and two were joined to coordinate with the July soil samples. Moreover, only soils data from the topsoil horizon or the 0-12 cm depth were treated in the data set.

Table VIII presents the correlations between soils data and Smilax plant data. Both plant protein and plant phosphorus were positively correlated with soil phosphorus. The relationship between soil phosphorus and plant protein may be partially explained by the positive correlation between plant phosphorus and plant protein and reflect in general the soil fertility gradient. Figure 9 shows the relationship between plant phosphorus and soil phosphorus and Figure 10 shows the relationship between plant protein and plant phosphorus. Finally Table VIII shows the positive correlation which exists between the top six centimeters of stem tissue with the bottom six centimeters of stem tissue.

The same statistical procedures were performed again to include all the plant data, Table IX. The same correlations occurred but in some instances the correlations were higher, perhaps reflecting the greater amount of data. For example, the correlation for plant

TABLE VIII
CORRELATIONS FOR SOILS DATA AND SMILAX
PLANT DATA TOGETHER

Correlated Pair	Corr. Coef.[r]	Sign. Level
<u>Smilax</u> protein x <u>Smilax</u> phos.	0. 57527	0.0157
<u>Smilax</u> protein x Soil phos.	0. 60071	0.0108
<u>Smilax</u> phos. x Soil phos.	*0. 41228	*0.0794
Top stem prot. x Bottom prot.	0. 51549	0.0286

*Significant at the .10 significance level. All other values significant at the .05 level.

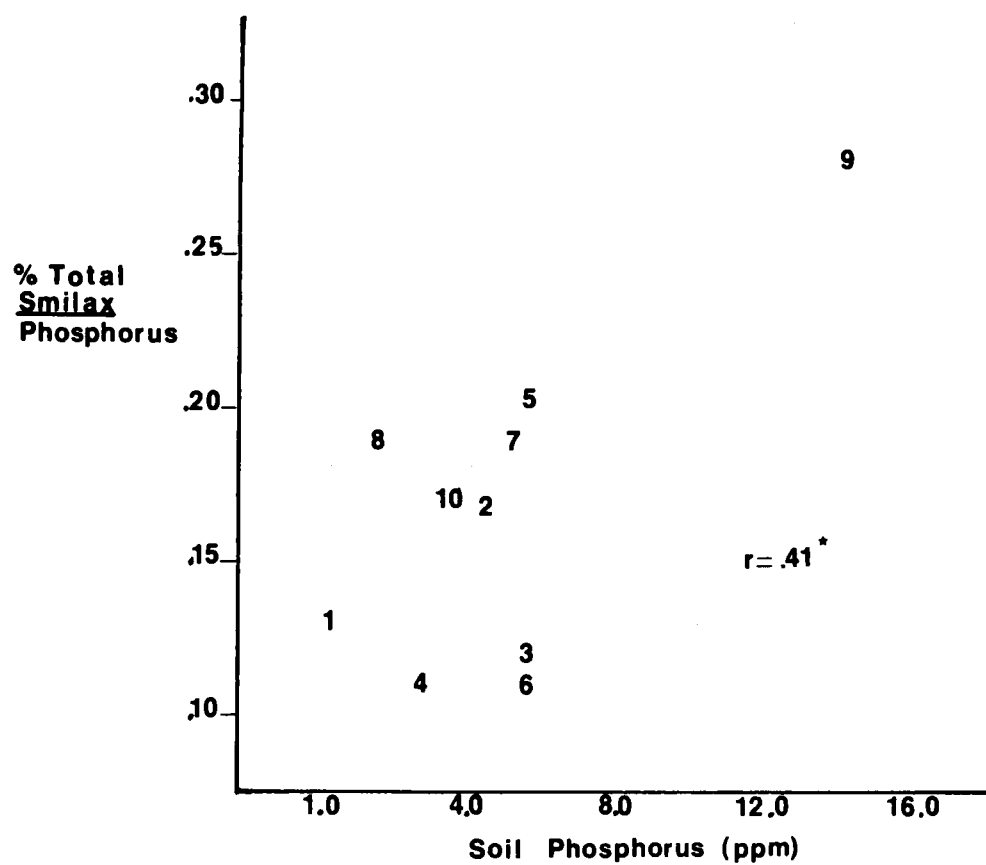


Figure 9. Mean total Smilax phosphorus versus soil phosphorus by site for pooled spring and summer means.

*Significant at the .10 level.

Sites are identified by numerals 1-10.

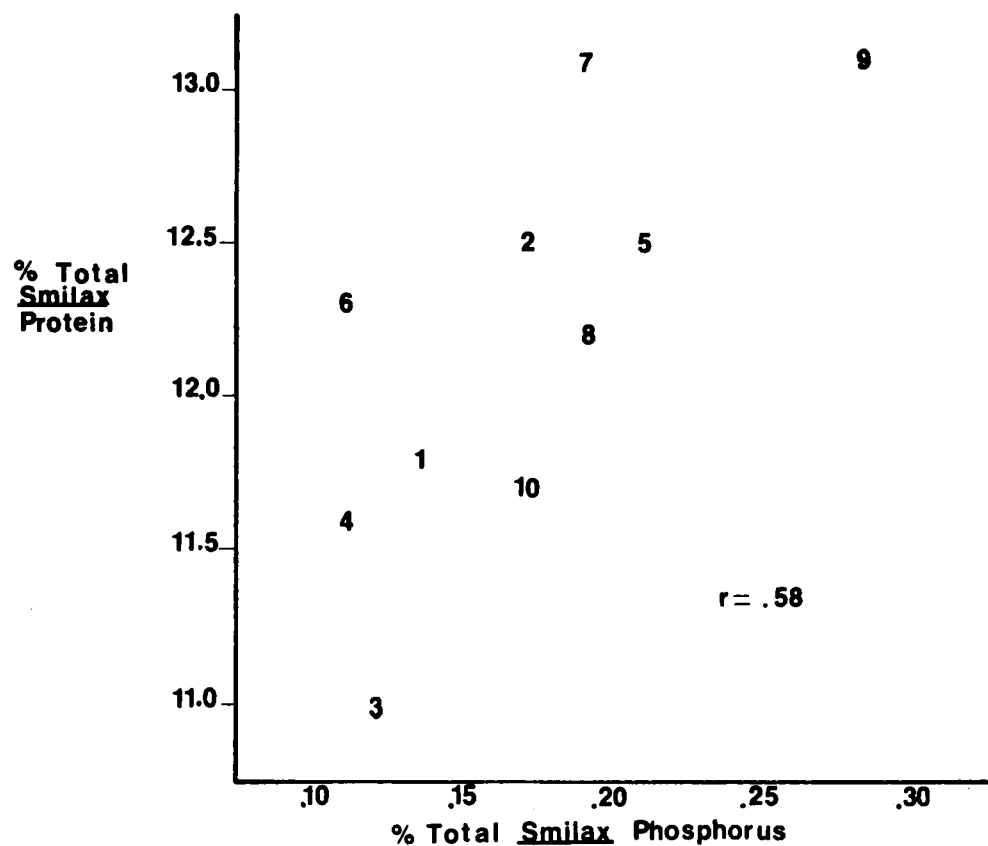


Figure 10. Mean total Smilax protein versus Smilax phosphorus by site for pooled spring and summer means.

Sites are identified by numerals 1-10.

TABLE IX
CORRELATIONS FOR SOILS DATA AND ALL
PLANT SPECIES TOGETHER

Correlated Pair			Corr. Coef., r	Sign. Level
Plant Protein	x	Plant Phos.	0 . 73	0 . 0002
Plant Protein	x	Plant Moist.	0 . 70	0 . 0004
Plant Protein	x	Soil Phos.	0 . 55	0 . 0127
Plant Phos.	x	Soil Phos.	0 . 73	0 . 0003
Plant Phos.	x	Plant Moist.	0 . 59	0 . 0058

All values significant at the .05 level.

phosphorus versus soil phosphorus was much higher than for Smilax alone. The plant nutrients were both correlated with plant moisture using this data set, perhaps reflecting a nearly constant nutrient content on a fresh weight basis.

Several more correlation procedures were conducted with certain seasons deleted in an attempt to achieve the highest correlations. The procedure was run considering only the spring season with Smilax data. The only significant correlation occurred between plant protein and plant phosphorus with a correlation coefficient of 0.85. This coefficient was higher than the coefficient with all seasons included, Figure 11. The lack of other significant correlations may result from the smaller data set.

When the spring and summer seasons were pooled together, deleting winter, using Smilax data only, the number of significant correlations increased from one to three. The correlation between plant phosphorus and soil phosphorus increased from $r = .41$ to $r = .71$ and was significant at the .05 level instead of the .10 level, the level of significance when winter values were included.

When the entire plant data set was run with a deletion of the winter season, the same correlations appeared as when the entire data set was considered. The same procedure was run for the spring season only. The correlation which occurred between plant phosphorus and soil phosphorus was lower than the value received for the entire data set ($r = .73$ versus $r = .87$), Figure 12. These relationships indicate that the correlation between plant phosphorus and soil phosphorus was not due strictly to seasonal variation, but also reflected site differences.

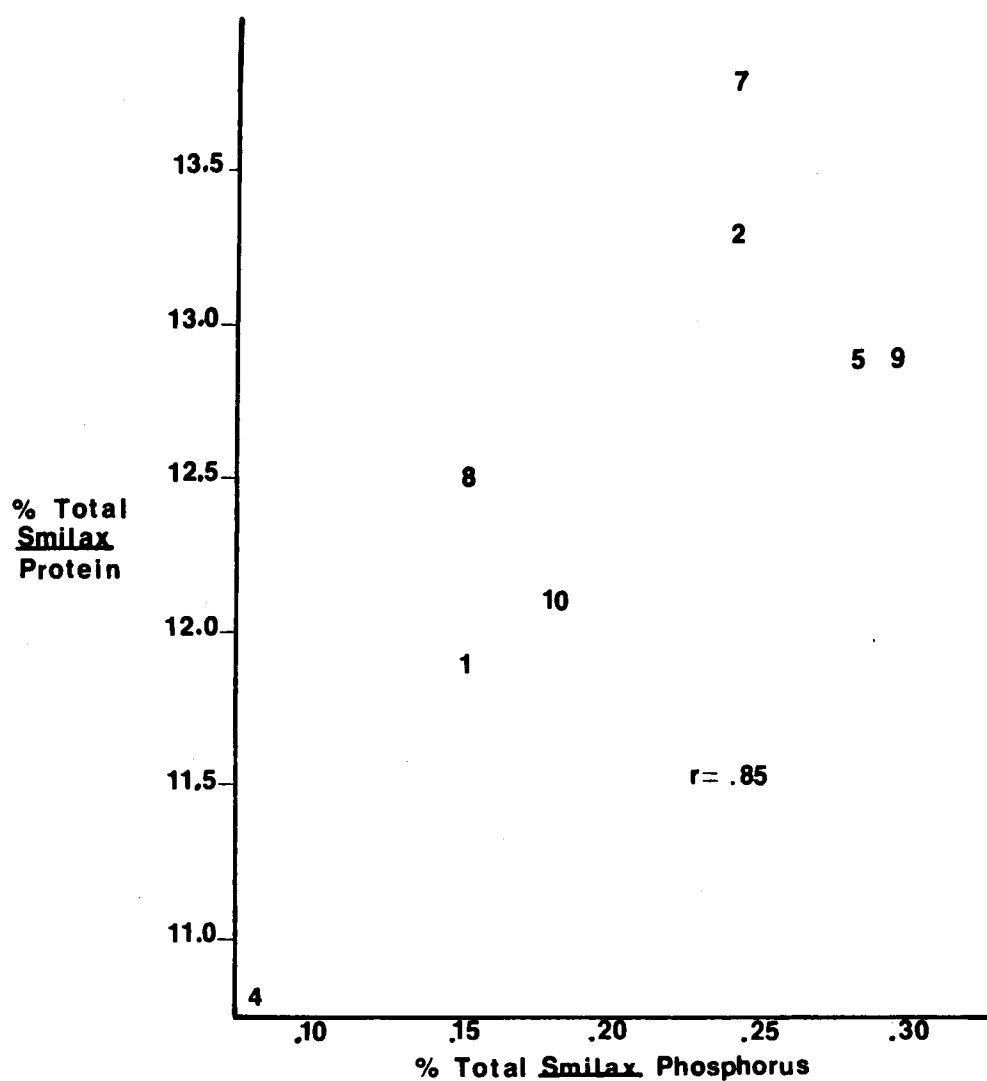


Figure 11. Mean total Smilax protein versus Smilax phosphorus by site for spring only.

Sites are identified by numerals 1-10.

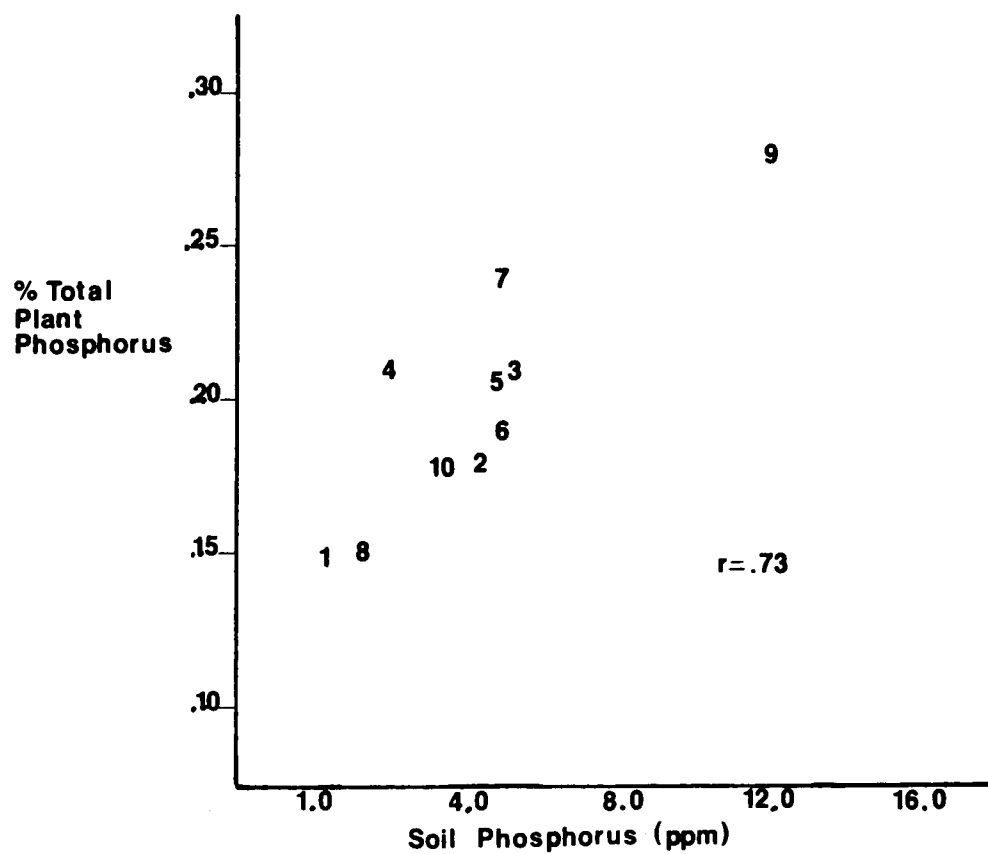


Figure 12. Mean total plant phosphorus versus soil phosphorus by site for spring only.

Sites are identified by numerals 1-10.

All of these procedures with their various changes or reductions in the original pooled data did prove helpful. The original data sets produced nine correlations using Smilax only and sixteen correlations using all plant species. The reduced sets failed to produce many of these correlations, perhaps reflecting the importance of seasonal variation, or the reduction in the data set on correlation coefficients.

CHAPTER IV

DISCUSSION

In the case of soil fertility, I found the following patterns: soil pH was less acidic in the winter months than the summer months, soil phosphorus dropped significantly in the winter months, and soil potassium increased significantly in the winter months from the summer months. One factor directly affecting all soils in this study area is the relationship between soil fertility and the leaching of soil nutrients due to the high rainfall. The pH of the soils averaged between 4.6 and 5.3, strongly to moderately acid (Brady, 1974). Leaching losses of exchangeable bases with subsequent replacement by hydrogen ions on the soil exchange sites produces more acid soils (Allaway, 1957). Many of the soils were derived from limestone parent material. The weathering of limestone by carbonation and organic acid formation by organisms can accentuate the soil acidity problem. There was a general increase in soil pH from the July to December sampling date which may have resulted from the rapid loss of mobile cations from senescent leaves and recently fallen litter (Witkamp, 1971). Also reduced microbial activity in the winter months reduces the amount of organic acids in the soil (Brady, 1974).

The effect of soil acidity upon soil fertility and plant and animal nutrition has been generally neglected. In a study by Hill (1972) on litter size of rabbits as influenced by soil fertility, pH was the most definitive variable found affecting rabbit productivity. Considering five Alabama soil regions, Hill found the more productive

rabbits with greater litter sizes come from regions with higher soil pH values. A positive correlation did exist between litter size and the percentage of soil samples with pH values over 6.0.

Soil pH and soil potassium were positively correlated in all sites, particularly the xeric sites. Moreover the seasonal pattern of increase for soil pH from July to December also occurred for potassium concentrations. Potassium normally is found in large quantities in mineral soils but is lost quite easily from the soil due to leaching. The mineral can be taken up by plants in a quantity three to four times greater than either phosphorus or nitrogen (Brady, 1974). The December increase in soil potassium concentration may be explained in part by the leaching of potassium into the soil from recently fallen leaf litter or senescent leaves. The low July values can be explained by high uptake of potassium in plant tissues and soil leaching.

Soil phosphorus concentrations are probably limiting for optimum plant growth and nutritive quality. Soil phosphorus values averaged five parts per million in all sites (except the island) which is considered too low for optimum plant growth (Francis and Loftus, 1977). Most phosphorus in soils is available for plant uptake only within a pH range of 6.0 to 7.0 (Brady, 1974). Because all pH values were less than this range, phosphorus limitation would be even more severe.

A more subtle factor affecting soil fertility is physiographic position. The difference between the xeric classification and mesic classification is basically the difference between ridges and slopes versus alluvial lowlands. Differences in soil fertility generally occurred between the grouped sites. For example, the large increase in

soil potassium in December occurred more noticeably in the xeric sites. In the mesic sites, potassium was positively correlated with phosphorus. Soil drainage, moisture supplying capacity of the soil, and plant cover are all affected by this factor.

Kramer and Kozlowski (1960) have shown that plants growing on nitrogen-rich soils contain more nitrogen than those growing on nitrogen-deficient soils. Oak and hickories were the dominant canopy trees in the xeric upland sites. Plant species such as red, white, and chestnut oak grow on soils low in nitrogen while bottomland species such as white ash, yellow-poplar, and basswood need soils with a high nitrogen content.

Decomposition of litter has a direct effect upon soil pH and nutrient content. Ovington and Madgwick (1957) found a broad correlation between pH of the soil and that of tree leaves and litter. The oak and hickory species composing the canopy of the upland sites are noted for highly lignified and base poor litter which accentuates soil acidity in those sites. The dominant mesic genera such as sycamore, red maple, and yellow-poplar produce litter with a high base content which does not contribute to soil acidity to as great a degree (Williams and Gray, 1974).

The seasonal variation of soil nutrients and pH is an anomaly which may be controlled by a combination of factors. Many potential decomposer organisms are less active when soil pH is less than 5.0. Consequently nutrients from litter are not recycled as quickly into the soil under these conditions (Williams and Gray, 1974). Potassium is a highly mobile cation which is lost very quickly from litter by leaching and also from leaves of trees in the canopy by precipitation

(Carlisle et al., 1966). Phosphorus values were much higher in the summer months than the winter. Harrison (1979) found this same pattern occurring in woodland sites in England. Available phosphorus is not released to the soil until microbial activity is sufficient and this occurs as soil temperature increases in the spring and summer months.

Plants

Phenological changes accounted for much of the variation in plant nutrient concentrations. Season was the only significant variable affecting plant protein. The growing season (spring) which included the months of March, April, May, and June, showed the highest plant protein and plant phosphorus concentrations. This seasonal pattern was found in other southern browse studies (Blair and Halls, 1967; Blair and Epps, 1967, 1969; Halls, 1973). The maintenance season (summer) which included the months July through October showed a gradual decrease in plant protein and a definite decrease in plant phosphorus. Blair and Epps (1969) found, on southern ranges, growth of many woody species slows and ceases after a relatively short period of time in early summer. The plant tissues begin to accumulate fiber and lignin with a subsequent reduction in growth.

The positive correlation between plant protein and plant phosphorus was due in part because of the plant nutrient relationship with season. But the positive correlations between the plant nutrients and soil phosphorus proves site differences were also affecting the variation. Site differences occurred throughout the year not just in the spring season. Considering the mesic sites including

the island showed the higher plant phosphorus concentrations and the higher soil phosphorus concentrations then the relationship between plant nutritive quality and soil fertility is established.

The only relationship found for plant moisture occurred in three of the four xeric sites. The plants analyzed from three of the sites had the highest plant moisture values. If nutrition had been based on a fresh weight basis instead of a dry weight basis then nutritional values would have been even less for these sites.

The highest concentrations of plant protein occurred in spring with a gradual drop throughout the remaining months. Protein content of leaves and stems are highest in young tissue during spring months prior to maturation (Blair and Epps, 1969). Plant protein varies little after the spring season. The lack of variability in protein concentration throughout the year might be attributed to the movement of nitrogen from senescent tissues back into more active tissues. This same pattern was reported for phosphorus (Kramer and Kozlowski, 1960). This mobile nature of nutrients could explain the positive correlation between stem nutrients.

Deer

The white-tailed deer is a thriving game animal in this region (TWRA Report, 1977). Managed hunts have been permitted in Nathan Bedford Forrest Park since 1975. Consequently, data concerning the present deer population and the use of hunts as a population control measure are inadequate. Browse surveys, mast surveys, and hunt results are utilized to determine population density in the park. Browse survey results from 1977 indicate a 30 percent use of preferred

browse species by deer and only a 5 percent utilization of emergency browse species (TWRA Report, 1977).

The utilization of browse by deer in this area probably varies with time of year. Lay (1964) says variety of food choices by deer is an environmental adaptation. Browse and mast are utilized in range surveys because of their annual availability. In the Southeast, mushrooms, fruits, grasses, mast, and browse all contribute to the available diet of deer. Several studies have shown browse composes deer diets mainly in the spring and summer seasons only, though evergreen species and species such as Smilax and honeysuckle may be utilized annually (Miller and Halls, 1969; Cushwa et al., 1970; Short, 1971, 1975). Thus range management must consider all food choices available for white-tailed deer before determination of the carrying capacity of the deer range.

Implicit in a management definition of carrying capacity is the nutritional quality of the food provided by the habitat is such that natality is not impaired and mortality is not induced by shortages of food or other essentials (Dassman, 1964). The protein quality of the forage in Nathan Bedford Forrest Park probably is adequate except for the winter months. The protein levels obtained, especially from the alluvial mesic areas, meet adequate standards established by Lay (1956) and Murphy and Coates (1966). According to these same sources the phosphorus levels do not meet adequate nutritional levels established for deer. Only one site, the island, met the established minimal phosphorus requirements. The problem could be more severe if population levels were allowed to increase.

The mobility of deer allows a non-restricted foraging habitat. Height of foraging is limited from ground level to approximately 60 centimeters above the ground. To supply browse in this feeding range it is important that the present areas of secondary growth be maintained in the park area. The areas such as the ridge sites provide a limited browse supply because of the reduction in understory plants due to the canopy coverage dominated by oak and hickory. Moreover the plant nutrition was lowest in these sites of low soil fertility. Deer, however, may utilize the mast available from these trees during the autumn months (Short, 1975).

Short (1969, 1973) found that deer from upland habitats in the South are smaller in size than deer taken from bottomlands because upland sites have highly leached and infertile soils, which provide vegetation high in fiber and low in protein. Thus the sites provide inadequate nutrition for deer.

The lowland mesic areas supply more secondary growth habitat along tributaries. The species dominating the secondary growth were dominated by preferred browse species. The increase in soil fertility from periodic alluvial inundation such as on the island and in site 7 has been established. With a greater variety of forage such as mushrooms, ferns, grasses, and browse occurring in the mesic sites, the habitat provides deer with a food supply throughout the year. The plant-soil correlations show these sites would better meet the nutritional needs of a population. Lay (1964) supports the theory that deer on southern ranges must have a habitat managed according to the diverse nature of deer food habits. The management implication

includes a habitat supplying a mixture of plant species, as well as treatments of forest stands with some clearing which will promote the forage variety deer need to assure adequate nutrition.

Management techniques involving controlled hunts help to assure a control on population. If the population is controlled, then the habitat can regenerate its capacity to nutritionally support the energy needs of the present and future populations (Carter and Dow, 1969).

CHAPTER V

CONCLUSIONS

Soil fertility is controlled by many interrelated factors such as parent material, climate, degree of erosion, soil type, age of soil, plant cover, and physiographic position. The alluvial, lowland sites studied were more fertile than the older, highly leached upland sites. These two distinct soil fertility groupings exhibited a direct influence upon the nutritional quality of plants. Browse plants taken from the alluvial sites showed higher values of plant protein and plant phosphorus than browse plants from the less fertile upland sites.

Plant protein and plant phosphorus values were influenced by season. The spring season when plants exhibited increased growth of stems and new leaves showed the highest levels of plant nutrients. As plant tissues matured in the summer months, nutrient levels decreased. Nutrient levels for both protein and phosphorus were lowest during the winter months.

These conclusions are valuable as a predictive tool for management of game populations utilizing browse as part of their diet. Deer population numbers fluctuate around an average value as the carrying capacity of the habitat is approached. Numbers increase above the average during the fawning period and decline during the more stressful winter season. The population numbers may increase above the average during favorable years, causing over-use of the habitat. Over-use or over-grazing will cause over-populations to be reduced

naturally by starvation or disease. It may take several years for recovery of such habitats as well as recovery of deer populations (Robertson, 1969).

In the study area, plant phosphorus was below minimum nutritional levels established for deer. Plant protein was consistent with maintenance standards established for deer populations, except in the winter months. Because of the sub-standard nutritional values of browse plants, the deer population should be controlled. The series of hunts sponsored by the Tennessee Wildlife Resource Agency and Nathan Bedford Forrest State Park are an attempt at population control. "Either Sex" hunts offered during the hunting season can increase the effectiveness of these measures.

Nutritional levels of browse in different habitats suggest that deer should prefer the alluvial, lowland areas throughout the year. Deer would prefer these areas because of the availability of secondary growth for cover, availability of preferred browse species high in nutrients, and availability of water. Deer may utilize the upland sites only in the fall when mast is available. If the population came under stress due to over-population then the upland areas would be utilized all year for secondary and tertiary browse species. This type of habitat could not adequately support the nutritional needs of the same population numbers.

For deer populations to remain in good condition and high numbers, areas such as the alluvial lowlands must be maintained for the nutritional benefit of the population. Continual habitat appraisals must be carried out to evaluate browse, mast, and other

indicators of population stress. These results will determine policy towards usage of deer habitat in a multi-purpose park area such as Nathan Bedford Forrest State Park.

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