MINERAL RELATIONSHIP BETWEEN RANGE FORAGE AND SOILS AT FOUR DIFFERENT LOCATIONS IN OKLAHOMA

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PREFACE

Basic to improvements in range management and animal nutrition is knowledge of the chemical composition of diets consumed by grazing animals. Characterization of animal diets on native ranges is complicated by animal selectivity for certain species and plant parts and by the heterogeneous herbage available for grazing. Grazing animals traditionally obtained their required nutrients from a variety of soil types and plant species as they freely grazed extensive areas of rangelands. Under these conditions, any deficiencies associated with a particular soil type would be eliminated because of averaging across a large variety of soils and vegetative types. However, modern systems of intensive livestock production have imposed restrictions on livestock movement so that animals become more dependent on only one or two soil types. If these soils and plants from these soils are deficient in certain nutrients, animal productivity will be reduced.

Mineral imbalances in domestic livestock can result from an undersupply, oversupply or abnormal dietary proportions of various minerals and trace elements. Imbalances occur across the world under a wide range of husbandry conditions. Serious nutritional abnormalities occur, as imbalances are further conditioned by the presence in the environment of other mineral elements which modify the mineral metabolism of plants or animals. Where nutritional abnormalities are acute, or severe, well-defined clinical signs appear which facilitate detection and simplify correction. But nutritional disorders are often mild or marginal and expressed only as sub-optimal growth, fertility or productivity. Such conditions are difficult to detect, define and prevent with any certainty in advance of specific forms of deficiency or toxicity. Since early diagnosis is the key to preventive treatment, it is important to determine the relative abundance of the essential minerals available to grazing animals from various forages.

The purpose of this study was to survey 1) the relationship between mineral content of soil and mineral content of range forage at different locations in Oklahoma, 2) the influence of soil, season of year and stage of plant maturity on mineral levels in standing forage and, 3) the general soil and vegetation characteristics associated with deficient or excessive mineral contents of plants.

The style and format of this thesis is in accordance with guidelines of the Journal of Range Management to facilitate its publication as a technical article. Permission to present this work in this manner was granted by the Oklahoma State University Graduate College.

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CHAPTER I

INTRODUCTION

Mineral composition of forages is important since growth may be retarded and productivity decreased when animals are fed hay or allowed to graze native grasses containing deficient or excessive concentrations of certain elements. Ruminants must receive all essential dietary nutrients, including mineral elements, in optimum amounts to maximize health, growth and reproduction. Several factors may modify the concentration of minerals in plants. Response to supplementation relies upon an adequate supply of other essential nutrients and satisfactory animal management. Feeding supplemental protein or energy to cattle generally will not increase growth rate if some other essential nutrient is lacking.

Soil-plant Interrelations

The influence of mineral contents of soil on the mineral content of forage plants has been examined by many researchers since early reports by Armstrong (1907), Godden (1926) and Aston (1928). In general, low correlations between available minerals in the soil and their total concentration in plants have been reported. Similar studies by Daniel and Harper (1934) in Oklahoma indicated that soil moisture conditions markedly affected phosphorous (P) content of grass. They found that the P composition of the soil was not closely associated with the P composition of plants.

A negative correlation between P in plants and potassium (K) and calcium (Ca) in soil was noted. This may be explained by the antagonism between K and Ca and the disturbing influence of organic phosphates in soils high in organic matter. However, due to lack of knowledge about soil phenomena as well as plant physiology, the analyses used in the above studies were of little help in interpreting the true soil-plant interrelationships. In the past, it was assumed that the amount of nutrients extracted from the soil by plants was equal to that extracted by conventional chemical methods. This did not account for colloidal phenomena in soil and the dynamics of these minerals. Recent developments in methodology use acids of different concentrations to more realistically determine the concentrations of available nutrients in soil (Hall, et al., 1953; Melsted and Peck, 1967; Lindsay and Norvell, 1973; Braga, 1978; Goncalvez, 1978).

In a pasture-ruminant animal system, a major part of animal's requirements for minerals can be satisfied if plants have satisfactory soil and climate for their proper development to produce high dry matter yields of adequate quality. Under this situation, plants withdraw from soil essential elements in quantities sufficient to satisfy their requirements and in turn satisfying most of the requirements for grazing livestock (Volkweiss, 1978). In a given soil, uptake of elements by plants is quantitatively proportional to mineral concentration in the soil solution except when concentrations exceed absorption capacity of plants or physiologically disturb plants (Black, 1968). The deficiency or toxicity of an element alters absorption of other elements and reduces the growth rate of plants. Certain microorganisms in the soil can also cause such abnormalities (Corey and Schulte, 1972).

For a more adequate discussion of properties of soils which affect the availability of elements to plants, it is necessary to consider both factors which regulate the concentration of elements in the soil solution as well as those factors affecting their translocation in solution to roots (Carson, 1974). The liberation of elements from the solid to the solution phase and later absorption by the plants is dynamic; consequently, some factors, such as precipitation, solubilization, and chemical absorption, affect the uptake of elements or their availability to plants (Ponnemperuma, 1972). The movement of elements to root surfaces from the soil has been discussed by Olsen and Kemper (1968) and Carson (1974). They determined that three mechanisms are responsible for movement of elements to the surface of the roots: (1) root interception, (2) mass flow, and (3) diffusion. Certain adverse soil conditions can decrease the ability of roots to absorb elements in solution as well. Required quantities of nutrient elements are necessary to maintain an adequate proportion in soil solution and to avoid antagonistic effects which can decrease uptake of other elements (Volkweiss, 1978).

When studying soil-plant relationships, many difficulties arise associated with analytical procedures (Braga, 1978). First, it is necessary to determine the concentration of particular elements in the soil immediately adjacent to the roots (Jackson, 1967). Another problem is understanding the complexity of the soil-plant and plant-plant associations. When a single plant species is studied, the difficulties are reduced, but difficulty increases with number and competition of plant species (Bergh, 1969).

The analysis of the soil system uses chemical and biological methods (Braga, 1978). In the first group, evaluation is made through chemical agents that, after activation in the soil, extract a solution containing the element under study. In the second group, plants replace the chemical agent.

The program of soil analysis has motivated investigators to develop a methodology capable of rapidly furnishing information about the chemical characteristics of soils. These techniques use extraction solutions derived from studies which correlated mineral extraction with plant growth responses. Consequently, the extraction solution should measure only the amount of the element in the soil available for plant uptake. Thomas and Peaslee (1973) studied different extraction solutions and recommended some requisites. The extractor should: (1) rapidly dissolve or reabsorb specific minerals from the soil with the same intensity for up to 30 minutes; (2) maintain the organic matter and the flocculated soil clays; (3) avoid precipitation and hydrolysis of the dissolved element; (4) not contain excessive amounts of chemicals that interfere with analytical determinations; (5) produce extracts containing other elements; (6) be simple to prepare, store, and use. Difficulties arise in correlating the soil data with the amounts of the elements found in plants. These problems result from: differences in elemental needs for plant growth; full plant development depends on a perfect balance of elements in the soil; plant requirements fluctuate according to stage of maturity, but total amounts of elements remain the same; and finally, the quantity absorbed depends on the quantity available in soil.

Plant Analysis

Earlier procedures of plant analysis were based on the concept that the concentration of a particular element in the plant reflects of all factors influencing the nutrient concentration at the moment when the plant sample is taken (Ulrich and Hills, 1967). For every element, there is some critical concentration below which growth, yield or quality declines significantly. Critical nutrient concentrations have been determined for 11 essential nutrients in corn, soybean, wheat, alfalfa, and some forages (Walsh and Beaton, 1973). This data involved several thousand plant analyses from different locations. However, critical values have limited value since they designate only the lower end of the minimum required range.

Plants are not homogenous in their nutrient composition. Plant parts differ in mineral content. Therefore, it becomes essential to select a specific plant part from a definite location during a specific growth stage (Aldrich, 1973). Large changes in element concentration occur in the initial stages of growth and after pollination. Essential nutrients usually do not enter the plant at a constant rate; consequently, concentration or dilution occur depending on the extent of the differences between plant growth and element absorption. The mineral concentration obtained from plant analyses can be placed into categories of critical, adequate or toxic for plant growth. Irving (1970) published interpretative data for plant analysis using these categorires. Numerous researchers have pointed out the complexities associated with interpreting plant leaf analysis (Ulrich, 1943; Melsted et al., 1969; Murry et al., 1978). Regression analysis of corn yields using leaf levels of 10 elements as independent variables showed significant relationships, indicating that the critical level of any particular nutrient can vary with leaf levels of other nutrients (Peck et al., 1969).

Shear et al. (1946) indicated that if all other factors were constant, plant growth is a function of two nutrition variables; intensity and balance, as they are reflected in the composition of leaves of plants at a specified stage of growth. Thus, maximum growth and yield occur only upon coincidence of optimum intensity and balance of nutrients. They concluded that leaf composition represents a measure of all environmental factors, both internal and external, which influence nutrient accumulation by the plant. More information is required concerning chemical analysis of native plants giving an integrated value of all factors influencing their composition. Most of the literature available is related to crop plants such as corn, soybean, wheat and others.

Current Status of Mineral Toxicities and Deficiencies in Cattle

Mineral deficiencies and toxicities have been reported throughout the world (Bennetts and Beck, 1942; Andrews, 1965; Lee and Martsan, 1969; De Alba, 1971; Grace, 1972; Thornton, 1974; Fishwick et al., 1977; Underwood, 1977; Conrad and McDowell, 1978; MacPherson et al., 1978). It is difficult to estimate the extent of affected areas. Mineral problems appear to be highly associated with geographical areas. Surveys based on stream-sediment sampling have recently been published (Kubota, 1968; Subcommittee on GERHD, 1974; Thornton, 1974). Maps for 20 trace elements indicate widespread patterns relating the composition of parent material and soil, and contamination from industry to the regional distribution of these elements (Thornton, 1974). Therefore, domestic animals can be exposed to potentially toxic mineral elements from various sources (James et al., 1966; Bremner, 1974; Case, 1974; Buck, 1975; Ammerman et al., 1977). Nutritional imbalances of copper (Cu), manganese (Mn), zinc (Zn) and iron (Fe) were identified in domestic ruminant long before the recognition of such nutritional problems in humans (Mertz, 1977). This is probably because animals are more directly exposed to influences of the geochemical environment. In fact, animals serve as an effective buffer in the food chain by reducing the impact of environmental factors on humans (Subbcommittee on GERHD, 1974).

A highly complicated situation arises when gross imbalance of even a single trace element exists in the geochemical environment of an area. For example, excessive concentrations of molybdenum (Mo) induce a secondary Cu deficiency in animals despite an intake of an adequate amount of Cu under normal situations (Bremner, 1974). Mo deficiency can be counteracted by feeding levels of Cu considered excessive under normal conditions. Mills (1974) reviewed the existing literature concerning antagonistic interactions between individual trace elements. He concluded that elevated concentrations of cadmium (Cd) increased the concentration of Zn in the liver and strongly depressed the concentration of Cu while Zn depressed the retention of Cd and Cu. No conclusions could be drawn about the effects of high dietary concentrations of Cu on Cd. An understanding of the nutritional interactions among mineral elements is necessary to determine levels of such compounds toxic for animals. The complicated and incompletely understood interactions among trace elements and the complex effects of other dietary ingredients on the biological availability of inorganic nutrients creates a wide variety of situations that affect the nutrient status of animals.

Relationships between forage fertilization and animal health have been discussed by Noller and Rykerd (1973); Reid and Jung (1973), and Jung (1977). They concluded that exchangeable soil K levels were increased greatly through fertilization, reducing soil magnesium (Mg) levels such that grass tetany occurred. Effects of seasonal change and fertilization on mineral composition of forages were observed. K in growing forage is usually quite high (1 to 4%); thus, cattle consuming a forage diet would receive adequate K (Karn and Clanton, 1977). Research directed toward determining the adequacy of K in roughage rations fed to cattle is limited (Ward, 1966; Beal and Budz-Olsen, 1968). They determined that ruminants consuming a natural diet would probably never be deficient in K. However, Karn and Clanton (1977) reported low intakes of K by animals grazing winter forage. K toxicities have been very difficult to find.

The amount of nitrogen (N) fertilizer used in the United States increased ninefold between 1959 and 1975. This is still another measure of agricultural intensification to increase yield. N fertilization affects both the Mg concentration in plants and its availability to ruminants (Jung, 1977). In studies with orchardgrass, researchers found higher Mg values associated with N fertilization; however, Mg availability for sheep decreased when N was increased from 60 to 240 kg/ha (Reid et al., 1974).

Ca and P are vitally concerned with several functions and metabolic processes. These elements are very closely related. A deficiency or an over-abundance of one interferes with the proper utilization of the other (Boda and Cole, 1954; Rucker et al., 1968; Borle, 1974; Thompson, 1978). Symptoms of Ca deficiency characterized as rickets and osteomalacia do not occur frequently in cattle because of the long period that calves are on milk and the high roughage diets that are ordinarily fed to pregnant cows. Ca deficiency occurs most frequently in beef animals fed high energy grain rations and is manifested by poor gains, poor digestibility of nutrients, low blood Ca, brittle bones and in some cases, tetany (Nicolaysen et al., 1953; Bartter, 1964; Wills, 1973; Thompson, 1978).

Livestock production in many grazing areas is largely dependent upon the vast tracts of unimproved open grassland which cover 42% the earth's land surface. Subnormal levels of certain minerals may be provided by plants seasonally in many such areas. The performance of unsupplemented animals kept under these conditions may be severely restricted by the extreme variation in nutritive value of the available forage. Both the quantity and quality of available forage closely follows the seasonality of the rainfall pattern. Mineral elements may vary over a relatively wide range of dietary concentrations which may fall outside the requirement range needed by animals (Ammerman et al., 1977).

In general, a complete evaluation of mineral deficiencies and toxicities in livestock requires information on concentration, form and distribution of the element in water, soils and air; geochemical and industrial mineral contributions; uptake and distribution of the element in plants which may be consumed by the animal; and retention and metabolic management of the element by humans following consumption of the products from exposed plants and animals. A considerable body of information on certain of these factors has been reviewed in this chapter. Important gaps in the data remain to be filled for an accurate evaluation of potential mineral deficiencies or toxicities of grazing animals.

CHAPTER II

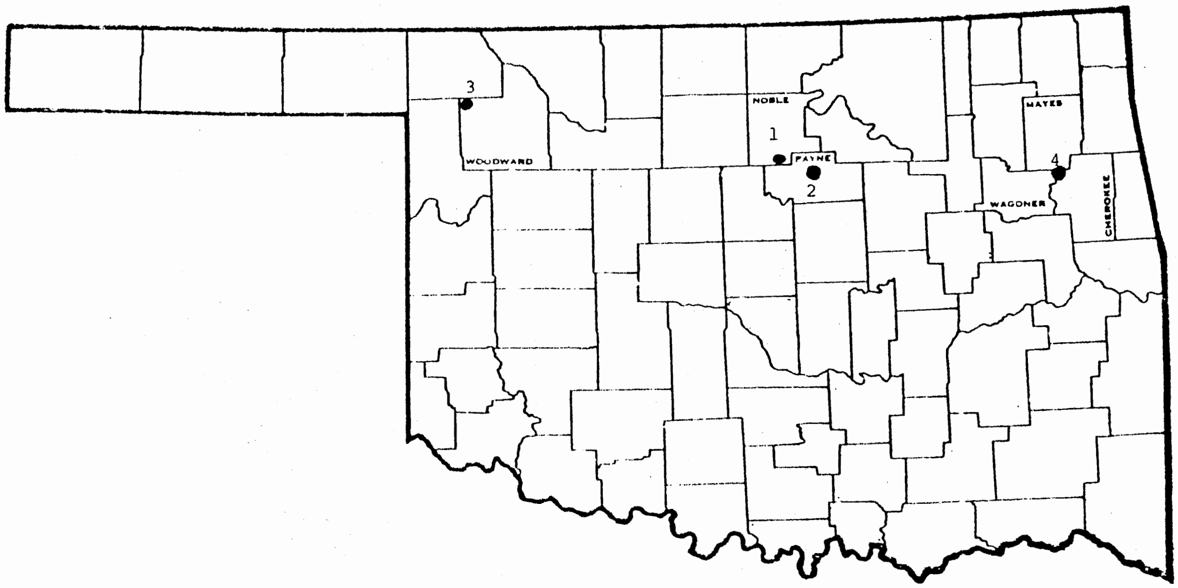
STUDY AREAS

The plant and soil samples used in this study were obtained during earlier research projects on range forage quality conducted at four different locations in the state of Oklahoma (Figure 1). This project is part of the continuing research being conducted by the Range Management section of the Agronomy Department.

Lake Carl Blackwell Experimental Watershed

An experimental watershed is located 16 km northwest of Stillwater Oklahoma and is part of the Lake Carl Blackwell watershed (Lat.38° N, Long. 97°W, elevation 290-318 m) in the NW¼, Section 32, T20N, RIE of the Indian Meridian. The remainder of the watershed is located in the SW¼, Section 32 and the eastern edge of Section 31, Noble County. The climate is continental with hot summers and variable winters. The average absolute minimum temperature is -26°C in January. Mean wind speed varies from 15 km/hr in August to 25 km/hr in March. The mean relative humidity varies from 62% in July and August to 71% in December and January. The average number of frost-free days is 206 from early April to late October. Annual precipitation is 820 mm with about 75% occurring during the growing season.

The topography is rolling with 3 to 5% slopes on the ridges and upland areas. The 57.5 ha watershed has two major drainageways. The



1. Lake Carl Blackwell Experimental Watershed
2. Stillwater
3. Fort Supply
4. Fort Gibson

Figure 1. Study areas at four different locations in the state of Oklahoma.

fall is 26 m over a distance of 1060 m. The area has an eastwardly slope and a triangular shape. The soils are predominantly very-fine or fine-loamy, mixed thermic Vertic Haplustalfs. On a range site basis, the area is composed of 53% loamy prairie, 32% shallow prairie, 7% claypan prairie, 6% shallow savannah and 2% sandy savannah. The watershed is grazed by Oklahoma State University cattle under a year-long grazing, cow-calf management system. It is generally not grazed during the last two weeks of April and during 75 days between August 1 and October 15. The average grazing use for the total watershed was about 70 AUD/ha during the sampling year.

Many of the plant species present on the watershed are those tall-grass prairie climax species; other existing grassland species are common to lower successional stages of the tallgrass prairie. The vegetation and range sites have been described by Powell et al.(1978a).

Stillwater

This area is a 2.25 ha east-facing, loamy upland rangeland located 11 km north of Stillwater, Oklahoma. The elevation is about 280 m above sea level. Stillwater has a continental climate with average absolute maximum temperatures exceeding 40°C from June through September, and average absolute minimum temperatures below -20°C from December through March. Annual precipitation averages 820 $\pm$ 250 mm and its distribution during the 210 day growing season is 21% (April-May), 28% (June-August), 17% (September-October), plus 34% (November-March) in winter.

The topography is rolling with smooth areas confined to broad interstream divides (Gray and Galloway, 1959). The slope of the land varies from 2 to 6% eastward. The soils are predominantely fine-loamy, mixed, thermic Udic Arguistolls. The range site is a good condition, loamy prairie which had been used as a native hay meadow or grazed moderately for more than 10 years. The area is part of a rotational grazing system with introduced pastures; grazing occurs during July to September and during the winter months as necessary. The major species on the study area have been described by Baker (1978).

Fort Supply

This area is 4 ha of sandhill rangeland, 3 km north of Fort Supply, Oklahoma, on the Southern Great Plains Experimental Range (Lat.36° 35'N, Long. 99 35'W at 510 m elevation). The average absolute maximum temperatures during the 177-day growing season exceed 40°C, and average absolute minimum temperatures fall below -20°C from December to March. Annual precipitation averages 570 mm with a seasonal distribution of 24% (April-May), 37% (June-August), 18% (September-October), and 21% (November-March).

The study area is on rolling, stablized sand dunes which originated from a river one km to the south. The soils are mixed, thermic, typic Ustipsamments on the dunes and are mixed, thermic, Psammentic Haplustalfs in the swales. The range site was a good to excellent condition sandy prairie which was continuously grazed at a moderate stocking rate for six years prior to this forage collection.

Major plant species in the study area included Andropogon hallii, Schizachyrium scoparium, Sporobolus cryptandrus, Panicum virgatum, Bouteloua gracilis, Calamovilfa gigantea, Ambrosia psilostachya, Eriogonum annuum, and Artemisia filifolia.

Fort Gibson

The Corps of Engineers Fort Gibson Project (Lat. 36°17' - 35°51'N, Long. 95°22' - 95°7'E) is approximately 60 km east of Tulsa, Oklahoma in Cherokee, Mayes and Wagoner counties. The project land area includes 132 grazing and hay production allotments on 9000ha. The Fort Gibson Project area has a humid, temperate climate with a 210-day growing season (Soil Conservation Service, 1975). The annual precipitation distribution is 320 mm in April and May, 290 mm June through August, 250 mm in September and October, and 140 mm in the five winter months. The average relative hunidity is over 50% throughout the year. Windspeeds range from 18 km/hr in March to 13 km/hr in July and August. The Project is on the eastern edge of the Cherokee Prairies and the northern edge of the Quachita Highlands. Seventy percent of the study sites were in the Cherokee Prairies. The Cherokee Prairies occupy level to gently sloping plains, broken by sharp east-facing escarpments and low bottle-like knobs. Cherokee Prairies developed on sandy and clayey shales and sandstones. Prairie soils are moderately dark to dark-colored, considerably leached and have a moderately acid surface. A representative soil of the Cherokee Prairies and the Loamy Prairie Range sites is Dennis silt loam, fine mixed, thermic Aquic Paleudoll. Thirty percent of the study sites were within the Quachita Highlands land resource area. Soils in the Highlands developed on shales and fill material in the valleys, and sandstones, shales and slates on the ridges. The soils are strongly leached and are light-colored on the surface. A representative soil of the Quachita Highlands and Shallow Savannah range site is Hector fine sandy loam, siliceous, thermic, Lithic cystrochrept.

The climax vegetation of the Cherokee Prairies is dominated by tall grasses intermingled with forbs and woody species. While the climax vegetation of the Quachita Highlands is dominated by an overstory of Quercus sp., the understory is comprised of woody and herbaceous plants. Dominant species on both range sites were described by Powell and Knight (1979).

CHAPTER III

METHODS

Soil and vegetation samples for this study were taken from previously collected specimens at each of the four selected study areas. Sampling procedures, sample preparation, and treatments involved in each situation, have been described elsewhere (Table 1).

All samples were analyzed for nine essential nutrients. N analyses were by macro-Kjeldahl procedure (AOAC, 1970); all other elements (Ca, Mg, K, Na, Mn, Cu, Zn and Fe) were analyzed by atomic absorption spectrophotometer, Perkin-Elmer 403 (Anonymous, 1973).

The soil samples were prepared for chemical determination by using methods of analysis currently in use by the Oklahoma State University Soil Fertility Laboratory (Table 2).

The plant samples were analyzed as shown in Table 3. The method of preparing plant material for analysis, depends on the ultimate analytical technique. Therefore, plant samples were analyzed by wet digestion procedures utilizing a mixture of nitric and perchloric acid. All glassware were washed with a non-phosphate detergent, followed by a distilled water rinse, acid washing in hydrochloric acid solution and three rinses in deionized water.

All data were recorded in the laboratory on forms designed to facilitate immediate key punching of computer cards (Appendix A).

Table 1. Identification of sampling procedures, treatments and sample preparation.

Location		Sampling dates		Treatments	References
		Vegetation	Soil		
Lake Carl Blackwell Experimental Watershed	1977	Mar Jun Aug Dec	Variable	Grazing	Powell et al. (1978a)
Stillwater	1975	Jun Aug Dec	Variable	Atrazine Fertilizer:[1/] NPK	Baker (1978)
	1976	Jun Jul Oct	Variable	Residual Retreated Atrazine Fertilizer:[1/] NPK	
Fort Supply	1976	Jun Aug Dec	Variable	Atrazine Fertilizer: N	Powell et al. (1978b)
Fort Gibson	1978	Variable (Jun-Nov)	Variable	Bottomland Prairie Savannah	Powell and Knight (1979)

[1/] Fertilizer treatments with different combinations of NPK.

Table 2. Analytical procedures used for chemical analysis of soil samples.

Nutrient, ppm	Procedure
N	Macro-Kjeldhal analysis
Ca, Mg, K, Na	1 N ammonium acetate extractant (1:5 soil:solution), measured by atomic absorption.
Fe, Zn, Mn, Cu	.005 DTPA extractant (1:2 soil:solution) measured by atomic absorption.

Table 3. Analytical procedures used for chemical analysis of plant sample.

Nutrient	Procedure
N, %	Macro-Kjeldhal analysis
K, %	Nitroperchloric acid digestion, determined by atomic absorption.
Ca, Mg, %	Nitroperchloric acid digestion, determined by atomic absorption after adding $LaCl_2$.
Fe, Zn, Mn, Cu, ppm	Nitroperchloric acid digestion, determined by atomic absorption.

Data was analyzed through descriptive statistics (mean and standard deviation) by using an IBM 370/158 computer following procedures of the Statistical Analysis System (Barr and Goodnight, 1972; Barr et al., 1976).

Computer comment statements and computer input programs for standing vegetation and soil analysis for each site are shown in Appendices B and C respectively. Statistical analyses of several soil and plant variables were accomplished by a correlation procedures devised for computer as shown in Appendix D.

CHAPTER IV

RESULTS AND DISCUSSION

Lake Carl Blackwell Experimental Watershed

Standing vegetation. The means and standard deviation of mineral concentration as a percentage and/or ppm of dry matter by date for this area are presented in Table 4. Seasonal fluctuations of mineral content in vegetation occurred consistently among all minerals analyzed. Ca values exhibited seasonal variation. Peak concentrations of Ca occurred in July. At this time, a higher percentage of mid and short grasses and late summer forbs occurred. The decline of Ca from September to March was consistent at all sampling locations. K and Mg showed similar patterns of seasonal change with highest concentrations in live vegetation during July and September. K itself exhibited a great degree of change. Minerals not active in plant material may be leached more easily from mature plants than minerals associated with cell wall material. N declined from 0.9% in March to 0.7% in December. This decrease has been associated with plant maturity. N remained relatively constant throughout July and September possibly because of some regrowth and increased content of late summer forbs. When compared among seasons, Zn and Fe were minerals that fluctuated most. Na and Mn were less variable with season. This may be indicative of drought since Na, under wet conditions, tends to change. Lowest values

Table 4. Average ($\bar{x} \pm sd$) mineral content of standing vegetation on four sampling dates. 1977. Lake Carl Blackwell Experimental Watershed area. Oklahoma. (On a dry matter basis)

Date	%					ppm			
	Ca	Mg	K	Na	N	Zn	Mn	Cu	Fe
Mar	.41 ± .10	.07 ± .01	.76 ± .29	.06 ± .02	.89 ± .23	131 ± 29	68 ± 33	13 ± 4	547 ± 161
Jul	.72 ± .14	.16 ± .03	1.01 ± .23	.05 ± .02	.90 ± .28	134 ± 37	60 ± 26	13 ± 4	243 ± 61
Sep	.63 ± .12	.16 ± .03	1.03 ± .19	.05 ± .01	.78 ± .13	113 ± 46	63 ± 31	15 ± 6	341 ± 139
Dec	.54 ± .11	.10 ± .03	.14 ± .07	.04 ± .01	.66 ± .18	72 ± 30	78 ± 37	11 ± 3	455 ± 153
1/	.18	.18	.60	.06	1.47	30	10	4	10

n = 29

1/ Mineral Requirements for a lactating cow (NRC, 1976).

for Na were found in December.

Soil. The mean mineral content from the 29 sampling locations at the Environmental Research Watershed is shown on Table 5. Average N was 1139 ppm with a range of 905 ppm at site number 1 corresponding to a Stoneburg soil series. The highest value was 1576 ppm at site number 24 in a Graniola-like soil. Ca content was very similar in all sampling locations with a peak value in a Graniola soil (1020 ppm). Total Ca in soil was usually less than total K or Mg; however, Ca (829 ppm) was much higher than either K or Mg, 207 and 210 ppm respectively. Average Na content was 29 ppm. Stoneburg soils were 30% higher in Zn than other soil types. Lucien soils tended to be lower (40%) in Mg than the mean of other soils. The lowest value, however, occurred at site number 17 in a Graniola soil type, but this could be due to an unusual dryness of the sample since Mg is particularly sensitive to dehydration. Much less is known about the effect of drying on the extractability and animal availability of the micronutrients (Walsh and Beaton, 1973).

Cu content ranged from 70 ppm in a Stoneburg soil to 208 ppm in a Renfrow soil. According to Buckman and Brady (1960), this range corresponds to a Cu sulfide form. The mean content of Fe was 24 ppm. This concentration seems to be low according to Walsh and Beaton (1973). The activity of Fe in soil however, may be decreased by an increased soil pH value.

Correlation studies provide one basis for selecting potential laboratory tests that would provide the best index of nutrient availability to plants in the soil samples to be tested. Nevertheless, in developing the basic relationships among growth rate, yield, nutrient

Table 5. Average ($\bar{x} \pm sd$) soil mineral content at Lake Carl Blackwell Watershed, 1977. Oklahoma.

Element ppm	Mean		Standard deviation
Ca	829	±	101
Mg	210	±	15
K	207	±	95
Na	29	±	9
N	1139	±	269
Zn	71	±	32
Mn	34	±	10
Cu	111	±	46
Fe	24	±	8

n = 29

supply and concentration in the plant, several mineral elements are usually involved. Correlation coefficients between plant mineral content and soil concentration of various minerals herein were gleaned from all possible combinations between mineral soil and plant analysis. Table 6 shows significant correlations on different dates for the watershed area. K in soil was correlated to several plant nutrients throughout different sampling dates. Na in soil was positively correlated with plant K, Zn and Mn at different times. Cu in plant and K in soil were positively correlated during March and September but negatively correlated in December. Soil Ca tended to be negatively correlated with plant N in March and July N and Ca. Plant Fe was negatively correlated to Fe in soil in March which suggest a poor uptake of Fe by the plant. It is well known that soil moisture influences the release of many elements from soil organic matter (Corey and Shulte, 1972). In July and September samples, several correlations of plant and soil nutrients (K, Zn, N) were obtained.

K in soil was found to be positively correlated to K, Zn, Cu and Fe in plants during the relatively dry late summer and early December periods.

Stillwater Study Area

Standing vegetation. Drought conditions occurred throughout the two years of this study. There was an eight-week summer drought in July and August, 1975 and in 1976, only March precipitation was above average but no single rainfall provided more than 25 mm precipitation. By late summer, available soil water was very low and many plants were under water stress for the rest of the growing season.

Table 6. Correlation coefficients (r) between standing vegetation and soil on sampling dates, 1977. Lake Carl Blackwell, Oklahoma.

Element Plant	Element Soil	Sampling Mar	Sampling Jul	Sampling Sep	Sampling Dec
Na	K	.546[b]	.354[a]	NS	NS
	Cu	.356[a]	NS	NS	NS
	Zn	NS	.357[a]	NS	NS
K	Na	.387[a]	NS	NS	NS
	K	NS	NS	.415[a]	NS
	Cu	NS	NS	NS	.554[b]
N	Ca	-.367[a]	-.404[b]	NS	NS
	Zn	NS	-.393[a]	NS	NS
	Cu	NS	.401[a]	NS	NS
	N	NS	.363[a]	NS	NS
Cu	K	.480[b]	NS	.520[b]	-.380[a]
Zn	Cu	-.488[b]	NS	NS	NS
	Ca	NS	.465[b]	NS	NS
	Mg	NS	.409[a]	NS	NS
	Zn	NS	.431[b]	NS	NS
	K	NS	NS	.365[a]	.358[a]
	Na	NS	NS	NS	.361[a]
Fe	Fe	-.423	NS	NS	NS
	K	NS	NS	.550[b]	NS
Mn	Ca	NS	-.367[a]	NS	NS
	Na	NS	NS	NS	.355[a]

[a,b]Statistically significant at $P<.05$ and $P<.01$ respectively.

First Year Treatment Responses. Ca yield in June's standing vegetation were nearly equal in all treatment areas (Table 7). The Ca content in NPK treated areas, however, was high during August. In December 1975, all treatments contained very similar Ca values except in areas treated with N + atrazine. This decrease was primarily due to a reduction of forbs, which are normally high in Ca. When nutrients such as NPK are added, it is difficult to predict whether or not the concentration of a given element in the plant will increase, remain unchanged or be decreased. Mg tends to decrease with such NPK additions, especially during drought condition (Walsh and Beaton, 1973). This finding was observed during December; meanwhile in other months, Mg values remained nearly the same. Applications of fertilizer NPK reduced the effects of the moisture stress and K levels were kept relatively high as compared with nontreated areas. Na responses to atrazine and fertilizer were quite variable at all sampling dates during the first year of treatment, although fertilization tended to favor Na uptake by plants. N yield in June ranged from 1.43% to 2.08%. The N content was greater on NP and NPK areas than on N and untreated areas. This was probably due to grass production on these areas being nearly equal, but NP and NPK treatments produced 400 kg/ha more forbs (Baker, 1978). December values for N were lowest. N applications increased Zn content during early winter. This finding is consistent with that reported by Boawn (1971). Mn remained unaffected by treatments during the first year. Because of possible available moisture, Cu tended to increase on treated area between June and August. Fe content was higher during winter for all treated and untreated areas.

Table 7. Average ($\bar{x}\pm sd$) mineral content of standing vegetation by treatments on sampling dates 1975. Stillwater, Oklahoma. (On a dry matter basis)

Treatment[1/]	Element	Sampling Jun	Aug	Dec	2/
1	Ca, %	.71 ± .02	.46 ± .09	.72 ± .04	.18
2		.88 ± .36	.82 ± .05	.94 ± .03	
3		.53 ± .01	.61 ± .07	.93 ± .06	
4		.73 ± .06	.60 ± .04	.91 ± .03	
5		.75 ± .02	.77 ± .05	.94 ± .04	
6		.54 ± .06	1.16 ± .04	.93 ± .05	
7		.53 ± .03	.64 ± .10	.94 ± .04	
1	Mg, %	.21 ± .01	.25 ± .02	.21 ± .01	.18
2		.19 ± .04	.30 ± .01	.14 ± .00	
3		.19 ± .01	.25 ± .03	.24 ± .02	
4		.21 ± .01	.23 ± .01	.14 ± .00	
5		.21 ± .02	.23 ± .01	.12 ± .02	
6		.22 ± .02	.24 ± .02	.13 ± .01	
7		.19 ± .01	.27 ± .01	.14 ± .01	
1	K, %	.95 ± .13	.88 ± .10	.15 ± .01	.60
2		1.10 ± .01	.99 ± .09	.21 ± .03	
3		.75 ± .09	1.02 ± .09	.20 ± .03	
4		.75 ± .01	.96 ± .01	.13 ± .01	
5		.53 ± .15	.99 ± .08	.24 ± .01	
6		1.11 ± .07	.97 ± .02	.22 ± .01	
7		.74 ± .03	.84 ± .05	.23 ± .02	
1	Na, %	.003± .000	.009± .001	.026± .002	.06
2		.011± .001	.011± .001	.006± .001	
3		.013± .003	.014± .001	.016± .001	
4		.010± .001	.008± .001	.005± .000	
5		.010± .001	.022± .002	.013± .001	
6		.023± .002	.011± .001	.016± .004	
7		.012± .002	.011± .002	.026± .003	
1	N, %	1.43 ± .11	1.96 ± .60	.81 ± .05	1.47
2		1.78 ± .31	1.52 ± .36	.94 ± .06	
3		1.65 ± .25	1.59 ± .20	1.01 ± .19	
4		1.55 ± .22	1.20 ± .26	.85 ± .05	
5		2.08 ± .28	1.17 ± .10	.88 ± .09	
6		1.78 ± .22	1.28 ± .20	.84 ± .10	
7		1.47 ± .04	1.06 ± .12	.91 ± .07	

Table 7. (Continued)

Treatment[1/]	Element	Sampling Jun	Aug	Dec	[2/]
1	Zn, ppm	214 ± 15	113 ± 10	375 ± 25	30
2		262 ± 41	84 ± 1	416 ± 28	
3		140 ± 52	150 ± 43	425 ± 25	
4		228 ± 19	213 ± 12	279 ± 15	
5		260 ± 35	228 ± 30	400 ± 25	
6		198 ± 19	290 ± 13	403 ± 20	
7		176 ± 22	253 ± 25	401 ± 41	
1	Mn, ppm	119 ± 19	144 ± 16	144 ± 6	10
2		115 ± 14	115 ± 8	115 ± 13	
3		103 ± 12	121 ± 1	114 ± 5	
4		124 ± 13	131 ± 17	162 ± 13	
5		124 ± 6	134 ± 11	150 ± 20	
6		125 ± 6	143 ± 7	150 ± 25	
7		112 ± 12	148 ± 11	115 ± 0	
1	Cu, ppm	19 ± 1	27 ± 1	12 ± 2	4
2		18 ± 1	23 ± 5	10 ± 2	
3		18 ± 1	19 ± 1	16 ± 1	
4		20 ± 1	26 ± 1	19 ± 2	
5		23 ± 2	17 ± 2	11 ± 1	
6		22 ± 2	19 ± 1	11 ± 1	
7		18 ± 3	23 ± 2	12 ± 2	
1	Fe, ppm	216 ± 28	133 ± 15	216 ± 28	10
2		150 ± 25	118 ± 16	208 ± 14	
3		100 ± 00	111 ± 20	241 ± 28	
4		150 ± 11	156 ± 00	233 ± 28	
5		158 ± 14	140 ± 25	176 ± 25	
6		158 ± 14	141 ± 14	205 ± 8	
7		216 ± 28	141 ± 14	195 ± 18	

n=3

1/ 1. A63N
2. A63NPK
3. A63NP
4. CONTROL
5. 6N
6. 6NPK
7. 6NP

A = Atrazine
6 = June application
3 = 3.4 kg/ha Atrazine
N = 67 kg/ha N
P = 45 kg/ha P_2O_5
K = 45 kg/ha K_2O

2/ Mineral requirements for a lactating cow (NRC, 1976)

Second Year Treatment Responses. The greatest response on areas receiving the same treatments in two successive years was the very large increase in tallgrass on atrazine plus fertilizer areas (Baker and Powell, 1978). The mineral response to treatments is shown in Table 8. Retreated area vegetation was consistently higher in Ca and Mg content as compared to that from residual areas except during late fall when a decline of both minerals occurred as a consequence of plant water stress. Second year herbicide and fertilizer treatments created differences in June to October K content in standing vegetation except for NP treatment in July. Available moisture from rainfall in July produced high levels of K in retreated areas. Na however, remained constant because a possible lowered content in treated areas. N yields were greater on all areas retreated with fertilizer than on residual areas in 1976. As moisture stress increased, the concentration of N decreased and although application of fertilizer reduced the effects of drought, concentrations were still very low. Zn, Mn, Cu and Fe values were more affected by seasonal changes than by atrazine and NPK fertilization. This is in agreement with Viets (1962) who established that availability of micronutrient cations is particularly sensitive to changes in the soil environment. Part of the sensitivity to these changes is related directly to the performance of the root system in exploring the soil for these nonmobile elements.

Soil. The average soil mineral content for 1975 and 1976 are presented in Table 9. The total exchangeable Ca was higher than either K or Mg, especially in retreated areas. This effect was noticed in standing vegetation which tend to accumulate more Ca. It is known that exchangeable Mg is higher than exchangeable K in soil; however, the up-

Table 8. Average ($\bar{x}$±sd) mineral content of standing vegetation by treatments from residual and retreated areas on sampling dates 1976. Stillwater, Oklahoma. (On a dry matter basis)

Treatment[1/]	Element	Residual Sampling Jun	Residual Sampling Jul	Residual Sampling Oct	Retreated Sampling Jun	Retreated Sampling Jul	Retreated Sampling Oct	2/
1	Ca, %	.49 ± .03	.26 ± .02	.70 ± .04	.54 ± .04	.37 ± .04	.45 ± .04	.18
2		.37 ± .02	.37 ± .03	.45 ± .05	.43 ± .02	.35 ± .05	.43 ± .05	
3		.40 ± .09	.76 ± .09	.74 ± .04	.52 ± .03	.42 ± .03	.57 ± .03	
4		.54 ± .09	.64 ± .04	.92 ± .04	.77 ± .03	.50 ± .06	.59 ± .04	
5		.57 ± .03	.59 ± .06	.54 ± .02	.65 ± .06	.71 ± .06	.54 ± .04	
6		.74 ± .04	.65 ± .05	.80 ± .01	.69 ± .07	.42 ± .07	.64 ± .04	
7		.63 ± .05	.65 ± .05	.67 ± .02	.60 ± .01	.58 ± .08	.60 ± .01	
1	Mg, %	.27 ± .02	.24 ± .02	.25 ± .01	.25 ± .01	.22 ± .03	.24 ± .01	.18
2		.23 ± .03	.31 ± .03	.21 ± .03	.29 ± .03	.24 ± .05	.23 ± .03	
3		.31 ± .03	.25 ± .03	.27 ± .03	.27 ± .03	.40 ± .05	.26 ± .02	
4		.21 ± .02	.24 ± .01	.16 ± .01	.27 ± .03	.22 ± .03	.17 ± .02	
5		.29 ± .02	.18 ± .01	.26 ± .01	.24 ± .03	.20 ± .00	.20 ± .01	
6		.34 ± .04	.34 ± .02	.21 ± .02	.34 ± .05	.25 ± .05	.24 ± .03	
7		.24 ± .05	.39 ± .03	.28 ± .03	.23 ± .04	.38 ± .01	.23 ± .04	
1	K, %	.71 ± .02	.83 ± .05	.20 ± .01	.87 ± .09	.99 ± .05	.22 ± .02	.60
2		.74 ± .05	.99 ± .10	.25 ± .03	.71 ± .05	1.12 ± .03	.20 ± .03	
3		.73 ± .02	.87 ± .03	.21 ± .01	.90 ± .10	.93 ± .06	.24 ± .04	
4		.34 ± .04	.99 ± .08	.15 ± .02	1.04 ± .08	.90 ± .10	.26 ± .01	
5		.96 ± .07	.97 ± .11	.24 ± .03	.90 ± .09	1.05 ± .05	.25 ± .04	
6		.94 ± .10	1.00 ± .10	.30 ± .04	.95 ± .12	.96 ± .12	.35 ± .04	
7		.94 ± .07	1.01 ± .07	.22 ± .04	.76 ± .03	.84 ± .04	.26 ± .04	
1	Na, %	.015 ± .004	.034 ± .002	.011 ± .001	.063 ± .001	.016 ± .003	.011 ± .001	.06
2		.018 ± .003	.019 ± .001	.012 ± .000	.025 ± .004	.019 ± .001	.008 ± .000	
3		.015 ± .001	.074 ± .010	.012 ± .000	.020 ± .002	.015 ± .004	.014 ± .003	
4		.015 ± .001	.020 ± .004	.011 ± .001	.033 ± .004	.024 ± .008	.016 ± .004	
5		.027 ± .006	.045 ± .004	.015 ± .005	.016 ± .001	.018 ± .001	.008 ± .001	
6		.015 ± .004	.035 ± .005	.013 ± .002	.020 ± .005	.022 ± .005	.012 ± .003	
7		.017 ± .003	.030 ± .007	.011 ± .001	.019 ± .001	.020 ± .000	.011 ± .003	
1	N, %	1.46 ± .21	.82 ± .02	.52 ± .09	1.54 ± .05	.94 ± .13	.73 ± .12	1.47
2		1.42 ± .30	.75 ± .14	.78 ± .08	2.07 ± .30	1.18 ± .21	.87 ± .08	
3		1.28 ± .16	.74 ± .16	.68 ± .11	1.97 ± .26	.95 ± .07	1.00 ± .22	
4		1.70 ± .27	.75 ± .06	.69 ± .19	1.45 ± .12	.81 ± .06	.79 ± .28	
5		1.55 ± .28	.82 ± .11	.66 ± .09	2.06 ± .33	1.17 ± .19	.88 ± .10	
6		1.35 ± .21	.88 ± .20	.77 ± .13	2.59 ± .28	1.14 ± .11	.75 ± .07	
7		1.48 ± .23	.68 ± .08	.59 ± .12	1.85 ± .16	.96 ± .08	.81 ± .21	

Table 8. (Continued)

Treatment[1/]	Element	Residual Sampling			Retreated Sampling			[2/]
		Jun	Jul	Oct	Jun	Jul	Oct	
1	Zn, ppm	139 ± 52	174 ± 21	241 ± 35	333 ± 59	160 ± 34	127 ± 5	30
2		191 ± 7	246 ± 50	211 ± 11	155 ± 8	184 ± 32	160 ± 11	
3		303 ± 57	366 ± 57	340 ± 15	173 ± 41	188 ± 29	337 ± 25	
4		162 ± 33	243 ± 39	174 ± 12	325 ± 22	308 ± 96	270 ± 22	
5		152 ± 36	327 ± 35	150 ± 11	299 ± 3	283 ± 28	127 ± 30	
6		279 ± 25	312 ± 33	270 ± 28	166 ± 76	148 ± 44	320 ± 34	
7		245 ± 43	313 ± 48	185 ± 32	345 ± 80	137 ± 54	387 ± 32	
1	Mn, ppm	77 ± 2	64 ± 11	73 ± 5	62 ± 8	99 ± 9	78 ± 3	10
2		63 ± 3	86 ± 15	113 ± 13	102 ± 3	107 ± 11	119 ± 13	
3		63 ± 4	70 ± 4	91 ± 1	70 ± 9	101 ± 16	104 ± 6	
4		123 ± 6	87 ± 4	130 ± 8	87 ± 12	100 ± 5	112 ± 2	
5		108 ± 10	71 ± 5	120 ± 6	141 ± 9	129 ± 24	115 ± 4	
6		100 ± 6	115 ± 16	145 ± 10	108 ± 14	129 ± 16	127 ± 24	
7		90 ± 1	99 ± 11	124 ± 22	127 ± 4	105 ± 18	126 ± 2	
1	Cu, ppm	13 ± 1	14 ± 2	10 ± 2	11 ± 1	10 ± 0	8 ± 1	4
2		10 ± 1	12 ± 2	10 ± 0	10 ± 1	13 ± 3	8 ± 0	
3		12 ± 2	18 ± 2	12 ± 2	9 ± 1	10 ± 2	10 ± 1	
4		12 ± 2	10 ± 1	12 ± 2	12 ± 0	10 ± 2	8 ± 0	
5		10 ± 1	12 ± 2	12 ± 2	11 ± 1	16 ± 1	8 ± 1	
6		9 ± 1	15 ± 2	9 ± 2	10 ± 1	10 ± 2	8 ± 0	
7		13 ± 1	11 ± 1	10 ± 2	10 ± 2	9 ± 1	10 ± 2	
1	Fe, ppm	183 ± 14	100 ± 0	150 ± 25	175 ± 25	141 ± 38	175 ± 25	10
2		166 ± 38	166 ± 38	200 ± 25	150 ± 38	125 ± 25	325 ± 25	
3		191 ± 14	191 ± 14	175 ± 25	141 ± 38	133 ± 38	175 ± 25	
4		150 ± 50	141 ± 14	183 ± 22	158 ± 14	141 ± 14	158 ± 38	
5		175 ± 25	141 ± 28	183 ± 38	166 ± 14	191 ± 14	200 ± 25	
6		141 ± 50	191 ± 14	150 ± 25	175 ± 25	108 ± 38	133 ± 38	
7		125 ± 25	158 ± 38	158 ± 14	191 ± 38	125 ± 25	191 ± 14	

n = 3

1/
1. A63N
2. A63NPK
3. A63NP
4. CONTROL
5. 6N
6. 6NPK
7. 6NP

A = Atrazine
6 = June application
3 = 3.4 kg/ha Atrazine
N = 67 kg/ha N
P = 45 kg/ha P_2O_5
K = 45 kg/ha K_2O

2/ Mineral requirements for a lactating cow (NRC, 1976)

Table 9. Average ($\bar{x} \pm sd$) soil mineral content by treatments in 1975 and from residual and retreated areas in 1976. Stillwater, Oklahoma.

Treatment[1/]	Element ppm	1975 Treated	1976 Residual	1976 Retreated
1	Ca	884 ± 36	955 ± 112	1002 ± 96
2		873 ± 12	989 ± 72	1124 ± 135
3		839 ± 61	937 ± 76	962 ± 41
4		862 ± 27	1073 ± 134	1042 ± 132
5		938 ± 53	974 ± 83	902 ± 182
6		964 ± 93	1089 ± 243	979 ± 181
7		843 ± 49	1077 ± 274	971 ± 123
1	Mg	371 ± 44	478 ± 100	464 ± 58
2		381 ± 22	440 ± 27	519 ± 75
3		363 ± 30	441 ± 24	444 ± 12
4		418 ± 6	484 ± 32	479 ± 19
5		398 ± 14	464 ± 43	437 ± 36
6		449 ± 87	507 ± 105	447 ± 96
7		421 ± 80	505 ± 102	459 ± 73
1	K	170 ± 8	208 ± 14	225 ± 43
2		166 ± 28	266 ± 14	303 ± 5
3		191 ± 14	225 ± 25	216 ± 14
4		158 ± 14	183 ± 14	256 ± 5
5		183 ± 14	276 ± 2	233 ± 28
6		166 ± 14	291 ± 14	266 ± 14
7		166 ± 28	241 ± 28	241 ± 38
1	Na	24 ± 2	27 ± 1	28 ± 2
2		24 ± 3	22 ± 1	35 ± 3
3		26 ± 3	23 ± 1	24 ± 2
4		23 ± 2	25 ± 1	22 ± 1
5		23 ± 1	22 ± 1	23 ± 2
6		26 ± 5	34 ± 2	24 ± 1
7		26 ± 2	58 ± 2	24 ± 2
1	Zn	115 ± 4	258 ± 38	466 ± 38
2		86 ± 8	318 ± 16	366 ± 52
3		114 ± 3	300 ± 9	300 ± 10
4		109 ± 9	233 ± 7	100 ± 10
5		82 ± 7	358 ± 38	558 ± 62
6		118 ± 3	225 ± 43	288 ± 20
7		105 ± 6	333 ± 14	308 ± 28

Table 9. (Continued)

Treatment[1/]	Element ppm	1975	1976	
		Treated	Residual	Retreated
1	Mn	13 ± 1	18 ± 4	12 ± 5
2		12 ± 1	19 ± 6	13 ± 4
3		9 ± 2	17 ± 1	11 ± 2
4		17 ± 2	11 ± 1	14 ± 1
5		8 ± 1	10 ± 2	5 ± 2
6		11 ± 5	10 ± 4	13 ± 6
7		9 ± 1	10 ± 2	14 ± 2
1	Cu	62 ± 2	52 ± 4	64 ± 6
2		52 ± 4	42 ± 2	52 ± 4
3		46 ± 1	64 ± 1	51 ± 4
4		62 ± 4	69 ±12	133 ±57
5		54 ± 4	61 ± 1	56 ± 5
6		62 ± 4	52 ± 1	42 ± 6
7		49 ± 2	67 ± 4	68 ± 5
1	Fe	10 ± 1	30 ± 5	30 ± 5
2		20 ± 1	20 ± 1	24 ± 6
3		10 ± 1	28 ± 1	27 ± 2
4		12 ± 1	27 ± 2	25 ± 1
5		10 ± 2	27 ± 8	23 ± 5
6		10 ± 1	28 ± 9	25 ± 9
7		9 ± 2	25 ± 5	21 ± 1

n = 3

1/

1. A63N
2. A63NPK
3. A63NP
4. CONTROL
5. 6N
6. 6NPK
7. 6NP

A = Atrazine
6 = June application
3 = 3.4 kg/ha Atrazine
N = 67 kg/ha N
P = 45 kg/ha P_2O_5
K = 45 kg/ha K_2O

take of K by plants was higher than Mg. Soil pH has been reported to have diverse effects upon availability of soil Mg. Salmon (1964) found that soil pH and exchangeable K accounted for much of the variation in Mg uptake by plants. At constant K levels, a fourfold increase of soil Mg was needed to double Mg levels in grass.

Na levels in soil samples during 1975 were very similar among treatments. The residual effect in 1976 and retreated application of fertilizer did not affect its concentration. However, Na content in plant was increased during the month of July on residual areas probably because it replaced K to a slightly extent. Zn content was increased on most fertilized areas in 1976. N application has been associated with Zn availability because of its effect on pH. All retreated areas in 1976 were higher in Zn content than residual and control areas. Plant responses however, seemed to be only slightly affected. The Mn responses to NPK treatments were inconsistent. Higher values were related to atrazine application on residual areas. Standing vegetation on the other hand, tended to take up more Mn from soils under N, NP and NPK fertilization treatments without atrazine.

Cu content in soil samples was similar among treatments during 1975 and 1976. There were no apparent differences in concentration. after retreatment. When compared with plant responses a change in seasonal pattern was observed. This may be an effect of the sensitivity of different plant species to available supply of Cu. Fe seemed to be higher in soil samples from 1976 than in 1975 soil collections. Apparently differences in Fe content were not due to treatment effect. Differences on Fe content in standing vegetation were due to plant species included in the sample. Plants vary widely in the amount which they concentrate. Not only the quantity but also the form has considerable effect upon Fe uptake by plants.

Fort Supply Study Area

Standing vegetation. Average mineral content of standing vegetation is shown in Table 10. In June, 1976, the average Ca content for Andropogon hallii (ANHA) was higher in the control area followed by atrazine treatments. Higher Ca content for August and December samples occurred in those plants treated with both N and atrazine. Mg content increased consistently on all treated areas during year, while K decreased in June on N treated plots. K content in all treatments decreased slightly between July and August and decreased greatly on all areas by December. Concentration of Na in plant tissues was highly variable among treatments during June. August and December values for Na were very consistent without apparent differences among treatments. Average N content was generally greater on atrazine plus N areas than on areas treated with N alone. The increased N content due to treatments dissipated by December and the small differences in N concentration in dormant plants were not significant. Zn values on treated areas were generally higher on treated areas except for the N only treatment in July. The greatest increase occurred in December on areas treated with atrazine plus N and N only. Mn content increased on all treatments between June and August except for the control area. In December the average Mn content on atrazine treated areas decreased while all other treatments including control, tended to increase. Although, Cu content in ANHA was variable across seasons and differences between treatments were much different, Cu levels were generally

Table 10. Average ($\bar{x} \pm sd$) mineral content of standing vegetation by treatments on sampling dates, 1976. Fort Supply, Oklahoma. (On a dry matter basis)

TMT 1/	Element	Sampling date Jun	Aug	Dec	2/
1	Ca, %	.53 ± .01	.53 ± .04	.63 ± .04	.18
2		.57 ± .01	.83 ± .01	.61 ± .03	
3		.60 ± .02	.60 ± .01	.47 ± .02	
4		.44 ± .09	.45 ± .09	.71 ± .03	
1	Mg, %	.27 ± .01	.26 ± .01	.19 ± .04	.18
2		.34 ± .02	.36 ± .02	.16 ± .01	
3		.24 ± .01	.22 ± .00	.13 ± .01	
4		.23 ± .02	.29 ± .02	.17 ± .01	
1	K, %	1.31 ± .04	.88 ± .03	.15 ± .01	.60
2		1.29 ± .01	1.03 ± .11	.17 ± .00	
3		1.05 ± .11	.76 ± .02	.19 ± .04	
4		.87 ± .08	.84 ± .08	.21 ± .03	
1	Na, %	.007± .001	.014± .003	.011± .001	.06
2		.019± .003	.012± .001	.015± .001	
3		.015± .006	.014± .001	.015± .004	
4		.033± .002	.014± .001	.018± .001	
1	N, %	1.51 ± .10	1.10 ± .24	1.03 ± .38	1.47
2		1.49 ± .13	1.20 ± .07	.91 ± .10	
3		1.36 ± .15	1.02 ± .15	.71 ± .24	
4		1.30 ± .21	1.04 ± .26	.88 ± .20	
1	Zn, ppm	87 ± 3	55 ± 7	101 ± 1	30
2		79 ± 5	97 ± 6	78 ± 4	
3		76 ± 12	64 ± 5	59 ± 5	
4		106 ± 4	62 ± 4	106 ± 7	
1	Mn, ppm	28 ± 3	32 ± 2	36 ± 2	10
2		25 ± 2	46 ± 3	28 ± 1	
3		28 ± 3	21 ± 2	29 ± 1	
4		25 ± 2	28 ± 2	31 ± 4	
1	Cu, ppm	15 ± 1	16 ± 1	17 ± 1	4
2		22 ± 1	21 ± 1	18 ± 1	
3		22 ± 2	19 ± 2	20 ± 0	
4		19 ± 1	20 ± 1	23 ± 1	

Table 10. (Continued)

TMT 1/	Element	Sampling date Jun	Aug	Dec	2/
1	Fe, ppm	10 ± 0	20 ± 1	31 ± 2	10
2		15 ± 1	21 ± 1	33 ± 0	
3		15 ± 1	33 ± 1	36 ± 1	
4		11 ± 1	16 ± 1	30 ± 1	

n = 3

1/
1. A63N — A = Atrazine
2. A63 — 6 = June application
3. CONTROL — 3 = 3.4 kg/ha Atrazine
4. 6N — N = 45 kg/ha N

2/ Mineral requirements for a lactating cow (NRC, 1976).

lower on atrazine plus N treatments and higher on the control and atrazine treatments. Compared to that on treated areas, Fe content was slightly greater on untreated areas at all sampling dates. Fe levels in plant tissue were about equal on all other treatments.

Soil. Generally, soil mineral values were variable in response to treatments, but mineral content on atrazine treated areas were lower for all elements except Cu (Table 11). Average Ca and Mg content did not differ. Compared to atrazine plus N and N treatments, control areas were 10% higher in K and Na content, and over 30% greater than atrazine treated areas. Zn average was about the same on control and treated areas. Mn and Cu showed a higher concentration in soil treated with N alone. This observation has been previously reported by Walsh and Beaton (1973). The availability of these micronutrient cations are particularly sensitive to changes in the soil environment since Mn and Cu are highly pH dependent. Fe values were similar in all treatments including control. However, the concentration of the element in these soils was low and this was reflected in the Fe content of plant tissue.

Fort Gibson Study Area

Standing vegetation. Means and standard deviations for mineral content of standing vegetation are presented in Table 12. Ca content was similar in prairie and savannah vegetation types, but higher than bottomland values. The Mg content ranged from .26% in savannah vegetation to .31% in prairie vegetation. K and Na content were about equal on bottomland and on prairie, and over 20% lower in savannah vegetation. N content was similar in prairie and savannah standing vegetation, but

Table 11. Average ($\bar{x} \pm sd$) soil mineral content by treatments at Fort Supply, Oklahoma. 1976.

Treatment 1/	Element	Mean	Standard Deviation
1	Ca	1126	± 166
2		1118	± 168
3		1119	± 145
4		1164	± 122
1	Mg	105	± 18
2		89	± 7
3		100	± 27
4		114	± 13
1	K	431	± 37
2		343	± 51
3		487	± 75
4		412	± 43
1	Na	17	± 1
2		16	± 1
3		21	± 2
4		18	± 1
1	Zn	65	± 19
2		42	± 15
3		62	± 12
4		65	± 19
1	Mn	15	± 2
2		13	± 2
3		16	± 1
4		20	± 7
1	Cu	30	± 1
2		29	± 2
3		27	± 3
4		34	± 2
1	Fe	5	± 1
2		4	± 1
3		6	± 1
4		6	± 1

n = 4

1/ 1. A63N
2. A63
3. CONTROL
4. 6N

A = Atrazine
6 = June application
3 = 3.4 kg/ha Atrazine
N = 45 kg/ha N

Table 12. Average ($\bar{x} \pm sd$) mineral content of standing vegetation on three different vegetation types at Fort Gibson, Oklahoma. 1978. (On a dry matter basis)

Element	Bottomland n = 10	Prairie n = 10	Savannah n = 8	1/
Ca, %	0.68 ± .28	0.80 ± .21	0.80 ± .20	.18
Mg, %	0.29 ± .09	0.31 ± .08	0.26 ± .08	.18
K, %	0.78 ± .28	0.76 ± .20	0.60 ± .33	.60
Na, %	0.02 ± .001	0.019± .001	0.014± .003	.06
N, %	1.69 ± .09	0.92 ± .08	0.95 ± .07	1.47
Zn, ppm	119 ± 30	103 ± 45	123 ± 29	30
Mn, ppm	90 ± 30	122 ± 43	108 ± 42	10
Cu, ppm	10 ± 2	11 ± 4	13 ± 3	4
Fe, ppm	262 ±117	190 ± 69	244 ± 92	10

1/ Mineral requirements for a lactating cow (NRC, 1976).

much lower than bottomland (.92, .95 and 1.69% respectivelly). Zn from prairie vegetation averaged only 103 ppm as compared to bottomland and savannah vegetation which were about 120 ppm. In general, bottomland samples had relatively low Mn content (90 ppm), whereas prairie vegetation had relatively high levels (122 ppm). Savannah samples had intermediate levels (108 ppm). The Cu content was relatively similar among vegetation types, although, savannah type had the higher value. Fe content on bottomland averaged about 30% higher than prairie vegetation and only 77% over savannah type.

Soil. According to Powell and Knight (1979), the pH of the soils on this area was similar for the three vegetation types. Means and standard deviation of mineral components of the soil are given in Table 13. The Ca content was similar in prairie and savannah soils but greater in bottomland. This tendency however, was not observed in plant analysis of the same vegetation types. Ca content in soils was statistically correlated to Na and Mn plant values on bottomland; to Fe in prairie vegetation, and to K and Mn plant tissue on savannah vegetation type (Table 14). Mg content in soils ranged from 144 ppm in savannah soils to 221 ppm in bottomland soils (Table 13). Mg in soil was significantly correlated to bottomland plant Mg content and to Zn on savannah vegetation (Table 14). K was about twice as high in savannah soils as in prairie soils and 28% higher than bottomland soil samples (Table 13). K content was correlated to Na plant content on bottomland vegetation and to Mg plant concentration on savannah. Prairie soil samples had the greatest Na content (33 ppm), whereas savannah soils had the lowest (20 ppm) Na content (Table 13). Significant correlations were found between soil Na content and Na and Mn in plants

Table 13. Average ($\bar{x}\pm sd$) soil mineral content on three different vegetation types at Fort Gibson, Oklahoma. 1978.

Element, ppm	Bottomland n = 10	Prairie n = 10	Savannah n = 8
Ca	968 ± 143	913 ± 140	920 ± 181
Mg	221 ± 28	198 ± 15	144 ± 23
K	349 ± 181	254 ± 67	509 ± 198
Na	29 ± 6	33 ± 12	20 ± 4
Zn	11 ± 6	7 ± 3	14 ± 4
Mn	20 ± 1	19 ± 1	18 ± 3
Cu	56 ± 15	47 ± 16	41 ± 21
Fe	30 ± 7	29 + 6	23 ± 9

Table 14. Correlation coefficients (r) between standing vegetation and soil by vegetation type on Fort Gibson, 1978.

Element		Vegetation type		
Plant	Soil	Bottomland	Prairie	Savannah
Na	Ca	.663[a]	NS	NS
	Mg	-.637[a]	NS	NS
	K	.633[a]	NS	NS
	Na	NS	.781[b]	NS
Mn	Ca	-.812[b]	-.623[a]	-.800[b]
	Na	NS	.829[b]	NS
Fe	Mn	.686[a]	NS	NS
	Fe	.689[a]	NS	NS
	Ca	NS	.761[b]	NS
Ca	Fe	NS	-.715[a]	NS
	Cu	NS	-.740[b]	NS
Cu	Mn	NS	-.783[b]	NS
	Cu	NS	-.630[a]	NS
	Na	NS	NS	.708[a]
K	Ca	NS	NS	.789[b]
Mg	K	NS	NS	-.830[b]
Zn	Mg	NS	NS	-.712[a]
	Fe	NS	NS	.732[a]

[a,b]Statistically significant at $P<.05$ and $P<.01$ respectively.

from prairie vegetation, whereas Na was correlated to Cu in savannah vegetation (Table 14). In general, Fort Gibson soil samples were low in Zn content (Table 13). Their highest average occurred on savannah soils (14 ppm) and the minimum in the prairie vegetation type (7 ppm). Plant tissues however, tend to concentrate available Zn (Table 12). Soil Mn values were very similar in all vegetation types. Nevertheless it was only statistically correlated to Fe plant content on bottomland, and to plant Cu in prairie vegetation (Table 14). Average soil Cu content was high in all three vegetation types (Table 13), although Cu concentration in plant tissues was generally low (Table 12). This suggests a poor availability of existing Cu in these soils. Because of this, a significant negative correlation was observed between soil Cu and plant Cu on prairie vegetation. Cu was also positively correlated to plant Ca content on the same vegetation type (Table 14). Fe content in bottomland and prairie soils were very similar, whereas savannah soils had about 25% less Fe (Table 13). This relationship was not observed on standing vegetation. Fe however, was statistically correlated to plant Fe content in bottomland, to plant Ca content in prairie vegetation, and to Zn in savannah plants (Table 14).

Nutritional Analysis

The final purpose of this study was to present an overall view of mineral supply and recommendations for grazing cattle at four different locations in Oklahoma. Averages for plant mineral content are presented by location in Figure 2. The line in each graph represents the nutrient requirement for that mineral for a lactating cow as recommend by the National Research Council (NRC, 1976). Certain limitations of

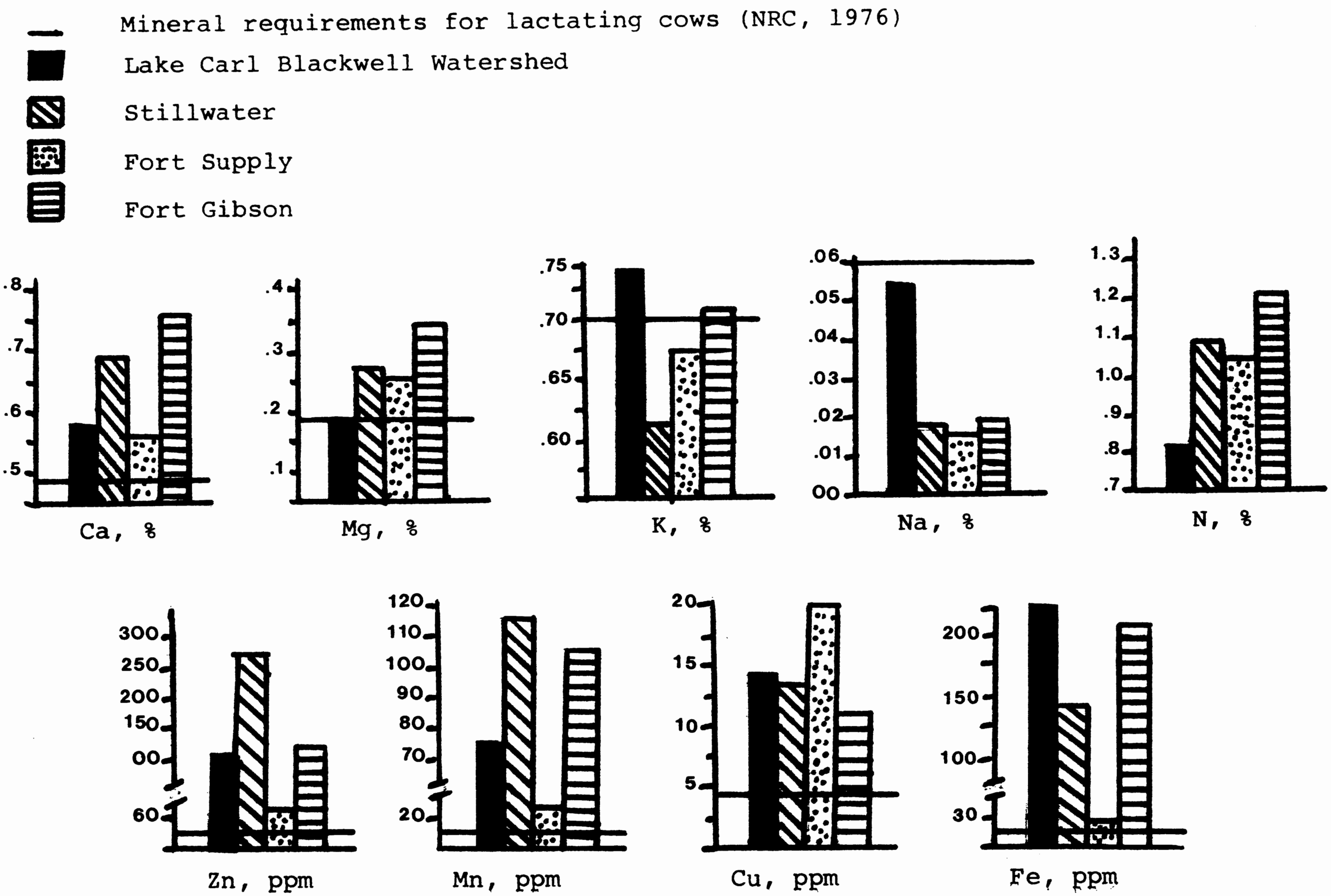


Figure 2. Average mineral content of plant material on four locations in Oklahoma

the approach are recognized. NRC presents the requirements separately for growing and finishing steers and heifers, dry pregnant cows and breeding bulls and lactating cows. In contrast with lactating cows where higher values are suggested, K, Mg, Fe, Cu and Zn requirements are similar for heifers and pregnant cows. Despite the limitations that mineral requirements may not be accurate for all classes of ruminants, and that averages are across seasons, some preliminary conclusions can be drawn.

In general, Ca content exceeded nutrient recommendations except for the high level of Ca suggested for growing and finishing cattle. Mg content exceeded Mg requirements at all locations except at Lake Carl Blackwell where Mg content was just below the recommendations for breeding bulls and lactating cows. K only exceed the NRC recommendations at Lake Carl Blackwell and Fort Gibson locations. Even at these locations the seasonal drop in K would make winter range forage marginal in K. Na was totally deficient for lactating cows in all four study areas but the practice of salt supplementation should obviate this problem. Temperate plant species vary considerable in their capacity to accumulate Na. Morris (1980) reported large and consistent differences in Na content among grass genera. But even those species with a low Na potential show variation in Na content.

Average N content was approximately equivalent to 7% crude protein however, seasonality may again be a problem. This material seems to be generally low in N content for cattle. Zn exceeded NRC recommendations for cattle by several fold, although plant material from Fort Supply, Oklahoma was only slightly above the animal requirement. Cu far exceeded NRC recommendations as did Fe, with the exception of Fort Supply where Fe content only slightly exceeded the recommended level.

At the present time under field conditions in Oklahoma, no generalized mineral malnutrition has been reported. Failure in detection does not deny existence of deficiencies. Chronic trace mineral malnutrition may commonly depress performance of livestock grazing Oklahoma rangelands. Besides general attention to N and Na supplementation, K, Mg and Fe need seasonal and/or regional attention to assure adequate mineral intake.

CHAPTER V

CONCLUSIONS

Studies of mineral content on soil and native standing vegetation from four different locations in Oklahoma have provided important basic information on their seasonal content of Ca, Mg, K, Na, Mn, Cu, Fe and N.

Data presented for northcentral Oklahoma have shown variation in mineral values across different seasons of the year. The pattern of seasonal change in Ca content at the Lake Carl Blackwell area did not coincide with patterns of all other minerals analyzed. It appeared that major soil types exerted strong influences on such patterns. Drought conditions during sampling period were responsible for high degree of mobility of K, which, when not mobile in the plant material, is readily leached. During certain seasons, N content of plant material was low. This decrease reflected maturation of certain species and possible leaching. Results at the Stillwater area indicated that herbicide and fertilization treatments influenced nutrient content of forages. Applications of atrazine alone and in combination with N, P and K, increased Ca, K, Zn, N and Fe in plant material. The largest increase occurred with NPK treatments. The second year of retreatment produced an increase on K content in plants between June and October. N was consistently greater on all retreated areas while Ca content remained about the same. Zn, Mn, Cu and Fe were more affected by seasonal changes than by imposed N, P, K or atrazine treatments.

Atrazine and N application increased Mn, Zn and N content of Andropogon hallii from a western Oklahoma sandhill prairie. Total Ca, K and Mn levels in treated areas, were higher than untreated areas. Low levels of Zn and Fe content were observed in soil samples from Fort Supply. Plant values were also low in Zn, Mn and Fe.

Soil and plant material samples from the three vegetation types studies at the Fort Gibson Project area varied widely in mineral content. Bottomland and prairie types had higher values for Mg, K, Na, N and Mn in plant material. Similar tendencies were observed in soil samples except for K which was high in savannah soils. In general, low levels of Zn were found in Fort Gibson soils.

Comparing nutritional requirements of cattle with plant nutrient concentrations, Ca exceeded the NRC (1976) mineral requirements for beef cattle except for rapidly growing animals. Mg was below requirements for breeding bulls and lactating cows at Lake Carl Blackwell. Na was deficient in all study areas. Nearly deficient at Fort Supply were Zn, Mn and Fe.

At present time, no generalized mineral malnutrition has been reported in Oklahoma. However, concentrations of minerals in forages suggests that mineral deficiencies may occur regionally and seasonally for cattle grazing Oklahoma rangelands.

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APPENDICES

APPENDIX A

LABORATORY DATA WORKSHEETS, 1980

OKLAHOMA STATE UNIVERSITY
FORTRAN CODING FORM

RANGE MANAGEMENT-1980

SOIL-VEGETATION MINERAL STUDY

NAME	YR	STUDY	TMT	MATR	CA	MG	K	NA	ZN	MN	CU	FE	N	DATE	REP

APPENDIX B

COMPUTER COMMENT STATEMENTS

STANDING VEGETATION DATA.

STDV-MINERAL CONTENT STUDY AT LAKE BLACKWELL, LOCATION 8A

```
          TITLE 'SOIL-VEGETATION STUDY AT LAKE BLACKWELL, LOCATION 8A';
          DATA VEG; INPUT NAME $1-4 YR 6-7 LOC $8-12 TMT $14-21 MATR $23-26
          CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56 CU 58-61
          FE 63-66 N 68-71 2 DATE $73-75;
          CARDS;

NOTE: DATA SET WORK.VEG HAS 116 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.28 SECONDS AND 100K.

          PROC SORT DATA=VEG; BY LOC DATE;

NOTE: DATA SET WORK.VEG HAS 116 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.55 SECONDS AND 110K.

          PROC MEANS DATA=VEG; BY LOC DATE;
          VAR CA MG K NA ZN MN CU FE N;
          OUTPUT OUT=VEGM MEAN=CA MG K NA ZN MN CU FE  N
          STD=SCA SMG SK SNA SZN SMN SCU SFE SN;

NOTE: DATA SET WORK.VEGM HAS 4 OBSERVATIONS AND 20 VARIABLES. 122 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.48 SECONDS AND 142K AND PRINTED PAGE 1.

          PROC PRINT DATA=VEGM; BY LOC DATE;
          VAR CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE PRINT USED 0.33 SECONDS AND 108K AND PRINTED PAGE 2.

          PROC PRINT DATA=VEGM; BY LOC DATE;
          VAR SCA SMG SK SNA SZN SMN SCU SFE SN;
```

STDV-MINERAL CONTENT STUDY AT STILLWATER, LOCATION 3AS-75

```
          TITLE 'STDV-MINERAL CONTENT STUDY AT STILLWATER, 3AS-75';
          DATA VEG; INPUT NAME $ 1-4 YR $6-7  LOC $10-12 TMT $14-21 MATR $ 23-26
          CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56 CU 58-61
          FE 63-66 N 68-71 2 DATE $73-75 REP 77;
          CARDS;

NOTE: DATA SET WORK.VEG HAS 63 OBSERVATIONS AND 16 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.23 SECONDS AND 100K.

          PROC SORT DATA=VEG; BY LOC TMT DATE;

NOTE: DATA SET WORK.VEG HAS 63 OBSERVATIONS AND 16 VARIABLES. 176 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.54 SECONDS AND 110K.

          PROC MEANS DATA=VEG; BY LOC TMT DATE;
          VAR CA MG K NA ZN MN CU FE N;
          OUTPUT OUT=VEGM MEAN= CA MG K NA ZN MN CU FE N
          STD=SCA SMG SK SNA SZN SMN SCU SFE SN;

NOTE: DATA SET WORK.VEGM HAS 21 OBSERVATIONS AND 21 VARIABLES. 117 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.81 SECONDS AND 142K AND PRINTED PAGES 1 TO 6.

          PROC PRINT DATA=VEGM;BY LOC TMT DATE;
          VAR TMT DATE CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE PRINT USED 0.47 SECONDS AND 108K AND PRINTED PAGES 7 TO 9.

          PROC PRINT DATA=VEGM;BY LOC TMT DATE;
          VAR TMT DATE SCA SMG SK SNA SZN SMN SCU SFE SN;
```

STDV-MINERAL CONTENT STUDY AT STILLWATER, LOCATION 3AS-76

```
          TITLE 'STDV-MINERAL CONTENT STUDY AT STILLWATER, 3AS-76';
          DATA VEG; INPUT NAME $ 1-4 YR $6-7  LOC $10-12 TMT $14-21 MATR $ 23-26
          CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56 CU 58-61
          FE 63-66 N 68-71 2 DATE $73-75 REP 77;
          CARDS;

NOTE: DATA SET WORK.VEG HAS 126 OBSERVATIONS AND 16 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.28 SECONDS AND 100K.

          PROC SORT DATA=VEG; BY LOC TMT DATE;

NOTE: DATA SET WORK.VEG HAS 126 OBSERVATIONS AND 16 VARIABLES. 176 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.56 SECONDS AND 110K.

          PROC MEANS DATA=VEG; BY LOC TMT DATE;
          VAR CA MG K NA ZN MN CU FE N;
          OUTPUT OUT=VEGM MEAN= CA MG K NA ZN MN CU FE N
          STD=SCA SMG SK SNA SZN SMN SCU SFE SN;

NOTE: DATA SET WORK.VEGM HAS 42 OBSERVATIONS AND 21 VARIABLES. 117 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 1.23 SECONDS AND 142K AND PRINTED PAGES 1 TO 11.

          PROC PRINT DATA=VEGM;BY LOC TMT DATE;
          VAR TMT DATE CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE PRINT USED 0.64 SECONDS AND 108K AND PRINTED PAGES 12 TO 17.

          PROC PRINT DATA=VEGM;BY LOC TMT DATE;
          VAR TMT DATE SCA SMG SK SNA SZN SMN SCU SFE SN;
```

STDV-MINERAL CONTENT STUDY AT FT SUPPLY, LOCATION 3AW

```
          TITLE 'STDV-MINERAL CONTENT STUDY AT FT SUPPLY, LOCATION 3AW';
          DATA VEG; INPUT NAME $ 1-4 YR $6-7  LOC $10-12 TMT $14-21 MATR $ 23-26
          CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56 CU 58-61
          FE 63-66 N 68-71 2 DATE $73-75 REP 77;
          CARDS;

NOTE: DATA SET WORK.VEG HAS 48 OBSERVATIONS AND 16 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.22 SECONDS AND 100K.

          PROC SORT DATA=VEG; BY LOC TMT DATE;

NOTE: DATA SET WORK.VEG HAS 48 OBSERVATIONS AND 16 VARIABLES. 176 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.53 SECONDS AND 110K.

          PROC MEANS DATA=VEG; BY LOC TMT DATE;
          VAR CA MG K NA ZN MN CU FE N;
          OUTPUT OUT=VEGM MEAN= CA MG K NA ZN MN CU FE N
          STD=SCA SMG SK SNA SZN SMN SCU SFE SN;

NOTE: DATA SET WORK.VEGM HAS 12 OBSERVATIONS AND 21 VARIABLES. 117 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.61 SECONDS AND 142K AND PRINTED PAGES 1 TO 3.

          PROC PRINT DATA=VEGM;BY LOC TMT DATE;
          VAR TMT DATE CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE PRINT USED 0.39 SECONDS AND 108K AND PRINTED PAGES 4 TO 5.

          PROC PRINT DATA=VEGM;BY LOC TMT DATE;
          VAR TMT DATE SCA SMG SK SNA SZN SMN SCU SFE SN;
```

STDV-MINERAL CONTENT STUDY AT FT GIBSON, LOCATION FTGB

```
          TITLE 'STDV-MINERAL CONTENT STUDY AT FT GIBSON, LOCATION FTGB';
          DATA VEG; INPUT NAME $1-4 YR 6-7 LOC $ 8-12 TMT $ 14-21 MATR $ 23-26
          CA 28-31 2 MG 35-35 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56
          CU 58-61 FE 63-66 SITE $ 68-70;
          CARDS;

NOTE: DATA SET WORK.VEG HAS 28 OBSERVATIONS AND 14 VARIABLES. 190 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.19 SECONDS AND 100K.

          PROC MEANS DATA=VEG; BY LOC SITE;
          VAR CA MG K NA ZN MN CU FE;
          OUTPUT OUT=VEGM MEAN= CA MG K NA ZN MN CU FE N
          STD=SCA SMG SK SNA SZN SMN SCU SFE SN;

NOTE: DATA SET WORK.VEGM HAS 3 OBSERVATIONS AND 20 VARIABLES. 122 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.42 SECONDS AND 134K AND PRINTED PAGE 1.

          PROC PRINT DATA=VEGM; BY LOC SITE;
          VAR CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE PRINT USED 0.30 SECONDS AND 108K AND PRINTED PAGE 2.

          PROC PRINT DATA=VEGM; BY LOC SITE;
          VAR SCA SMG SK SNA SZN SMN SCU SFE SN;
```

APPENDIX C

COMPUTER COMMENT STATEMENTS

SOILS DATA

SOIL-MINERAL CONTENT STUDY AT LAKE BLACKWELL, LOCATION 8A

```
TITLE 'SOIL-VEGETATION STUDY AT LAKE BLACKWELL, LOCATION 8A';
DATA VEG; INPUT NAME $1-4 YR 6-7 LOC $8-12 TMT $14-21 MATR $23-26
CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56 CU 58-61
FE 63-66 N 68-71 2 DATE $73-75;
CARDS;

NOTE: DATA SET WORK.VEG HAS 116 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.27 SECONDS AND 100K.

DATA SOIL; INPUT NAME $1-4 YR 6-7 LOC $8-12 TMT $14-21 MATR $23-26
CA_S 28-31 MG_S 34-36 K_S 38-41 NA_S 43-46 ZN_S 48-51 MN_S 53-56
CU_S 58-61 FE_S 63-66 N_S 68-71 DATE $ 73-75;
CARDS;

NOTE: DATA SET WORK.SOIL HAS 29 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.16 SECONDS AND 100K.

PROC MEANS DATA=SOIL;
                  VAR  CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S N_S;
OUTPUT OUT=SOILM MEAN= CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S N_S
    STD=SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S SN_S
     MIN=LCA_S LMG_S  LK_S LNA_S LZN_S LMN_S LCU_S LFE_S LN_S
    MAX= UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S UN_S;

NOTE: DATA SET WORK.SOILM HAS 1 OBSERVATIONS AND 36 VARIABLES. 65 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.38 SECONDS AND 134K AND PRINTED PAGE 1.

PROC PRINT DATA=SOILM;
                  VAR  CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S N_S;

NOTE: THE PROCEDURE PRINT USED 0.29 SECONDS AND 108K AND PRINTED PAGE 2.

PROC PRINT DATA=SOILM;
    VAR SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S SN_S;

NOTE: THE PROCEDURE PRINT USED 0.29 SECONDS AND 108K AND PRINTED PAGE 3.

PROC PRINT DATA=SOILM;
     VAR LCA_S LMG_S  LK_S LNA_S LZN_S LMN_S LCU_S LFE_S LN_S;

NOTE: THE PROCEDURE PRINT USED 0.29 SECONDS AND 108K AND PRINTED PAGE 4.

PROC PRINT DATA=SOILM;
    VAR UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S UN_S;
```

SOIL-MINERAL CONTENT STUDY AT STILLWATER, LOCATION 3AS-75

```
          TITLE 'SOIL-MINERAL CONTENT STUDY AT STILLWATER, LOCATION 3AS-75';
          DATA SOIL; INPUT NAME $ 1-4 YR 6-7 LOC $10-12 TMT $ 14-21 MATR $ 23-26
          CA_S 28-31 MG_S 34-36 K_S 39-41 NA_S 45-46 ZN_S 49-51 MN_S 55-56
          CU_S 59-61 FE_S 65-66 REP 77;
          CARDS;

NOTE: DATA SET WORK.SOIL HAS 21 OBSERVATIONS AND 14 VARIABLES. 185 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.19 SECONDS AND 100K.

          PROC SORT DATA=SOIL; BY LOC TMT;

NOTE: DATA SET WORK.SOIL HAS 21 OBSERVATIONS AND 14 VARIABLES. 185 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.49 SECONDS AND 110K.

          PROC MEANS DATA=SOIL; BY LOC TMT;
          VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;
          OUTPUT OUT=SOILM MEAN= CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S
          STD=SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S
          MIN=LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S
          MAX=UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;

NOTE: DATA SET WORK.SOILM HAS 7 OBSERVATIONS AND 34 VARIABLES. 70 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.48 SECONDS AND 142K AND PRINTED PAGES 1 TO 2.

          PROC PRINT DATA=SOILM; BY LOC;
          VAR TMT CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;

NOTE: THE PROCEDURE PRINT USED 0.31 SECONDS AND 108K AND PRINTED PAGE 3.

          PROC PRINT DATA=SOILM; BY LOC;
          VAR TMT SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S;

NOTE: THE PROCEDURE PRINT USED 0.31 SECONDS AND 108K AND PRINTED PAGE 4.

          PROC PRINT DATA=SOILM; BY LOC;
          VAR TMT LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S;

NOTE: THE PROCEDURE PRINT USED 0.31 SECONDS AND 108K AND PRINTED PAGE 5.

          PROC PRINT DATA=SOILM; BY LOC;
          VAR TMT UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;
```

SOIL-MINERAL CONTENT STUDY AT STILLWATER, LOCATION 3AS-76

```
1          TITLE 'SOIL-MINERAL CONTENT STUDY AT STILLWATER, LOCATION 3AS-76';
2          DATA SOIL; INPUT NAME $ 1-4 YR 6-7 LOC $10-12 TMT $ 14-21 MATR $ 23-26
3          CA_S 28-31 MG_S 34-36 K_S 39-41 NA_S 45-46 ZN_S 49-51 MN_S 55-56
4          CU_S 59-61 FE_S 65-66 REP 77;
5          CARDS;

NOTE: DATA SET WORK.SOIL HAS 42 OBSERVATIONS AND 14 VARIABLES. 185 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.20 SECONDS AND 100K.

48         PROC SORT DATA=SOIL; BY LOC TMT;

NOTE: DATA SET WORK.SOIL HAS 42 OBSERVATIONS AND 14 VARIABLES. 185 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.52 SECONDS AND 110K.

49         PROC MEANS DATA=SOIL; BY LOC TMT;
50         VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;
51         OUTPUT OUT=SOILM MEAN= CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S
52         STD=SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S
53         MIN=LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S
54         MAX=UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;

NOTE: DATA SET WORK.SOILM HAS 14 OBSERVATIONS AND 34 VARIABLES. 70 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.62 SECONDS AND 142K AND PRINTED PAGES 1 TO 4.

55         PROC PRINT DATA=SOILM; BY LOC;
56         VAR TMT CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;

NOTE: THE PROCEDURE PRINT USED 0.33 SECONDS AND 108K AND PRINTED PAGE 5.

57         PROC PRINT DATA=SOILM; BY LOC;
58         VAR TMT SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S;

NOTE: THE PROCEDURE PRINT USED 0.33 SECONDS AND 108K AND PRINTED PAGE 6.

59         PROC PRINT DATA=SOILM; BY LOC;
60         VAR TMT LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S;

NOTE: THE PROCEDURE PRINT USED 0.33 SECONDS AND 108K AND PRINTED PAGE 7.

61         PROC PRINT DATA=SOILM; BY LOC;
62         VAR TMT UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;
```

SOIL-MINERAL CONTENT STUDY AT FT SUPPLY, LOCATION 3AW

```
          TITLE 'SOIL-MINERAL CONTENT STUDY AT WOODWARD, LOCATION 3AW';
          DATA SOIL; INPUT NAME $ 1-4 YR 6-7 LOC $10-12 TMT $ 14-21 MATR $ 23-26
          CA_S 28-31 MG_S 34-36 K_S 39-41 NA_S 45-46 ZN_S 49-51 MN_S 55-56
          CU_S 59-61 FE_S 65-66 REP 77;
          CARDS;

NOTE: DATA SET WORK.SOIL HAS 16 OBSERVATIONS AND 14 VARIABLES. 185 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.18 SECONDS AND 100K.

          PROC SORT DATA=SOIL; BY LOC TMT;

NOTE: DATA SET WORK.SOIL HAS 16 OBSERVATIONS AND 14 VARIABLES. 185 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.48 SECONDS AND 110K.

          PROC MEANS DATA=SOIL; BY LOC TMT;
          VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;
          OUTPUT OUT=SOILM MEAN= CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S
          STD=SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S
          MIN=LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S
          MAX=UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;

NOTE: DATA SET WORK.SOILM HAS 4 OBSERVATIONS AND 34 VARIABLES. 70 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.42 SECONDS AND 134K AND PRINTED PAGE 1.

          PROC PRINT DATA=SOILM; BY LOC;
          VAR TMT CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;

NOTE: THE PROCEDURE PRINT USED 0.29 SECONDS AND 108K AND PRINTED PAGE 2.

          PROC PRINT DATA=SOILM; BY LOC;
          VAR TMT SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S;

NOTE: THE PROCEDURE PRINT USED 0.30 SECONDS AND 108K AND PRINTED PAGE 3.

          PROC PRINT DATA=SOILM; BY LOC;
          VAR TMT LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S;

NOTE: THE PROCEDURE PRINT USED 0.30 SECONDS AND 108K AND PRINTED PAGE 4.

          PROC PRINT DATA=SCILM; BY LOC;
          VAR TMT UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;
```

SOIL-MINERAL CONTENT STUDY AT FT GIBSON, LOCATION FTGB

```
          TITLE 'SOIL VEGETATION STUDY AT FORT GIBSON, LOCATION FTGB';
          DATA VEG; INPUT NAME $ 1-4 YR 6-7  LOC $ 8-12 TMT $ 14-21 MATR $ 23-26
          #1 CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56
          #1 CU 58-61 FE 63-66 SITE $ 68-70
          #2 NAME2 $ 1-4 YR2 6-7 LOC2 $ 8-12 TMT2 $ 14-21 MATR2 $ 23-26 CA_S 28-31
          #2 MG_S 34-36 K_S 38-41 NA_S 43-46 ZN_S 48-51 MN_S 53-56 CU_S 58-61
          #2 FE_S 63-66 SITE2 $ 68-70;
          CARDS;

NOTE: DATA SET WORK.VEG HAS 28 OBSERVATIONS AND 28 VARIABLES. 97 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.24 SECONDS AND 100K.

          PROC MEANS DATA=VEG; BY LOC SITE;
          VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;
          OUTPUT OUT=SOILM MEAN= CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S
          STD=SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S
          MIN=LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S
          MAX=UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;

NOTE: DATA SET WORK.SOILM HAS 3 OBSERVATIONS AND 34 VARIABLES. 71 OBS/TRK.
NOTE: THE PROCEDURE MEANS USED 0.44 SECONDS AND 142K AND PRINTED PAGE 1.

          PROC PRINT DATA=SOILM; BY LOC SITE;
          VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S;

NOTE: THE PROCEDURE PRINT USED 0.31 SECONDS AND 108K AND PRINTED PAGE 2.

          PROC PRINT DATA=SOILM; BY LOC SITE;
          VAR SCA_S SMG_S SK_S SNA_S SZN_S SMN_S SCU_S SFE_S;

NOTE: THE PROCEDURE PRINT USED 0.31 SECONDS AND 108K AND PRINTED PAGE 3.

          PROC PRINT DATA=SOILM; BY LOC SITE;
          VAR LCA_S LMG_S LK_S LNA_S LZN_S LMN_S LCU_S LFE_S;

NOTE: THE PROCEDURE PRINT USED 0.31 SECONDS AND 108K AND PRINTED PAGE 4.

          PROC PRINT DATA=SOILM; BY LOC SITE;
          VAR UCA_S UMG_S UK_S UNA_S UZN_S UMN_S UCU_S UFE_S;
```

APPENDIX D

COMPUTER COMMENT STATEMENTS

SOIL-PLANT CORRELATIONS

SOIL-VEGETATION CORRELATION AT LAKE BLACKWELL, LOCATION 8A

```
1          TITLE 'SOIL-VEGETATION STUDY AT LAKE BLACKWELL, LOCATION 8A';
2          DATA VEG; INPUT NAME $1-4 YR 6-7 LOC $8-12 TMT $14-21 MATR $23-26
3          CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56 CU 58-61
4          FE 63-66 N 68-71 2 DATE $73-75;
5          CARDS;

NOTE: DATA SET WORK.VEG HAS 116 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.27 SECONDS AND 100K.

122        DATA SOIL; INPUT NAME $1-4 YR 6-7 LOC $8-12 TMT $14-21 MATR $23-26
123        CA_S 28-31 MG_S 34-36 K_S 38-41 NA_S 43-46 ZN_S 48-51 MN_S 53-56
124        CU_S 58-61 FE_S 63-66 N_S 68-71 DATE $ 73-75;
125        CARDS;

NOTE: DATA SET WORK.SOIL HAS 29 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.16 SECONDS AND 100K.

155        PROC SORT DATA=SOIL; BY TMT;

NOTE: DATA SET WORK.SOIL HAS 29 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.50 SECONDS AND 110K.

156        PROC SORT DATA=VEG; BY DATE TMT;

NOTE: DATA SET WORK.VEG HAS 116 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.51 SECONDS AND 110K.

157        DATA VEG1; SET VEG; IF DATE NE 'MAR' THEN DELETE;

NOTE: DATA SET WORK.VEG1 HAS 29 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.15 SECONDS AND 100K.

158        DATA VEG2; SET VEG; IF DATE NE 'JUL' THEN DELETE;

NOTE: DATA SET WORK.VEG2 HAS 29 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.15 SECONDS AND 100K.

159        DATA VEG3; SET VEG; IF DATE NE 'SEP' THEN DELETE;

NOTE: DATA SET WORK.VEG3 HAS 29 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.16 SECONDS AND 100K.

160        DATA VEG4; SET VEG; IF DATE NE 'DEC' THEN DELETE;
```

```
NOTE: DATA SET WORK.VEG4 HAS 29 OBSERVATIONS AND 15 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.16 SECONDS AND 100K.

      DATA VEG1SOIL;
      MERGE SOIL VEG1; BY LOC TMT;
      DATA VEG2SOIL;
      MERGE SOIL VEG2; BY LOC TMT;

NOTE: DATA SET WORK.VEG2SOIL HAS 29 OBSERVATIONS AND 24 VARIABLES. 105 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.19 SECONDS AND 120K.

      DATA VEG3SOIL;
      MERGE SOIL VEG3; BY LOC TMT;

NOTE: DATA SET WORK.VEG3SOIL HAS 29 OBSERVATIONS AND 24 VARIABLES. 105 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.19 SECONDS AND 120K.

      DATA VEG4SOIL;
      MERGE SOIL VEG4; BY LOC TMT;

NOTE: DATA SET WORK.VEG4SOIL HAS 29 OBSERVATIONS AND 24 VARIABLES. 105 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.19 SECONDS AND 120K.

      PROC CORR DATA=VEG1SOIL;
                       VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S N_S
                  CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE CORR USED 0.65 SECONDS AND 156K AND PRINTED PAGES 1 TO 4.

      PROC CORR DATA=VEG2SOIL;
                       VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S N_S
                  CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE CORR USED 0.65 SECONDS AND 156K AND PRINTED PAGES 5 TO 8.

      PROC CORR DATA=VEG3SOIL;
                       VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S N_S
                  CA MG K NA ZN MN CU FE N;

NOTE: THE PROCEDURE CORR USED 0.65 SECONDS AND 156K AND PRINTED PAGES 9 TO 12.

      PROC CORR DATA=VEG4SOIL;
                       VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S N_S
                  CA MG K NA ZN MN CU FE N;
```

SOIL-VEGETATION CORRELATION AT FT GIBSON, LOCATION FTGB

```
        TITLE 'SOIL VEGETATION STUDY AT FORT GIBSON, LOCATION FTGB';
        DATA VEG; INPUT NAME $ 1-4 YR 6-7  LOC $ 8-12 TMT $ 14-21 MATR $ 23-26
        #1 CA 28-31 2 MG 35-36 2 K 38-41 2 NA 43-46 4 ZN 48-51 MN 53-56
        #1 CU 58-61 FE 63-66 SITE $ 68-70
        #2 NAME2 $ 1-4 YR2 6-7 LOC2 $ 8-12 TMT2 $ 14-21 MATR2 $ 23-26 CA_S 28-31
        #2 MG_S 34-36 K_S 38-41 NA_S 43-46 ZN_S 48-51 MN_S 53-56 CU_S 58-61
        #2 FE_S 63-66 SITE2 $ 68-70;
        IF YR NE YR2 OR LOC NE LOC2 OR TMT NE TMT2 OR SITE NE SITE2 OR MATR NE
           'STDV' OR MATR2 NE 'SOIL' THEN PUT YR YR2 LOC LOC2 TMT TMT2  SITE SITE2
        MATR MATR2;
        IF YR NE YR2 OR LOC NE LOC2 OR TMT NE TMT2 OR SITE NE SITE2 OR MATR NE
           'STDV' OR MATR2 NE 'SOIL' THEN LOSTCARD;
        CARDS;

NOTE: DATA SET WORK.VEG HAS 26 OBSERVATIONS AND 28 VARIABLES. 97 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.26 SECONDS AND 100K.

        PROC CORR DATA=VEG; BY LOC SITE;
        VAR CA_S MG_S K_S NA_S ZN_S MN_S CU_S FE_S CA MG K NA ZN MN CU FE;
```

VITA

ENRIQUE JAVIER SANCHEZ-GRANILLO

Candidate for the Degree of

DOCTOR OF PHILOSOPHY

Thesis: MINERAL RELATIONSHIPS BETWEEN RANGE FORAGE AND SOILS AT FOUR DIFFERENT LOCATIONS IN OKLAHOMA.

Major Field: Crop Science

Biographical:

Personal Data: Born in Chihuahua, Chih. Mexico, May 1945, son of Mr. Manuel Sanchez and Evelina Granillo; married to Alma Kong in April 1973, father of Kike and Luis Raul Sanchez.

Education: Received the degree of Medico Veterinario Zootecnista from Universidad Nacional Autonoma de Mexico in December, 1970; received Master of Science degree in Animal Science from New Mexico State University in May 1975; completed requirements for the Doctor of Phylosophy degree at Oklahoma State University in May 1980.

Profesional Experience: Research assistant in Animal Nutrition, Instituto Nacional de Investigaciones Pecuarias (INIP), 1969-1971; research assistant in Range Cattle Nutrition, Agricultural Experimental Station "La Campana" (INIP) at Chihuahua Chih, 1971-1973; served two years as research coordinator for the department of Animal Nutrition (INIP) in Northern Mexico, 1975-1977.

Profesional Organizations:

Society for Range Management
American Society of Animal Science
Colegio de Medicos Veterinarios Zootecnistas de Chihuahua