OKLAHOMA TALLGRASS PRAIRIE SPECIES COMPOSITION AND PRODUCTION RESPONSES TO ROTATION FERTILIZATION ON DIFFERENT RANGE SITES

By

PATRICK JAMES BROYLES

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1975

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1978

OKLAHOMA TALLGRASS PRAIRIE SPECIES COMPOSITION

AND PRODUCTION RESPONSES TO ROTATION

FERTILIZATION ON DIFFERENT

RANGE SITES

Thesis Approved:

Jeff Powell

Thesis Adviser

W. E. McMurphy

Fenton Gray

Norman N Durham

Dean of the Graduate College

PREFACE

The work and research I have accomplished in this study is dedicated to the past, present, and future innovative managers of rangeland. There can be no worse finish to the end of our natural resources than to deplete them through a stagnant methodical philosophy. There are an infinite number of ways to conserve, yet utilize the natural renewable resources of rangeland, all that remains is for rangeland managers to find some of these methods and adapt them to the needs of society.

The leadership, help, and as I interpret it, the philosophy, of Dr. Jeff Powell has been an emulation to me, and cannot be overstated. The knowledge that I have acquired from my acquaintance with Dr. W. E. McMurphy and Dr. Fenton Gray has been an invaluable aid, and their help is gratefully acknowledged.

I wish to thank Bob Hammond for leading me by the hand through the maze of computers and computations that has bedeviled me and appreciation is also extended to Diane Monn for her assistance in typing this manuscript.

TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION 1

Objectives 2
Literature Review 2
Rangeland Forage Production Response to Fertilization 3
Cool-season annuals 3
Warm-season perennials 4
Fertilizers 5
Kind of fertilizer as related to range sites 6
Plant Resistance to Grazing 8
Cattle Grazing Response to Fertilization 9
Species of plant grazed 9
Grazing influences 10
Grazing Management Systems 11

II. STUDY AREA 16

III. PROCEDURES 20

IV. RESULTS AND DISCUSSION 25

Grazing Residue 28
Seasonal Effects 28
Fertilization 30
Range Condition 30
Total Vegetation Production Under Grazing Conditions 33
Total Production on All Range Sites 33
Total Production on Different Range Sites 36
Utilization 43
Monthly Utilization 43
Fertilization 46
Range Condition 46
Range Sites 49

V. SUMMARY AND CONCLUSIONS 52

LITERATURE CITED 54

Chapter Page

APPENDIX A 59

APPENDIX B 67

LIST OF TABLES

Table Page

1. Species classes and species within each class 26

2. Monthly and total utilization by species class, Stillwater, 1975 44

3. Total production (kg/ha) and utilization (%) by species class on unfertilized and rotationally fertilized rangeland, Stillwater, 1975 47

4. Total production (kg/ha) and utilization (%) by species class on fair and good condition rangeland, Stillwater, 1975 48

5. Total utilization (%) by species class on different range sites, Stillwater, 1975 50

LIST OF FIGURES

Figure Page

1. Aerial photo of soil series boundaries 18

2. Aerial photo of paddock and cage locations 21

3. Monthly precipitation (mm) for long-term average and three years of study period, Stillwater 27

4. Average grazing residue (kg/ha, oven-dry) by species class for summer and fall sampling periods, Stillwater, 1975. Average for all treatments and range condition classes . . 29

5. Average grazing residue (kg/ha, oven-dry) by species class on unfertilized and fertilized areas, Stillwater, 1975. Average for five sampling dates 31

6. Average grazing residue (kg/ha, oven-dry) by species class for fair and good range condition rangeland, Stillwater, 1975. Average for all treatments and sampling periods 32

7. Accumulative production (kg/ha, oven-dry) on successive sampling dates, Stillwater, 1975. Average for all treatments and range condition classes 34

8. Accumulative production (kg/ha, oven-dry) on successive sampling data on loamy prairie range sites, Stillwater, 1975 38

9. Accumulative production (kg/ha, oven-dry) on successive sampling dates on shallow prairie range sites, Stillwater, 1975 39

10. Accumulative production (kg/ha, oven-dry) on successive sampling dates on loamy bottomland range site in good range condition, Stillwater, 1975 42

CHAPTER I

INTRODUCTION

Rangeland has many resources without which the range livestock industry as it exists today could not survive. The consumer trend is for ever increasing demands of animal products. This is a challenge which range users cannot afford to refuse. With a readily available market for livestock products, an opportunity to increase range livestock production is offered.

In Oklahoma where the Tallgrass Prairie is a dominant ecotype opportunities exist to maintain or improve range condition. Fertilization to increase forage production, and rotation grazing to maintain or improve range conditions, are two methods that show promise of increasing livestock production levels on rangeland. Whether rangeland fertilization will economically increase forage production is open to discussion.

There has been little research done in Oklahoma concerning rangeland fertilization and virtually none conducted using fertilization as a rotational grazing tool. Previous research emphasis has been to view fertilization only as a means of increasing forage production.

The dual role of fertilizer as a means of improving species composition and as a tool to rotate grazing has not been studied in Oklahoma. Perhaps this is due to the traditional role of crossfences and a lack of interest in the feasibility of such a practice.

One of the most economical range improvement practices is a well managed livestock grazing system. The ability to properly manage rangeland is generally the difference between profit and loss. Hence, a serious consideration of any innovative grazing system, which will help achieve management goals, should be sought.

For rangeland vegetation to be used efficiently the differences in species response to various grazing practices must be determined. Therefore, additional research information is required in order to obtain the maximum grazing benefits from the forage of various rangeland species. Only with increased knowledge can rangeland species composition be manipulated to improve with different systems of grazing.

Objectives

This research project was designed to determine if there is a significant difference in forage production and utilization between an area continuously grazed and an area rotationally fertilized and grazed. The two objectives of this study were to determine the relative abundance of plant species, and to determine the responses of forage production by different species, on different range sites. The two study objectives were studied in an unfertilized continuously grazed area, and in a continuously grazed area that was fertilized in thirds over a three year period.

Literature Review

Generally, professional range managers have based any decisions that have been made on a subjective interpretation of basic inventory data. Perhpas due to bureaucratic regulations and traditional practices the decision-making process is often reached without a consideration of all possible alternatives and their potential impacts (Bartlett 1973).

Production and maintenance of native vegetation are of primary concern in management (Hormay 1970). An innovative practice such as fertilization may be one method of accomplishing these management goals. However, if fertilizer is utilized it is just one factor in successful rangeland management. Any effectiveness fertilizer has depends upon the degree to which its practice correlates with other limits in production (Harper 1957, Heady 1975).

Rangeland Forage Production Response to Fertilization

Several studies have been conducted in the Southern Great Plains involving fertilizer applications. The majority of the studies reported an increase in total herbage production. The increases, however, did not necessarily benefit the desired vegetation. In some instances changes in botanical composition occurred indicating that differences in species response should be studied before fertilization is applied indiscriminately upon rangeland (Allen et. al. 1976, Bryan and McMurphy 1968, Graves and McMurphy 1969, Harper 1957, Huffine and Elder 1960, Launchbaugh 1962, Lynd and Micka 1957, McMurphy 1968, McMurphy 1970, Owensby and Launchbaugh 1971, Owensby et. al. 1970, Thompson and Schaller 1960, Woolfolk et. al. 1975).

Cool-season annuals. - Fertilization research conducted upon the true prairie indicates herbage production is increased by the stimulation of cool-season species, undesirable forbs, or both at the sacrifice of desirable warm-season species (Heady 1975, McMurphy 1970).

Launchbaugh (1962) conducted research in west-central Kansas supporting this contention. Collected data showed that during the years when fertilizers were applied annual bromes responded more to nitrogen fertilizer than did warm-season grasses. Results also showed that the annual bromes responded significantly to carryover nitrogen one year.

McMurphy (1970) in a north-central Oklahoma research project concluded that nitrogen fertilization served to promote cool-season species. This increase in cool-season annual grasses is a serious problem since there are no aggressive cool-season decreasers for Oklahoma ranges and they compete with desirable warm-season grasses. In an earlier study on fertilized rangeland McMurphy (1968) found that there was often an increase in undesirable cool-season weedy annual species, including both grasses and forbs.

On a loamy upland bluestem range in Kansas forage increases from application of nitrogen fertilization approached economic feasibility. However, Owensby et. al. (1970) found changes in botanical composition of the native vegetation to cool-season species dominance would probably prove to be a deterrent to fertilization programs.

One reason why the botanical composition may change to a cool-season species dominance when rangeland is fertilized with nitrogen is that cool-season grasses make most of their growth in early spring. At this season of the year moisture is a less limiting factor upon the Tallgrass Prairie and the release of nitrogen is slower than later when warm-season species start growth (Harper 1957, Vallentine 1971).

Warm-season perennials. - The majority of research conducted in the Southern Great Plains utilizing commercial fertilizers indicate an increased production response by desirable warm-season species (Allen et. al. 1976, Blaser 1964, Bryan and McMurphy 1968, Graves and McMurphy 1969, Harper 1957, Launchbaugh 1962, McMurphy 1970, Owensby and Launchbaugh 1971, Smika et. al. 1965, Woolfolk et. al. 1975).

Perhaps the greatest potential of fertilizer usage has in the Southern Great Plains rangeland is its ability to increase carrying capacity and livestock products per unit area (Blaser 1964). Gains per hectare on fertilized paddocks generally exceed gains from non-fertilized paddocks primarily from a greater carrying capacity rather than increased animal performance (Woolfold et. al. 1975).

The average production of forage is not the ultimate potential of the native grass species. Owensby et. al. (1970) found increased dry matter yields of 1,681 kg/ha to 2,242 kg/ha on nitrogen fertilized plots above that of control plots in years of normal or above normal precipitation.

Fertilizers. - The amount of available nitrogen to grasses is a major limitation in forage production since rangeland soils do not contain sufficient available amounts of this nutrient for high yields of grasses. If these nitrogen deficient soils are treated with nitrogen fertilizers a greater carrying capacity of livestock and more meat products per hectare usually result. McMurphy (1968) found hay meadows in Oklahoma will produce an additional 10 kg to 17 kg of forage per kg of nitrogen applied.

The most widely used forms of nitrogen fertilizers, those containing ammonia and/or urea, tend to lower soil pH (Woodhouse and Griffith 1973). Large or frequent applications of fertilizers containing nitrogen may lead to a detrimental soil pH range for desirable grasses (Owensby and Launchbaugh 1971).

Applications of phosphate fertilizers result in residual accumulations in the soil. A large percentage of the phosphorus in a forage harvest often comes from fertilizers applied in past years. Therefore, any research determining the effects of phosphate fertilizers on forage must take into account the likelihood of residual phosphorus in the soil (Woodhouse and Griffith 1973).

The majority of rangeland soils are comparatively high in total potassium (Lynd and Micka 1957). Of the total amount of potassium retained in soils only a fraction is available by forage plants. The potassium in the soil can be classified in three forms: 1) relatively unavailable or fixed, 2) slowly available, and 3) readily available (Tisdale and Nelson 1966).

The problem of retaining and utilizing potassium is due to three major causes: 1) the majority of the potassium is in unavailable forms to higher plants, 2) when potassium is in soluble form it is subject to leaching losses, and 3) the removal of potassium by forage plants is high (Brady 1974).

<u>Kinds of fertilizer as related to range sites</u>. - Differences between sites have large effects on the productivity of native forage. Soil texture as it relates to range site is often a limiting factor to native forage production. Sandy textured soils generally do not have the fertility level or the ability to hold water as do fine textured soils (Heady 1975, Brady 1974).

Launchbaugh (1962) found forage yields to be significantly increased by fertilizers containing nitrogen and phosphorus on sites with low amounts of organic matter. On similar sites with low organic matter content phosphate fertilizers alone produced no increase in forage yields. McMurphy (1970) determined that low levels of fertilizer containing nitrogen and phosphate compounds when applied on phosphorus deficient sites produced satisfactory yields of forage, if weeds and other undesirable plants were controlled.

Lynd and Micka (1957) in an Oklahoma study found that plant response to potassium fertilizer was good when the soil contained less than 27 kg of exchangeable potassium per hectare, fair when soil contained 28 to 35 kg of available potassium per hectare, doubtful when soil contained 36 to 56 kg of available potassium per hectare, and undetectable when soil contained over 57 kg of available potassium per hectare. Plant responses to potassium fertilizer were influenced by the level of available nitrogen and phosphorus in the soils. Percentages of potassium in plants generally increased when potassium fertilizers were applied, while percentage of sodium, calcium, magnesium, and nitrogen decreased with potassium fertilization.

McMurphy (1968) found that droughty soils (shallow or claypan) are normally low forage producers because of poor water relations. Consequently, fertilization of droughty soils are more apt to be less successful unless good moisture relations can be maintained.

> "Range fertilization seeks an ideal; the ability to furnish each plant with the nutrients it needs on each particular soil as required within the vagaries of weather; the ability to control species composition of the forage; and the delivery of that forage to animals in ways that produce profit for the ranch enterprise. These are the problems, the objectives, and the challenges of range fertilization." (Heady 1975)

Plant Resistance to Grazing

Different grass species have varying responses to grazing or clipping. Of the major tallgrass species, the least resistant to top removal is switchgrass (Panicum virgatum) while big bluestem (Andropogon gerardii), Indiangrass (Sorghastrum nutans) and little bluestem (Schizachyrium scoparium) persist relatively better (Dwyer et. al. 1963). The shortgrasses found in a mixed grass prairie, such as gramagrasses (Bouteloua spp.), respond much better to grazing or clipping (Harlan 1960, Branson 1958). Scientific names for plant species were taken from Gould 1968 and WSSA 1971.

The varying responses of different grass species can be partially explained by the position of the apical meristem and dormant buds (Hyder 1970, Harlan 1960). Growth is initiated only in the meristemic regions of plants. The most important meristems in grass plants are the apical-root and apical-shoot. The apical-root and apical-shoot meristems govern the growth rate of the plant root and shoot, respectively. Leaves originate from the leaf primorida, which develop laterally from the apical-shoot meristem. The leaf petiole, midrib, and lateral veins are governed by auxins (Meyer et. al. 1973).

The degree of plant resistance to grazing or clipping depends on the timing of the treatment in relation to the position of the apical meristems (Harlan 1960, Branson 1953). In tallgrasses elongation of the internodes occurs while the plants are still growing vegetatively. This causes the apical growing points and many auxiliary buds to be raised high enough to be easily removed by grazing. After removal no more leaves or buds can be produced from the growing points (Hyder 1970). Even in tallgrasses there are varying responses between species. Little bluestem is more resistant to grazing pressure not only because it is not as desired by livestock early in the growing season but also because the shoots elongate somewhat later (Harlan 1960).

The recovery rate of nitrogen by grasses is usually in the range of 50% to 80%. If nitrogen fertilizer is applied at low rates considerable nitrogen may remain in the roots and stubble (Rhykerd and Noller 1973).

Cattle Grazing Response to Fertilization

Generally, fertilizer application, even on rangeland, is viewed only as an agronomic practice to increase forage production. The value of utilizing fertilizer as a tool for improving livestock distribution is often mentioned, but rarely measured. The potential value of fertilizer to improve livestock distribution may be of great importance. Therefore, any correct evaluation of fertilization must recognize both its influence on forage production and on livestock distribution (Hooper et. al. 1969). Most range scientists generally believe that fertilizer applications have an effect on plant preference by grazing animals (Hooper et. al. 1969, Staten 1949).

Species of plant grazed. - Staten (1949) in an Oklahoma study found cattle showed a preference for forage grown on plots fertilized with phosphorus over forage grown on unfertilized plots.

Plants whose growth is stimulated by fertilizer nitrogen are more palatable to livestock than unfertilized plants. The subsequent increased utilization and reduced selectivity of plants on fertilized areas have important management implications. When only a portion of a pasture is fertilized this portion receives above average grazing pressure (Vallentine 1971, McIlvain 1961).

There is a natural tendency for livestock to graze the most palatable and nutritious plants first, and most frequently. Because of this grazing habit and beneficial effect fertilizers have upon plants it is generally conceded that grazing animals prefer fertilized plants over unfertilized forage (Hooper et. al. 1969).

Grazing influences. - Simms and Dwyer (1965) found that perennial forbs decreased under light grazing, but increased as grazing became heavier. Annual forbs increased when overgrazing was permitted. Thus overgrazing can initiate a destructive form of secondary succession resulting in an unfavorable alteration of species composition and establishment of plant communities that are generally less nutritious and palatable to the livestock and are usually less productive (Anderson 1969, Hazell 1967, Simms and Dwyer 1965, Harlan 1960).

To compound the problem of overgrazing, cattle prefer some plant species and range sites to others and graze them intensively, which causes uneven utilization. Selective grazing of the same plants and areas generally occurs year after year, and is one of the main causes of range deterioration (Hormay and Talbot 1961). As intensity of grazing pressure increases tallgrasses decrease in species composition, while shortgrasses increase (Branson 1953).

If continuous overgrazing occurs perennial grass plants are not allowed to store food, and new roots are not produced. The resulting weak root system cannot take full advantage of available moisture or nutrients. Thus, desirable forage production is decreased allowing competing undesirable vegetation to increase in species composition (Anderson 1969).

Grazing Management Systems

The basis of traditionally approved grazing management systems is the moderate use of native vegetation (Harlan 1960). Continuous heavy overgrazing decreases native forage production and can result in the ultimate loss of desirable productive vegetation (Simms and Dwyer 1965, Harlan 1960).

Hazell (1967) found that heavy grazing causes a decline in range condition. The decline in range condition is largely due to an alteration of species composition from an increase in undesirable grasses and forbs. In addition to a poorer range condition, plant health also generally declines.

Herbel and Anderson (1959) concluded overgrazing may become so severe that normal plant cover cannot be maintained thus leading to soil erosion. The rate at which plant cover decreases depends on the degree of abuse it receives. Nitrogen fertilizer applications on overgrazed rangeland can extend areas of abusive use. However, nitrogen fertilizer applications on undergrazed rangeland can be a tool for producing more forage, more livestock products, and improving grazing distribution (Vallentine 1971, Hooper et. al. 1969).

The production and maintenance of native forage plants are of primary importance in management. Rangeland species composition is altered to a less desirable plant community because desirable plants are killed. The surface area left unoccupied is available to less desirable plants, or remains bare, and consequently easily subjected to erosive forces (Hormay 1970).

There are three common grazing systems used throughout the Great Plains. These are: 1) continuous grazing whereby livestock are permitted free access to any part of the rangeland throughout the grazing season, 2) rotation or alternate grazing whereby there is a systematic alteration, both within and among years, in the grazing use of two or more portions of the rangeland, and 3) deferred grazing whereby grazing is delayed during a part of the grazing season, usually after seed maturity (Jardine and Anderson 1919, Driscoll 1967).

Continuous moderate grazing has certain inherent advantages over other types of grazing systems. Continuous grazing permits native species in excess of the forage required by livestock to gain vigor. Animals that graze tend to select new growth over old growth, leaves over stems, and finer stemmed forage species over coarser stemmed forage plants. Also, continuous grazing is more easily managed and generally least expensive of most grazing systems (Simms 1970).

Continuous grazing has certain inherent risks and disadvantages. Some of these disadvantages include dangers of livestock grazing continually on the same plants creating a hazardous condition for the more palatable desirable forage. Because of possible spot-grazing a continuous grazing system works best with a moderate stocking rate. If the carrying capacity is too heavy the more palatable plants will lose vigor and eventually be eliminated from the species composition. Continued heavy grazing may also cause a reduction in litter cover. When litter cover is reduced the microclimate surrounding plants becomes drier, water infiltration is reduced creating a greater runoff and erosion problem, thus producing a man-made drought (Simms 1970). Not all the available forage if continually grazed, may be efficiently harvested due to poor livestock distribution (Driscoll 1967). Herbel and Anderson (1959) found moderate continuous grazing results in closer use of the forage than under deferred rotation stocking at the same stocking rate.

Rotation or alternate grazing systems may mean either rotation of livestock among pastures or a rotation of grazing periods or seasons among pastures. When rotation grazing is practiced there is a systematic order when each subdivision of the rangeland is both grazed and deferred during the same grazing season or calendar year (Simms 1970).

The philosophy behind implementing a rotation grazing system makes three basic assumptions, these are: 1) that livestock in large numbers graze forage more uniformly than under a continuous grazing system, 2) that deferment of rangeland from grazing pressure is beneficial to native plants even though the forage must support a greater carrying capacity of livestock during the shorter time interval it is grazed, and 3) that livestock responses are not sacrificed; but if livestock gains are not as great as under continuous grazing, the improvement in range condition is adequate enough to offset any economic loss of livestock performance (Simms 1970).

Rotation or alternate grazing does offer certain advantages, these may include increased forage yields and improved species composition (Hickey and Garcia 1964). Many harmful effects of grazing can be controlled by withholding grazing at certain periods to avoid uneven utilization of forage plants, promote plant vigor and avoid excessive soil disturbance (Driscoll 1967). By carrying twice as many, or more, livestock on a portion of the rangeland riding time may be appreciably decreased (Dyksterhuis 1949). Owensby et. al. (1973) concluded from their study a rotation type grazing system would benefit a rangeland in poor condition to a greater extent than rangeland in good or excellent condition. The removal of as much vegetation as possible minimizes the potential of undesirable fire by decreasing the accumulation of inflammable material (Sampson 1914).

Rotation or alternate grazing systems are practiced without specific regard for plant reproduction (Driscoll 1967). McMillen and Williams (1944) concluded there was not any appreciable difference with regards to effect on vegetation between continuous and rotation grazing.

Deferred grazing offers forage plants a better opportunity to reproduce than does continuous or rotation type grazing systems (Driscoll 1967). This is especially true for annual plants that reproduce by seed. Grazing after inflorescence occurs aids in scattering and trampling seeds into a more favorable position for germination and subsequent growth (Simms 1970). Deferment of grazing until after seed maturity is also generally less injurious to plant health than grazing during earlier phenological stages (Jardine and Anderson 1919).

Hickey (undated) stated that deferred grazing may be a range improvement system since the amount of rest provided native forage from grazing pressure dictates species composition improvement. The rate of improvement is directly correlated to frequency and duration of rest. Perhaps the quickest manner in which to improve deteriorated rangeland with sufficient cover for natural reseeding is by complete deferment of grazing throughout the growing season.

Owensby et. al. (1973) concluded from their study a deferred type grazing system would benefit a rangeland in poor condition to a greater extent than rangeland in good or excellent condition. McMillen and Williams (1944) determined deferred spring or summer-long grazing was extremely beneficial to improving native species composition. Numerous long rests from grazing usually result in a better species composition. Short rests usually result in better growth of plants already present (Dyksterhuis 1949).

Anderson (1940) found pastures managed with a deferred grazing system have a higher livestock carrying capacity than pastures continuously grazed. Owensby et. al. (1973) concluded a deferred type grazing system permitted pastures to have greater forage production than continuously grazed pastures.

Herbel and Anderson (1959) found there was no significant increase or decrease in the relative proportion of decreasers in species composition under a deferred grazing system. A continuous grazing system moderately stocked also resulted in closer use of the forage than occurred under a deferred type of grazing system with the same carrying capacity.

Another possible disadvantage of deferred grazing is the accumulation of dead standing plants and litter which can be a fire hazard. However, the watershed and soil conservation value of accumulated litter may more than offset any fire hazard potential (Simms 1970).

CHAPTER II

STUDY AREA

Geographically the study area is located in the north central region of Oklahoma in the Reddish Prairie land resource area, and borders the Cross Timbers Land resource area (Duck and Fletcher 1943). Definitively, the study area is 19 kilometers west of Stillwater, and located in the legal land description of the SW ¼ of Section 3, SE ¼ of Section 4, T19N, R1W of the Indian Meridian.

The climate is continental, with hot summers and variable winters. The average annual temperature, measured from 1951 to 1960, was 16°C. Temperatures may exceed 37°C in the summer, with a record low of -28°C. The last killing spring frost usually occurs in April and the first killing frost of fall is generally in October. The average number of frost-free days is 211 (U.S. Dept. of Commerce, 1965).

Average yearly precipitation is 817 mm, with approximately 50% occurring from June through October. Precipitation is frequently unevenly distributed through the year, with long dry periods, which is characteristic of the Southern Great Plains region. The wind is predominantly from the south during the growing season.

The parent material of the soil on the study area are predominantly sandstone and shale. These are common parent materials and predominate through the Oklahoma Reddish Prairies (Gray and Roozitalab 1976).

The Oklahoma Reddish Prairies are 304 to 425 meters in elevation, comprising about 1.8 million hectares of rangeland. The forage production varies with soil fertility and type. The deeper, higher water holding soils produce the best forage, and have a carrying capacity of 1 Animal Unit Year per 4 to 5 hectares.

There are four dominant soil series which comprise the study area (Fig. 1 and Appendix A, Gray and Nance 1976). The Zaneis soil series (fine-loamy, mixed, thermic Udic Argiustoll) is a loamy prairie range site. The Lucien soil series (loamy, mixed, thermic shallow Udic Haplustoll) is a shallow prairie range site and typically lacks a mollic epipedon. The Renfrow soil series (fine, mixed, thermic Udertic Paleustoll) is a claypan prairie range site. The Port soil series (fine-silty, mixed, thermic Cumulic Haplustoll) is a loamy bottomland range site.

Vegetation was typically that of a tallgrass prairie in various stages of succession. Some of the dominant grass species were little bluestem, Indiangrass, silver bluestem (*Bothriochloa saccharoides*), broomsedge (*A. virginicus*), gramagrasses, fall witchgrass (*Leptoloma cognatum*), Scribner's panicum (*P. scribnerianum*) and threeawn (*Aristida* spp.). Some of the dominant forb species were western ragweed (*Ambrosia psilostachya*), heath aster (*Aster ericoides*), annual broomweed (*Gutierrezia dracunculoides*), goldenrod (*Solidago* spp.), and nightshade (*Solanum* spp.).

The soil resources in the eastern portion of the study area were abused by past management and natural erosive forces. At one time the area was used for cultivated crops and poorly implemented contour terraces were constructed. As a result, the contours were built from

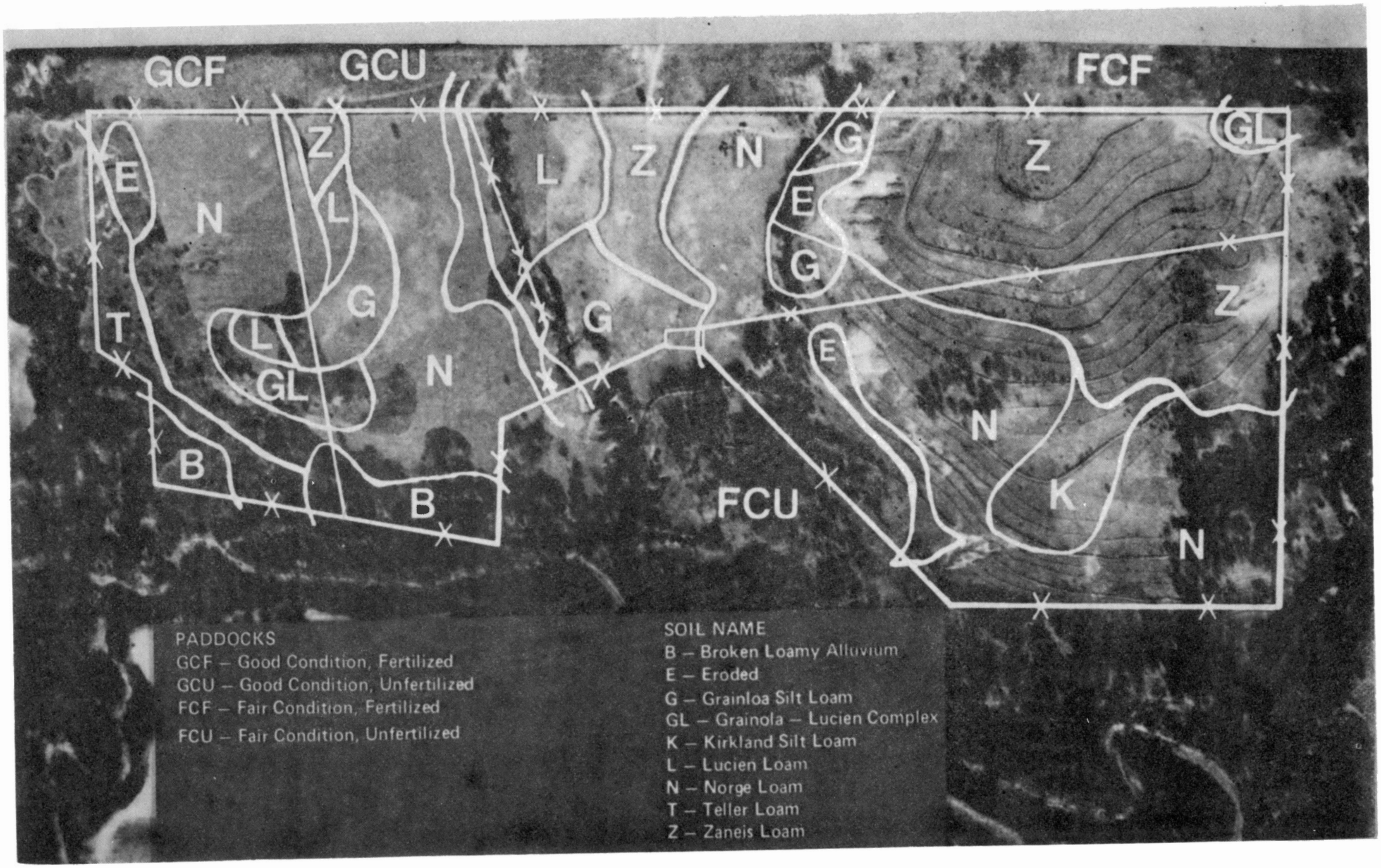


Figure 1. Aerial photo of soil series boundaries.

topsoil depleting much of the area's natural soil fertility. After cultivation ceased and the land became "go-back", overgrazing occurred. Due to past cultural practices and effect of climate the eastern portion was in fair range condition during the study.

The western portion of the study area was not nearly as abused by cultural practices as was the eastern portion. Therefore, natural erosive forces did not have as significant an effect upon the western portion, and most of the soil fertility was not depleted. Late summer cutting and removal of the native vegetation annually as prairie hay was the dominant cultural practice. Because of prior management practices the western portion was in good range condition.

CHAPTER III

PROCEDURES

The study area was divided into two replications (Fig. 2). The eastern replication was separated from the western replication by a fence running north and south along a creek. The eastern replication was subdivided by a fence running east and west. Each subdivision in the eastern replication was 9.7 ha in size. The western replication was subdivided by a fence running north and south. Each subdivision in the western replication was 4.8 ha in size.

The experiment was designed in two replication of different range conditions with two treatments in each replication. The two treatments were steers grazed on untreated rangeland, and steers grazed on rangeland that was fertilized annually in thirds over a three year period. The northern subpaddock in the eastern replication and the western subpaddock in the western replication were annually treated with fertilizer (Fig. 2). The fertilizer was applied in the springs of 1973 and 1974, and in the fall of 1974. The rate of fertilizer applied each time was 56 kg/ha of nitrogen and 20 kg/ha of actual phosphorus. The one fall application also included 18 kg/ha of potassium. The source of fertilizer was ammonium nitrate (33-0-0), triple superphosphate (0-46-0), and muriate of potash (0-0-60). The fertilizer rate was based upon initial soil test recommendation.

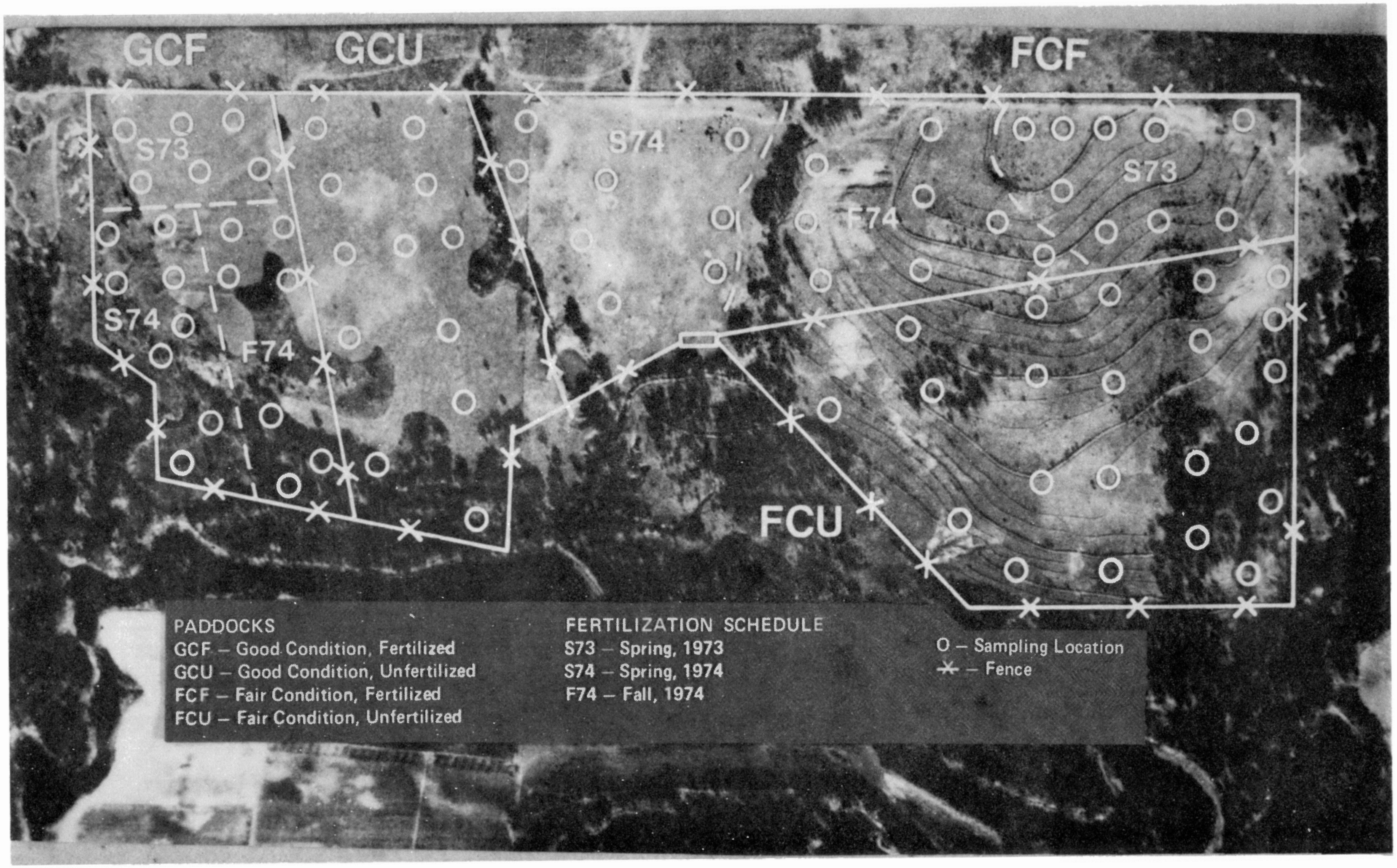


Figure 2. Aerial photo of paddock and cage locations.

Each year for three years yearling steers were placed on the study area in May and removed prior to frost. In 1973 grazing began May 15 and ended November 15. In 1974 grazing began May 15 and ended July 13. The reason for the early cessation of grazing in 1974 was primarily due to a drought. A lack of adequate summer precipitation resulted in a shortage of forage and stock water. In 1975 grazing began May 23 and ended October 10.

Beginning in August 1975 protein supplement was provided for the steers. The amount of supplement was about 1 kg of 21% crude protein range cubes per feeding fed three times a week.

The locations at which the forage was estimated and clipped plant samples taken were predetermined to prevent bias. A representative number of observations were taken on the various range sites within each subpaddock (Fig. 2). There were 25 locations in the eastern subpaddock that received fertilizer applications, 22 locations in the eastern subpaddock receiving no fertilizer, 22 locations in the western subpaddock that received fertilizer applications, and 12 locations in the western subpaddock which received no fertilizer.

Cages were located at each forage sample area. Each cage was fashioned out of interwoven wire fence to be 1 m in diameter. The caged, or ungrazed, observations were taken by removing the cage and placing a $0.5m^2$ circular steel hoop where the cage had been located. The grazed observations were taken by placing the same hoop used in determining caged vegetation 2 m from the caged location in a predetermined direction.

Whenever a forage sample was clipped the cage was anchored by stakes in a new position away from the clipped ground. If no clipping occurred at a location the cage was placed over the area where the grazed observation had been taken. The vegetation at each location inside the 0.5 m^2 hoop was estimated for both, species composition, and weight in grams of individual species using the weight estimate method (Pechanec and Pickford 1937).

In 1973 the vegetation was sampled once, November 16. In 1974 the vegetation was sampled twice, August 1 and November 20. Starting on May 23 in 1975 the vegetation was sampled every 28 days until October 10. The primary reason for the intensive sampling in 1975 was to determine the net results of three years of fertilization and grazing treatment versus no fertilization with grazing.

On a predetermined decision one out of every four sample forage locations were clipped and weighed in the field. Once the field weight was determined the clipped samples were oven-dried at a temperature of 60^{o}C to a constant weight.

All field observations were recorded on data sheets. The data was later keypunched onto computer cards. The field observations included the soil type, the subpaddock, when and if any fertilizer had been applied, climatological data, plant species composition, and weight of the individual species.

June production was the amount of vegetation within the cages. Production for the remaining sampling dates was determined by adding all prior production to the amount of caged minus grazed vegetation for a particular sampling date.

Standing biomass refers to a certain amount of vegetation at any one point in time. Grazing residue refers to the amount of vegetation remaining after a certain degree of grazing has occurred.

The terms production, standing biomass and grazing residue are necessary when discussing different effects resulting from this study. The results were derived from a grazing situation rather than a hay meadow. Hence, total production could be obtained only by adding the amount of monthly regrowth that occurred in cages. Grazing residue and standing biomass are used to differentiate the amount of vegetation remaining after grazing versus production when grazing is not a factor.

Statistical analyses were performed following the Statistical Analyses System procedures (Barr and Goodnight 1972), and using the Oklahoma State University IBM 370/158 computer.

CHAPTER IV

RESULTS AND DISCUSSION

All plant species found in the research area are listed in Appendix B. However, only those key species which were a major component of the plant communities, or were present at varying significant levels indicating a difference due to treatment effect are discussed individually. All species were classified into species classes (Table 1) based on cattle preference and climax plant communities loamy prairie range site.

Precipitation during the study was characterized by relatively short periods of low rainfall broken with heavy rains from convectional frontal thunderstorms (Fig. 3). Precipitation in those months with high amounts (100+ mm) was produced by a few, high intensity rainfall events. Because of relatively low infiltration rates (unpublished data), much of the precipitation on the area was listed as runoff. Seasonal droughts, especially in July or August, occurred during the growing season in each of the three years.

Table 1. Species classes and species within each class. (Scientific names of species are shown in Appendix B.)

Species Classes	Species Components
Herbage	All grass and forb species.
Grasses	All grass species.
Desirable	Tall plus little bluestem.
Tall	Big bluestem, Indiangrass, Switchgrass and purpletop.
Little bluestem	Little bluestem
Less Desirable	Gramagrasses, sedges, lovegrasses, fall witchgrass, silver bluestem, Scrubner's panicum and windmillgrass.
Other	Broomsedge, splitbeard bluestem, threeawn species, annuals and miscellaneous grass species.
Forbs	All forb species.
Desirable	Lespedeza species, scurfpea and catclaw sensitive brier.
Less Desirable	Western yarrow, western ragweed, Louisiana sagewort, aster species, showy partridgepea, daisy fleabane, annual broomweed, wooly plantain, blackeyed susan, nightshade species and goldenrod species.
Other	Miscellaneous forb species.

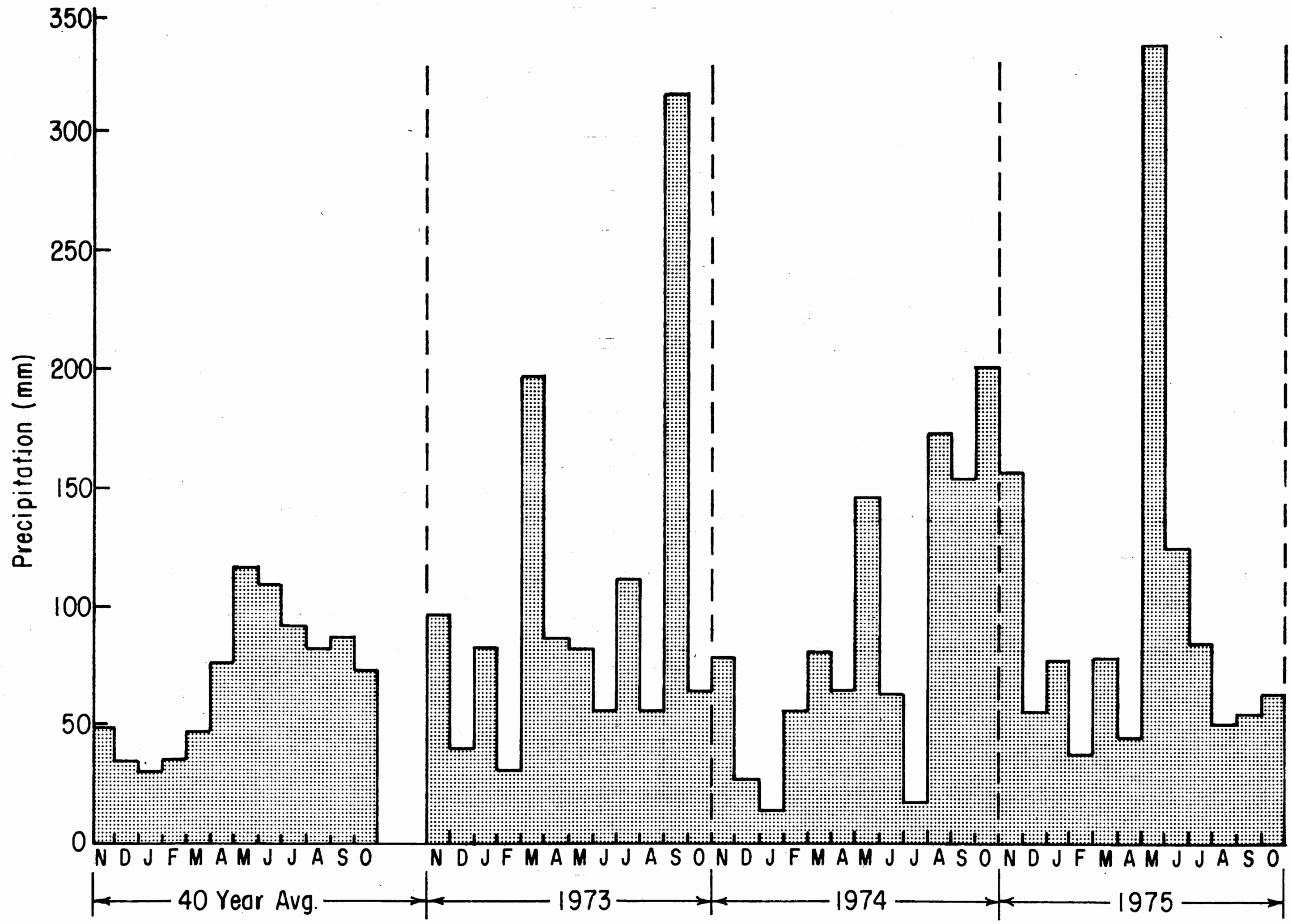


Figure 3. Monthly precipitation (mm) for long-term average and three years of study period, Stillwater.

Grazing Residue

Seasonal Effects

The total residue remaining after grazing in June was not greatly different from that in succeeding months; however, the composition of the residue did change (Fig. 4). In general, warm season, perennial grass residue was greatest in August and September and lowest at the beginning and end of the study period. The less desirable grass residue remained relatively constant for each sampling period.

Forb residue was less on each successive sampling date. Desirable and unclassified forbs were much less abundant at the end of the study, whereas less desirable forbs were reduced to a lesser extent. Most of the desirable and unclassified forbs were annuals or had a relatively early and short growing period. Many of these species are also relatively palatable during their early growth stages. Conversely, the less desirable forbs, especially western ragweed, were warm season perennials that became unpalatable early in the summer and persisted until frost.

Part of the relatively large difference in biomass in September and October was undoubtedly due to natural seed shattering and deterioration after plant maturity. Trampling may have also caused a reduction in the fall since most of the herbage present was composed of tall, coarse-stemmed plants. In September and October 90% of the standing biomass was composed of tallgrasses and less desirable grass and forbs. Low rainfall and the lack of succulent forage during the fall would force the steers to concentrate grazing on the limited palatable plants or on selected plant parts (e.g. seeds and leaves) of

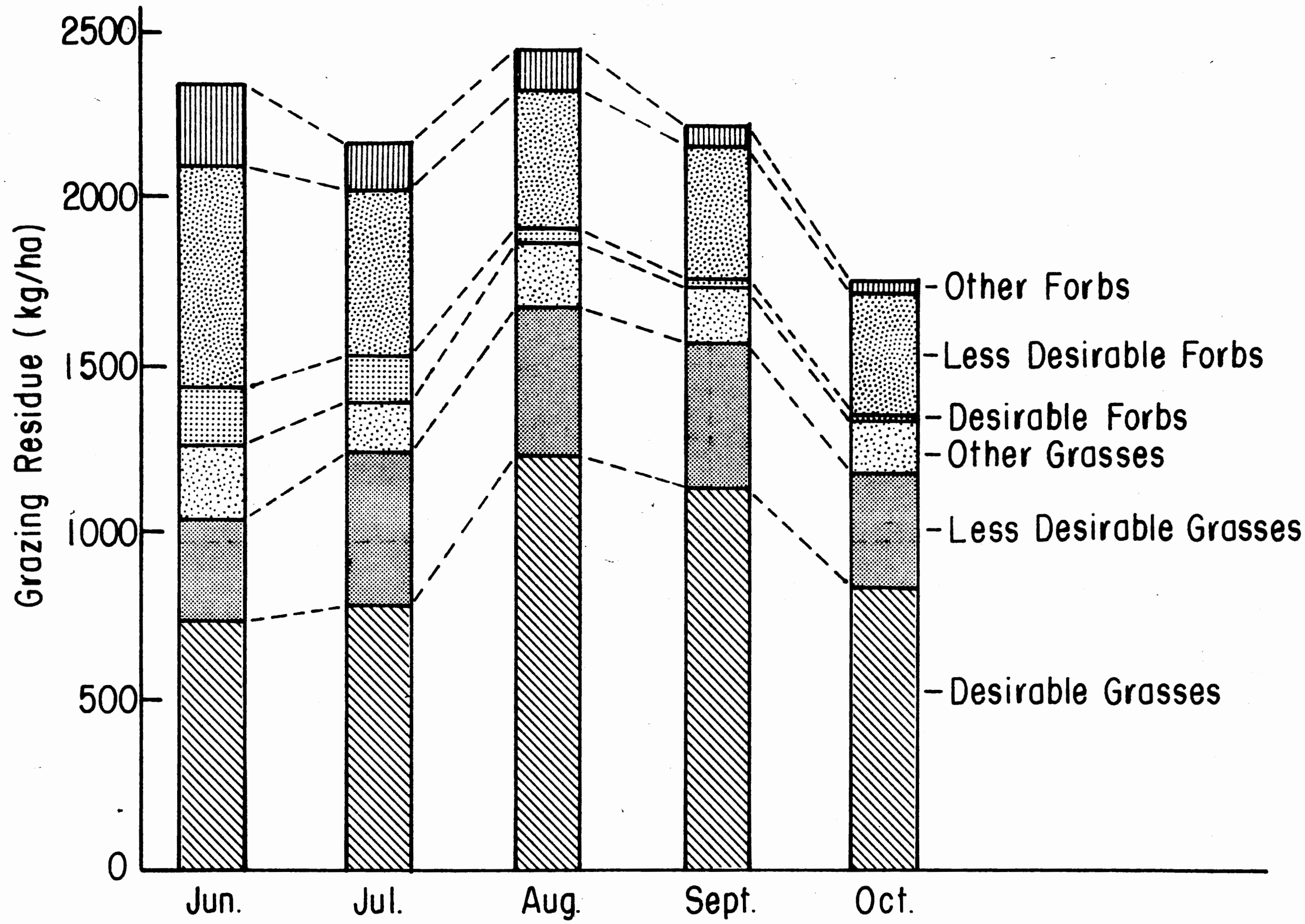


Figure 4. Average grazing residue (kg/ha,oven-dry) by species class for summer and fall sampling periods, Stillwater, 1975. Average for all treatments and range condition classes.

the coarse plants. Very little information is available concerning livestock selectivity for plant parts in the tallgrass prairie.

Fertilization

The grazing residue of either total herbage or any species class in the rotation fertilized paddocks was not different from that in the unfertilized paddocks when values from all sampling dates and range conditions were averaged (Fig. 5). In 1975 an average of about 2200 kg of oven-dry herbage per hectare remained after grazing. About 70% of this was grass. The grass component of the residue was comprised of 62% tallgrasses and little bluestem, 26% mid- and shortgrasses, and 12% other grass. The forb component was comprised of 12% desirable, 73% less desirable and 15% miscellaneous forbs. These values should be considered only for general reference because they represent the average of values from many different range sites and two range conditions.

Range Condition

Grazing residue in paddocks in good range condition (2610 kg/ha) was much greater ($P < .15$) than that (1730 kg/ha) in paddocks in fair range condition (Fig. 6). The greater amount of grazing residue in good condition areas was primarily because of the difference in tallgrasses and little bluestem. These species represented about one-third (640 kg/ha) of the total grazing residue on fair condition areas and about one-half (1250 kg/ha) of that on good condition areas. Less desirable grasses and desirable forbs were also greater on good condition rangeland.

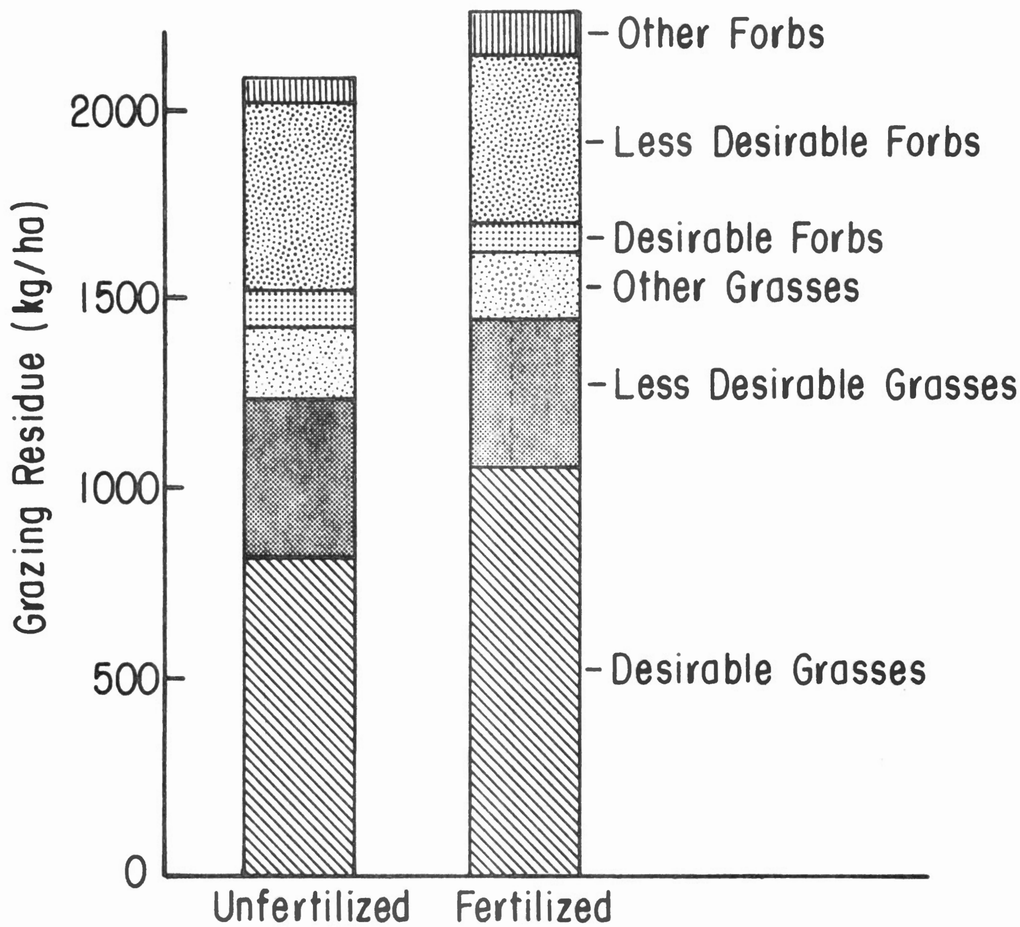


Figure 5. Average grazing residue (kg/ha, oven-dry) by species class on unfertilized and fertilized areas, Stillwater, 1975. Average for five sampling dates.

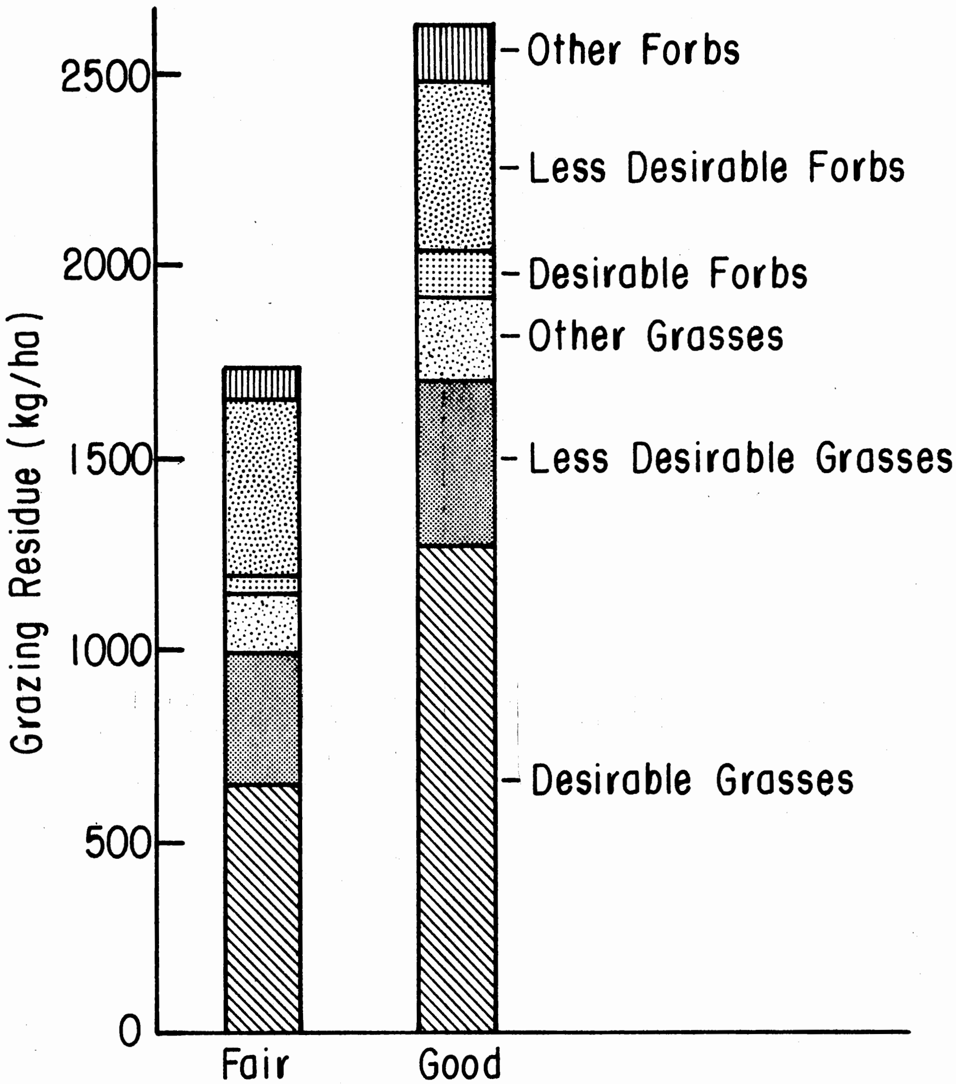


Figure 6. Average grazing residue (kg/ha, oven-dry) by species class for fair and good range condition rangeland, Stillwater, 1975. Average for all treatments and sampling periods.

Total Vegetation Production Under Grazing Conditions

Total Production on All Range Sites

Because of the numerous plant species with different growth cycles on rangeland it is often impossible for plant biomass determined at only one time during the year to accurately reflect the total biomass produced on a site in a year (Kelly et. al. 1974). For example, the production of spring annual and early maturing grasses and forbs is not measured when vegetation production is determined only at peak production of the dominant species or at the end of the growing season for warm-season perennial plants. The determination of plant biomass at only one time during the year would therefore indicate less production than actually produced by the sum of all species with their different growth cycles and different periods of peak production.

Total herbage production under grazing conditions is also difficult to determine because of the various effects of grazing on total growth and regrowth of different grazed plants. In this study a measure of total growth was determined by adding monthly growth or regrowth to the previously determined production. For example, total production in July was determined by subtracting the grazing residue in June from the caged biomass in July and adding this difference to the caged biomass in June. This was done for each sampling period and for each major species class.

The total "accumulative" production for different species classes averaged over all treatments and range condition classes is presented in Figure 7. Using this method total accumulative herbage production

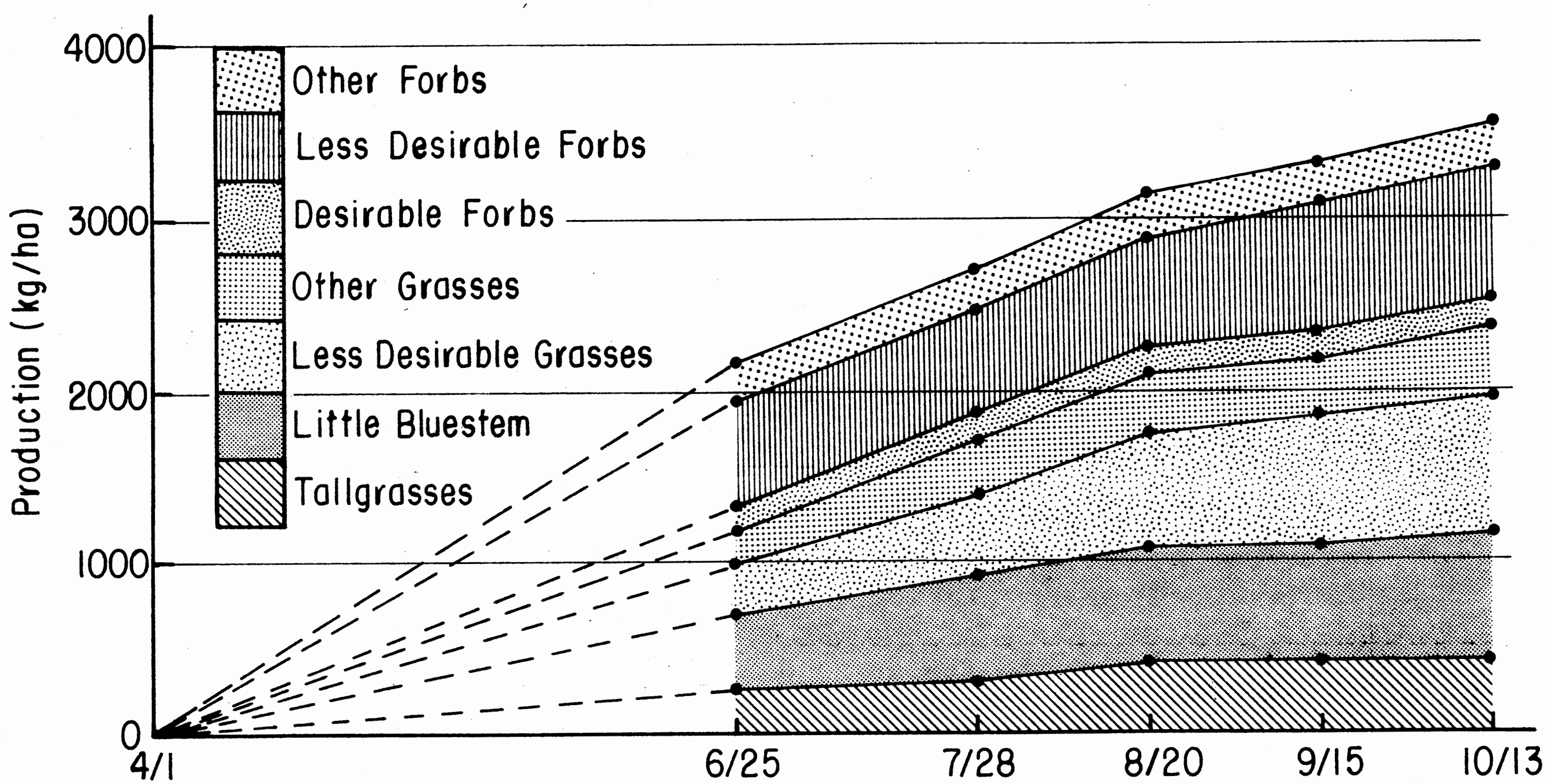


Figure 7. Accumulative production (kg/ha, oven-dry) on successive sampling dates, Stillwater, 1975. Average for all treatments and range condition classes.

was estimated to be about 3500 kg/ha by mid-October when the study was terminated.

Monthly production by different species classes was not consistent during the summer and fall growing period. Tallgrasses produced additional growth only in August and most of this additional growth was from flowering culm development and elongation. Little bluestem produced most of the additional (after June) growth in July, whereas plants in the less desirable grasses class produced additional growth during July, August, and September. Many of the less desirable grasses were late maturing perennials, such as grama grasses. Many of these species were capable of appreciable late season growth, while the tallgrass and little bluestem plants seemed to reach peak production earlier. This may have been influenced by limited rainfall in late summer.

Less desirable grasses and forbs produced more than twice as much production after June as that produced by the end of June. Species in other grasses class produced about as much production after June as that produced by the end of June. The large number of species with different growth cycles in these classes probably contributed to the more uniform monthly production increases.

Plant biomass of species in the desirable forbs and other forb classes declined between June and October. Therefore, very little additional production was added by these species after June. Both caged plant biomass and grazing residue of less desirable forbs declined by about half between June and October, but there was additional growth during this period. Total accumulative production increased from 620 kg/ha in June to 760 kg/ha in October and most of the additional production occurred in September and October. Plants in this species class were grazed each month and the caged plant biomass was greater each month than the grazing residue the previous month. This difference was also consistent for less desirable grasses. Apparently grazing stimulated regrowth for the grasses and forbs in these classes. If this apparent response is verified through additional, more intensive grazing research, the value of these species for grazing in late summer and fall may need to be reevaluated by rangeland managers and ranchers.

Total Production on Different Range Sites

A study of the data on total accumulative production indicated that production responses for plants in different species classes was not consistent for all range sites. This observation could not be statistically tested because the number of locations on two or more range sites in different paddocks was not adequate to eliminate the possible confounding effects of treatments and range conditions. However, the untested values are presented to indicate the need for future research designed to substantiate or refute the observations.

Three different range sites were selected because of the number of locations sampled on each of these sites. Fifty-six of the 81 total locations in the study were located on a loamy prairie range site. The Norge and Zaneis soil series are included in this range site. Thirty-seven of the loamy prairie locations were on fair range condition, naturally revegetated abandoned cropland grazed prior to the study and 19 locations were on unplowed good condition, "natural" rangeland used as a hay meadow prior to the study.

Twelve locations were on a shallow prairie range site which included the Grainola soil series. Eight locations were on fair condition, previously overgrazed, natural rangeland and four were on good condition natural hay meadow. Nine locations were on a loamy bottomland range site in good condition. Teller and unclassified bottomland soil series were included in this range site. The loamy bottomland range site had a nonuniform cover of trees which caused significant variation in herbage production among the limited number of locations.

Since locations on the loamy prairie represented about two-thirds of the total 81 locations on all sites, the accumulative production values on the loamy prairie (Fig. 8) were similar to those for the average of all sites (Fig. 7). Discussion concerning production responses for the average of all locations is therefore applicable to the responses of different species classes on the loamy prairie. Figure 8 is presented in order to make a more direct comparison of species class production responses on loamy prairie, shallow prairie and loamy bottomland range sites.

Total herbage production by October on the shallow prairie range site (3960 kg/ha) was slightly greater than that (3400 kg/ha) on the loamy prairie range site (Fig. 9). Most of this difference was because production at the end of June was 520 kg/ha greater on shallow prairie sites than on loamy prairie. This is in contrast to the production figures suggested by the Soil Conservation Service for shallow and loamy prairie range sites (SCS 1961). Although the differences cannot be interpreted with statistical confidence, one observed difference between the two sites in the study area deserves consideration and additional research. Most of the locations on the fair condition

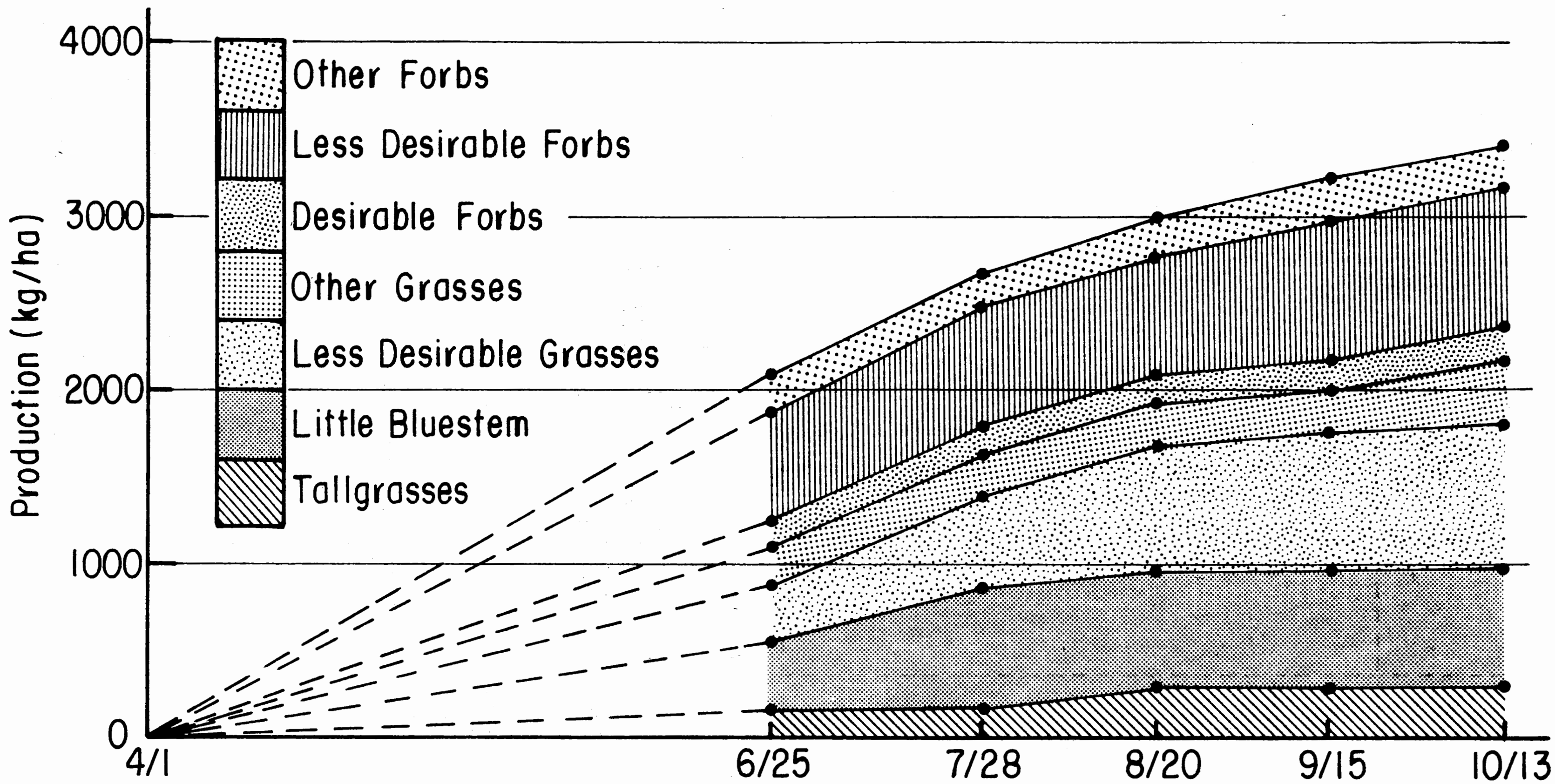


Figure 8. Accumulative production (kg/ha, oven-dry) on successive sampling data on loamy prairie range sites, Stillwater, 1975.

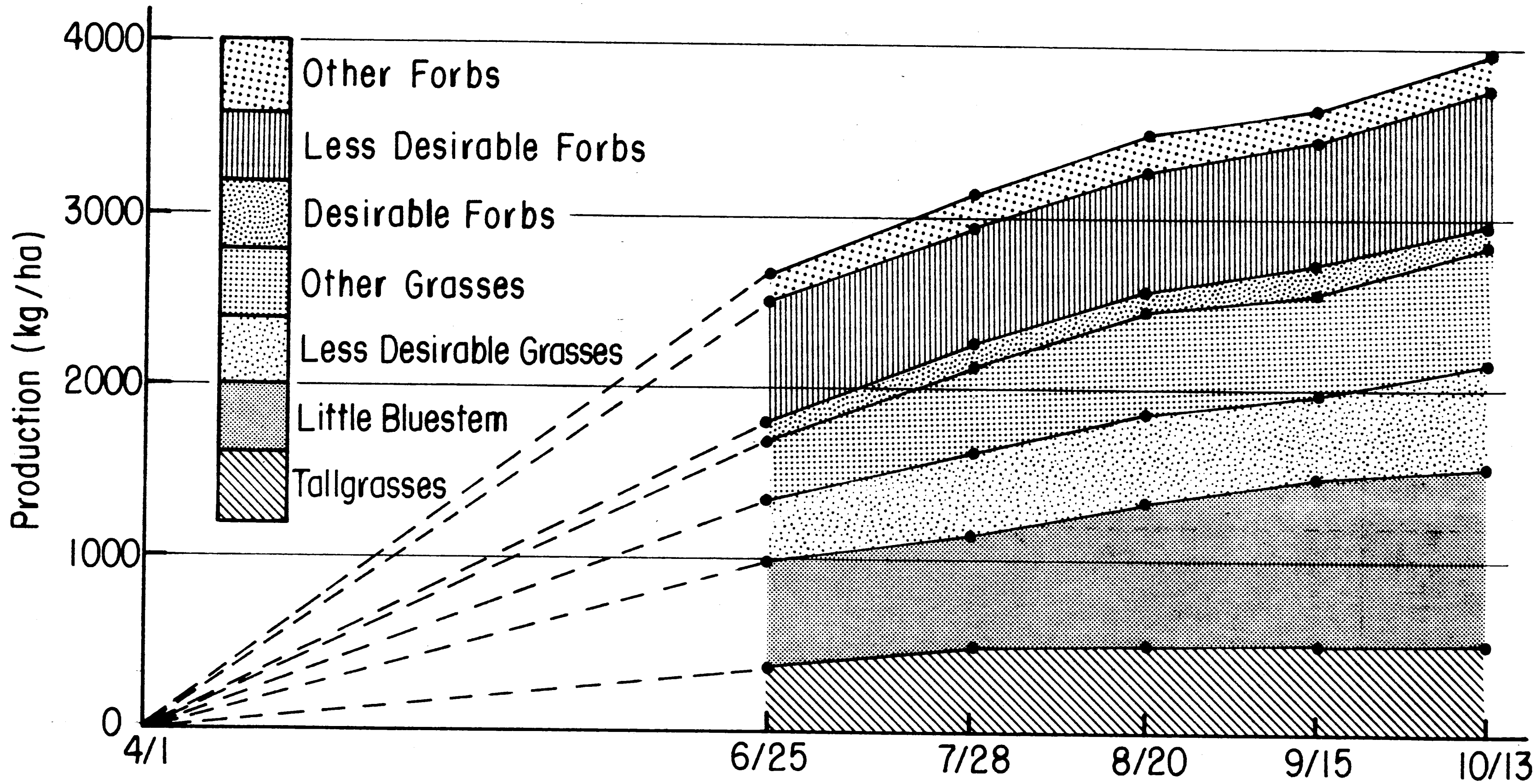


Figure 9. Accumulative production (kg/ha, oven-dry) on successive sampling dates on shallow prairie range sites, Stillwater, 1975.

shallow prairie site were on natural rangeland that showed no signs of having been plowed in the past. The locations were in the west end of the paddock indicated as "FCF" in Figures 1 and 2. However, most of the locations on the fair condition loamy prairie range site were on abandoned cropland.

Previous research by Powell (1974) in the same general area as this study showed that unplowed loamy prairie soils had higher organic matter, phosphorus, potassium and soil water content and much higher herbage production than loamy prairie soils on naturally revegetated, abandoned cropland. Although both the unplowed and previously plowed soils were classified with the same soil series, their productivity for rangeland vegetation was greatly different. Powell (1974) stated that ". . . range and soil scientists may need to reconsider range site classification and range condition guides for soils that have been plowed and cropped." Current soil survey and classification procedures using more quantitative data and measurements of physical soil factors may more accurately delineate soils that cause differences in rangeland vegetative production and species composition (Fenton Gray, Oklahoma State University Soil Scientist, 1977, Personal communication).

Little bluestem was the dominant species on the shallow prairie range site producing 1060 kg/ha by mid-October. Most of the additional growth occurred in August. Tallgrass production was only slightly greater by October than at the end of June. Limited soil water may have hastened plant maturity of tallgrasses or little bluestem plants may have been more adapted to the droughtly site than were tallgrasses.

Neither less desirable grasses or less desirable forbs produced as much additional production between June and October on the shallow site as on the loamy prairie site. Although cattle grazed plants in both species classes each month between June and October, the apparent response of these species to grazing on shallow prairie sites was not as consistent on the loamy prairie sites. Desirable forbs and other forbs produced very little additional growth in the summer and fall.

On loamy bottomland range sites total accumulative herbage production was 4890 kg/ha by mid-October (Fig. 10). More growth was produced between June and mid-October than was present at the end of June. Deeper soils with more total soil water probably allowed more consistent monthly growth than on the shallow and loamy prairie range sites. Average daily increases in herbage production for the four consecutive periods shown in Figure 10 were 25, 41, 12 and 22 kg/ha/day. The period of August 20 to September 15 produced limited growth on all range sites.

Tallgrasses more than doubled their June production between June 25 and August 20, but produced no additional growth after August 20. Most of the additional little bluestem growth occurred between June 25 and July 28 and between September 15 and October 13. Additional growth was produced each period for less desirable grasses, other grasses and less desirable forbs.

Because of better range conditions and partial shading on some locations on the loamy bottomland range sites, there was a large diversity of species. Except for tallgrasses, the other forbs species class produced more total growth than the other species classes. The composition of the other forbs or the other grasses species classes was

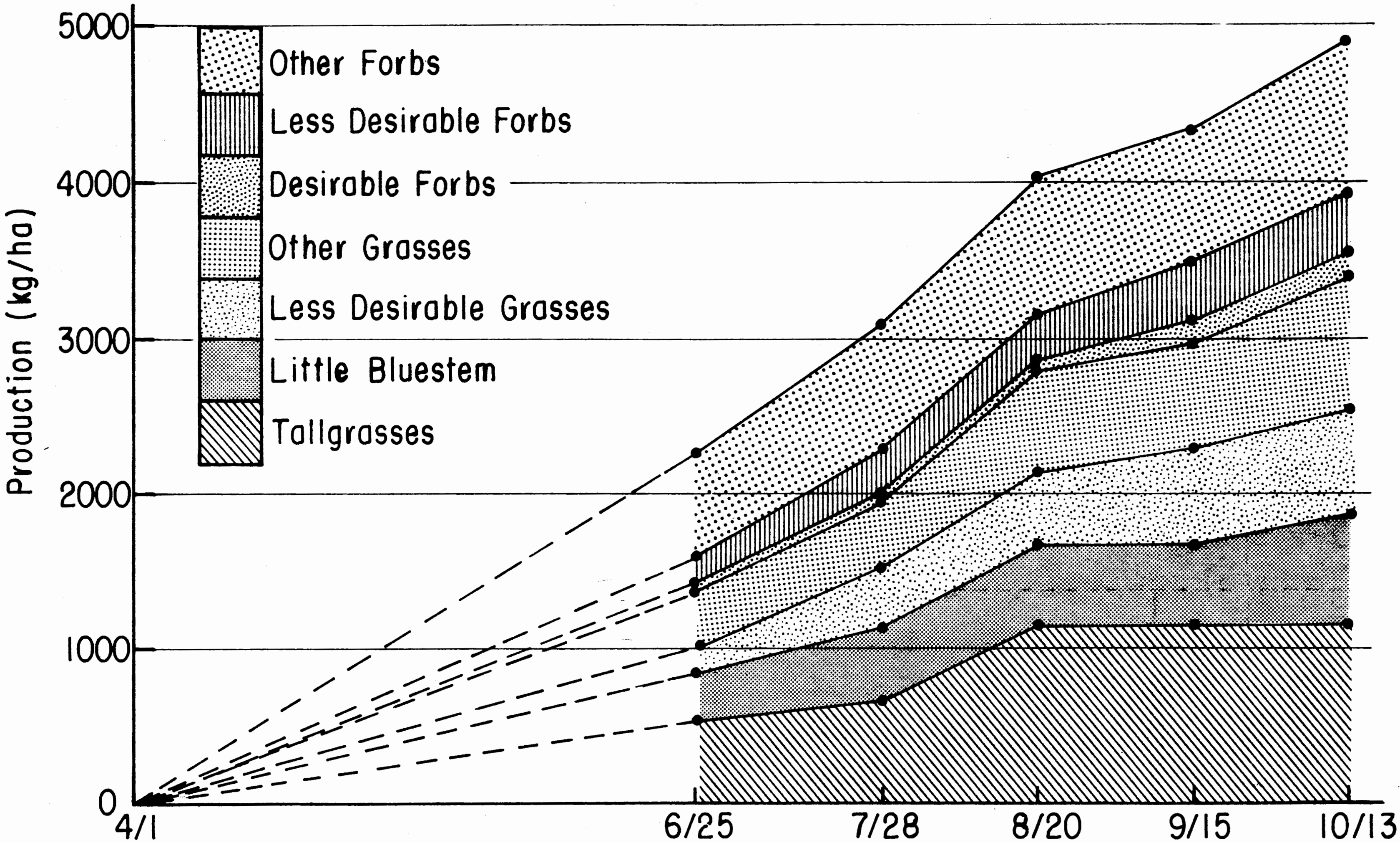


Figure 10. Accumulative production (kg/ha, oven-dry) on successive sampling dates on loamy bottomland range site in good range condition, Stillwater, 1975.

not consistent and there were no consistently dominant species in these classes.

Utilization

Monthly Utilization

The utilization of plants in different species classes in different grazing periods varied greatly (Table 2). Utilization (caged production - grazing residue) was greater than 200 kg/ha each period except between September 15 and October 13. During this period herbage utilization was determined to be -60 kg/ha. Logically, this was impossible and indicates a failure of the method used.

Spot-grazing was very common in late summer and fall and it is possible that closely grazed areas were not adequately sampled. Spot-grazing creates a mosaic of closely grazed and ungrazed areas. Consequently caged and grazed residue data were highly variable in late summer and fall. A much greater number of samples would no doubt have reduced the variance and provided a positive difference between the average caged residue and grazed residue.

Spot-grazing may not have been the only reason why grazed residue exceeded caged biomass for certain species classes and grazing periods. "Negative" utilization was most common for the desirable grasses and desirable forbs species classes. The greatest negative utilization value (-270 kg/ha) for desirable grasses was in July. At the end of this period little bluestem grazing residue was consistently greater than cage biomass on all range sites. Utilization of little bluestem was -320 kg/ha ($P < .05$) on loamy prairie, -240 kg/ha on shallow

Table 2. Monthly and total utilization[1] by species class, Stillwater, 1975.

Species Class	June (kg/ha)	July (kg/ha)	Aug. (kg/ha)	Sept. (kg/ha)	Oct. (kg/ha)	Level of Significance	June (%)	July (%)	Aug. (%)	Sept. (%)	Oct. (%)	Total (kg/ha)	Total (%)
Herbage	460	250	220	320	-60	.18	21	12	10	15	--[2]	1190	32
Grasses	250	-20	120	320	0	.18	22	--	7	19	0	660	27
Desirable	110	-270	20	180	-60	.09	16	--	2	17	--	-20	--
Less Desirable	60	210	110	100	20	.11	22	46	23	23	5	500	55
Other	80	40	-10	30	40	.55	36	28	--	22	25	180	49
Forbs	210	270	100	10	-60	.06	21	35	21	1	--	530	41
Desirable	20	100	-60	-50	-60	.05	13	68	--	--	--	-50	--
Less Desirable	110	80	150	40	30	.15	18	17	35	8	6	410	46
Other	80	90	10	20	-30	.21	34	69	33	40	--	170	57

[1] (kg/ha) - (Caged biomass - grazing residue); (%) - (Caged biomass - grazing residue) X 100/(Caged biomass); average for all treatments and range condition classes.

[2] Percent utilization not determined when caged biomass less than grazing residue.

prairie, -19 kg/ha on claypan prairie and -10 kg/ha on loamy bottomland range sites. In the last grazing period, utilization of little bluestem was -20 kg/ha, -19 kg/ha, -20 kg/ha and -60 kg/ha on loamy prairie, shallow prairie, claypan prairie and loamy bottomland range sites, respectively. Except for the claypan prairie in August, little bluestem grazing residue was always greater than caged biomass.

If the differences between little bluestem grazing residue and caged biomass were real in the second and fifth grazing periods, either grazing increased growth or cages retarded growth or both effects acted simultaneously. Research by M. McClendon and J. Powell (Oklahoma State University, 1974, Unpublished data) using similar cages on loamy bottomland vegetation indicated no difference in production between caged vegetation and uncaged, ungrazed vegetation. Additional research to determine if grazing during different phenological stages of little bluestem and under different growing conditions stimulates additional growth could provide useful information for grazing management.

The quantity of plant material consumed for different species classes was largely dependent on the amount of plant material available for each species class. The total forage consumed during the study period was 1190 kg/ha (Table 2). Most of this was provided by less desirable grasses and less desirable forbs. Plants in these species classes provided 44% of the total herbage, but 76% of the total forage consumed.

The percentage total utilization of less desirable grasses and forbs and other grasses and forbs species classes ranged from 46 to 57% of available plant material in these species classes. The relatively high percentage utilization of these species not usually considered as very desirable indicates the need for rangeland managers to reevaluate the relative value of many of these species. Under the conditions of this study and using the caged method of determining utilization, many of the less desirable species provided a significant amount of the forage consumed in summer and fall.

Fertilization

The practice of fertilizing only a portion of a paddock had very little effect on the total production of any species class. Total herbage production was 4350 kg/ha in unfertilized paddocks and 4275 kg/ha in fertilized paddocks (Table 3).

Rotation fertilization did affect the utilization of different species classes. Utilization of less desirable forbs ($P < .11$) and all forbs ($P < .06$) was increased by fertilization, whereas the utilization of desirable grasses (tallgrasses plus little bluestem) was decreased ($P < .18$). Utilization of total herbage was similar for fertilized and unfertilized paddocks.

Rotational fertilization under grazing conditions does appear promising as a means of increasing utilization of lower successional species. If this practice were continued for several years, the rate of change in species composition toward higher successional species could be increased without curtailing grazing.

Range Condition

Total herbage production on good condition rangeland was about 2400 kg/ha greater than that on fair condition rangeland (Table 4).

Table 3. Total production (kg/ha) and utilization[1/] (%) by species class on unfertilized and rotationally fertilized rangeland, Stillwater, 1975.

Species Class	Production			Utilization		
	Unfert.	Fert.	Signif.[2/]	Unfert.	Fert.	Signif.
Herbage	4350	4275	.77	30	25	.51
Grasses	2860	2870	.97	33	13	.27
Desirable	1250	1500	.64	33	-15[3/]	.18
Less Desirable	1120	880	.28	44	56	.59
Other	490	490	.97	28	35	.73
Forbs	1490	1400	.70	30	51	.06
Desirable	390	170	.13	-15	-20	-97
Less Desirable	850	850	.98	36	55	.11
Other	250	390	.63	31	71	.49

[1/]((Caged biomass - grazing residue) X 100)/(Caged biomass).

[2/]Level of significance.

[3/]Negative utilization indicates caged biomass less than grazing residue.

Table 4. Total production (kg/ha) and utilization[1/] (%) by species class on fair and good condition rangeland, Stillwater, 1975.

Species Class	Production Fair	Production Good	Signif.[2/]	Utilization Fair	Utilization Good	Signif.
Herbage	3120	5510	.06	19	31	.20
Grasses	1870	3870	.14	22	25	.85
Desirable	830	1930	.23	17	-4[3/]	.39
Less Desirable	690	1310	.11	49	51	.89
Other	350	630	.22	4	59	.19
Forbs	1250	1640	.30	19	45	.03
Desirable	290	270	.79	-83	54	.15
Less Desirable	740	960	.20	43	48	.43
Other	230	410	.56	68	34	.54

[1/]((Caged biomass - grazing residue)X 100)/(Caged biomass).

[2/]Level of significance.

[3/]Negative utilization indicates caged biomass less than grazing residue.

Most of this difference was due to grass production on good condition rangeland being more than twice as great as that on fair condition rangeland. Production of all species classes except desirable forbs was greater on good condition rangeland.

Utilization of plants on areas in different range condition classes varied with the species class. Utilization of total herbage ($P < .20$), other grasses ($P < .19$), total forbs ($P < .03$) and desirable forbs ($P < .15$) was higher on good condition rangeland. Greater utilization of forbs on good condition areas resulted in a diet of 57% grasses and 43% forbs. On fair condition areas the diet included 63% grasses and 37% forbs. The composition of total herbage was 30% forbs on good condition areas and 40% forbs on fair condition areas. Forbs provided a significant portion of the diet on both fair and condition areas; therefore, practices designed to eradicate forbs would not be desirable on rangeland grazing areas.

Range Sites

Utilization of different species classes varied widely between different range sites in the study area (Table 5). The differences between utilization on different range sites were not analyzed statistically because of confounding by treatment and range condition effects on utilization (Tables 3 and 4). However, the differences in utilization for different species classes were large enough to indicate the need for research with an experimental design wich will provide a basis for statistical analyses.

Utilization of tallgrasses, little bluestem and other grasses was greater on shallow prairie and loamy bottomland sites than on loamy

Table 5. Total utilization[1/] (%) by species class on different range sites, Stillwater, 1975.

Species Class	Range Sites[2/] LP	SH	LB	CP
Herbage	24	46	47	5
Grasses	19	49	35	-17[3/]
Desirable	-8	37	10	-58
Tall	15	83	53	-89
Little bluestem	-18	30	29	-11
Less Desirable	61	41	90	52
Other	5	71	56	20
Forbs	33	37	71	29
Desirable	-78	-7	93	-36
Less Desirable	48	57	50	36
Other	65	-15	76	70

[1/] ((Caged biomass - grazing residue)X 100)/(Caged biomass).

[2/] LP - Loamy Prairie (Average for 185 samples on fair condition, "go-back" land and 95 samples on good condition, natural land).
SH - Shallow Prairie (Average for 40 samples on fair condition, natural land and 20 samples on good condition, natural land).
LB - Loamy Bottomland (Average for 45 samples on good condition, natural land with scattered tree cover).
CP - Claypan Prairie (Average for 10 samples on fair condition, "go-back" land and 10 samples on good condition, natural land).

[3/] Negative utilization indicates caged biomass less than grazing residue.

and claypan prairie sites. Except on claypan prairie sites utilization of tallgrasses was greater than that of little bluestem. Utilization of less desirable grasses (especially shortgrasses) was greater than that of little bluestem on all sites. Apparently in the summer and fall little bluestem is not as palatable as tallgrasses and many of the lower successional species.

Forbs, especially desirable and other forbs, received heavy grazing pressure on the loamy bottomland site in good condition. Utilization of less desirable forbs ranged from 36 to 57% on the different sites and, therefore, was apparently less affected by range site characteristics than was the utilization of desirable forbs or other forbs. Utilization of less desirable grasses was consistently high on all sites and very high on loamy prairie range sites. The very high utilization of less desirable grasses and desirable forbs may have resulted from the relatively low abundance of these species on this site (Fig. 10). The cattle may have concentrated on these species if the more favorable soil water conditions on this site caused other species, such as tallgrasses and tall forbs, to have a lower leaf:stem ratio and be less palatable.

CHAPTER V

SUMMARY AND CONCLUSIONS

The amount of grazing residue was relatively consistent each sampling period, but warm-season perennial grasses increased in relative abundance as forbs declined in abundance. Fertilization caused no appreciable difference in the amount of or species composition of grazing residue. Total herbage and percentage of tallgrasses were greater in the good condition area.

Total production was much greater than grazing residue and the greatest production was on loamy bottomland range sites in good condition. Tallgrasses and little bluestem made very little additional growth after July. Less desirable grasses and less desirable forbs produced additional growth in every grazing period and appeared to respond favorably to grazing with additional growth. The summer and fall growth response by plants in different species classes varied greatly depending on range site and range condition. Most species classes produced additional growth on natural loamy bottomland range sites in good condition apparently because of more favorable soil water conditions. Little bluestem was the dominant species on the previously overgrazed, natural shallow prairie range site in fair condition, produced relatively more additional growth than did other species classes on this site, and was more responsive to grazing on the shallow and loamy prairie range sites than on the loamy bottomland site where it was less abundant and apparently less competitive. The relatively limited growth response of tallgrasses on the loamy prairie range site, usually considered to be more productive than the shallow prairie range site, indicates soil surveys and range site classifications should distinguish natural range site from naturally revegetated, abandoned cropland range sites.

Utilization of plants in different species classes and in different grazing periods varied greatly. Spot-grazing, inadequate sample numbers, or increased production due to grazing created several situations where grazing residue was significantly greater than caged plant biomass. This was especially so for desirable grasses, especially little bluestem, in July and October and for desirable forbs in August, September and October. Utilization of less desirable grasses and less desirable forbs was relatively high during all grazing periods indicating these species classes can be a valuable source of forage for summer and fall grazing. Rotational fertilization increased grazing pressure on forbs, particularly less desirable forbs, and decreased grazing pressure on tallgrasses and little bluestem. Apparently if rotational fertilization is practiced for several years, the rate of change in species composition toward higher successional species could be increased without deferring or resting fair condition rangeland from grazing. Forb utilization was much greater in good condition areas than in fair condition areas, although forbs provided a significant portion of the diet in both areas. Any range improvement program designed to reduce forb production should first consider the species and relative abundance of forbs present or a valuable source of forage could be wasted.

LITERATURE CITED

Allen, L. J., L. H. Harbers, R. R. Schalles, C. E. Owensby and E. F. Smith. 1976. Range burning and fertilizing related to nutritive value of bluestem grass. J. Range Manage. 29:306-308.

Anderson, E. W. 1969. Why proper grazing use? J. Range Manage. 22:361-363.

Anderson, K. L. 1940. Deferred grazing of bluestem pastures. Kansas Agri. Exp. Sta. Bull. 291.

Barr, A. J. and J. H. Goodnight. 1972. A user's guide to the statistical analysis system. Dept. of Statistics, North Carolina State University, Raleigh, NC.

Bartlett, E. T. 1973. The range manager's response-selecting management strategies. Soc. Range Manage. 26:5 (Abstr.).

Black, C. A. 1957. Soil-plant relationships. Wiley and Sons, New York. 792 p.

Blaser, R. E. 1964. Symposium on forage utilization: Effects of fertility levels and stage of maturity on forage nutritive value. J. Anim. Sci. 23:246-253.

Brady, N. C. 1974. The nature and properties of soils. 8th Ed. Macmillan Publishing Co., Inc., New York. 639 p.

Branson, F. A. 1953. Two new factors affecting resistance of grasses to grazing. J. Range Manage. 6:165-171.

Bryan, C. G. and W. E. McMurphy. 1968. Competition and fertilization as influences on grass seedlings. J. Range Manage. 21:98-101.

Driscoll, R. S. 1967. Managing public rangelands; systems for national forests and national grasslands. U.S.D.A., Forest Service, Rocky Mountain Forest and Range Exp. Sta., Ft. Collins, CO.

Duck, L. G. and J. B. Fletcher. 1973. A game type map of Oklahoma. Oklahoma Game and Fish Department. Oklahoma City, OK. 1 p.

Dwyer, D. D., W. C. Elder and G. Singh. Effects of heights and frequence of clipping on pure stands of range grasses in north central Oklahoma. Okla. Agri. Exp. Sta. Bull. 614. 10 p.

Dyksterhuis, E. J. 1949. Deferred and rotation grazing. The Cattlemen. 35:21.

Gould, F. W. 1968. Grass systematics. McGraw-Hill, Inc., New York. 382 p.

Graves, J. E. and W. E. McMurphy. 1969. Burning and fertilization for range improvement in central Oklahoma. J. Range Manage. 22:165-168.

Gray, F. and E. Nance. 1976. Classification and correlation of the soils of S½ of Sec. 3, SE¼ Sec. 4, T19N, R1W Lake Carl Blackwell area, Payne County, Oklahoma. Okla. St. Univ., Stillwater, OK. Unpublished research. 41 p.

Gray, F. and Roozitalab, M. H. 1976. Benchmark and key soils of Oklahoma. Okla. Agri. Exp. Sta. MP-97. 36 p.

Harlan, J. R. 1960. Production characteristics of Oklahoma forages: native range. Okla. Agri. Exp. Sta. Bull. 547. 34 p.

Harper, H. J. 1957. Effects of fertilization and climatic conditions on prairie hay. Okla. Agri. Exp. Sta. Bull. 492. 23 p.

Hazell, D. B. 1967. Effect of grazing intensity on plant composition, vigor, and production. J. Range Manage. 20:249-252.

Heady, H. F. 1975. Rangeland management. McGraw-Hill, Inc., New York. 460 p.

Herbel, C. H. and K. L. Anderson. 1959. Response of true prairie vegetation on major Flint Hills range sites to grazing treatment. Ecol. Monog. 29:171-186.

Hickey, W. C., Jr. Undated. A discussion of grazing management systems and some pertinent literature (abstracts and excerpts); 1895-1966. U.S.D.A., Forest Service, Rocky Mountain Forest and Range Exp. Sta., Ft. Collins, CO.

Hickey, W. C., Jr. and G. Garcia. 1964. Range utilization patterns as affected by fencing and class of livestock. U.S.D.A., Forest Service, Rocky Mountain Forest and Range Exp. Sta. Res. Note RM-21.

Hooper, J. F., J. P. Workman, J. B. Grumbles and C. W. Cook. 1969. Improved livestock distribution with fertilizer - a preliminary economic evaluation. J. Range Manage. 22:108-110.

Hormay, A. L. 1970. Principles of rest-rotation grazing and multiple-use land management. U.S.D.A., Forest Service, Training Text 4(2200). 25 p.

Hormay, A. L. and M. W. Talbot. 1961. Rest-rotation grazing . . . a new management for perennial bunchgrass ranges. U.S.D.A., Forest Service, Prod. Res. Rept. No. 51. 43 p.

Huffine, W. W. and W. C. Elder. 1960. Effect of fertilization on native grass pastures in Oklahoma. J. Range Manage. 13:34-36.

Humphrey, R. R. 1959. Forage and water. J. Range Manage. 12:164-169.

Hyder, D. N. 1970. The leaf-replacement potential of forage grasses. Society for Range Manage. 23:64 (Abstr).

Jardine, J. T. and M. Anderson. 1919. Range management on the national forests. U.S.D.A. Bull. No. 790. 98 p.

Kelly, J. M., G. M. Van Dyne, and W. F. Harris. 1974. Comparison of three methods of assessing grassland productivity and biomass dynamics. The Amer. Midland Natur. 92:357-369.

Launchbaugh, J. L. 1962. Soil fertility investigations and effects of commercial fertilizers on reseeded vegetation in west central Kansas. J. Range Manage. 15:27-34.

Lynd, J. Q. and J. J. Micka. 1957. Fixation and release of potassium in several eastern Oklahoma soils. Okla. Agri. Exp. Sta. Tech. Bull. 69.

McIlvain, E. H. 1961. Summary of range and pasture fertilization studies in the Southern Great Plains. U.S.D.A. Agri. Res. Serv., Woodward, OK (Mimeo).

McMillen, W. N. and O. Milliams. 1944. Range and pasture studies and grazing recommendations for Southern Great Plains. Panhandle Agri. Exp. Sta. (OK) Bull. 67. 48 p.

McMurphy, W. E. 1968. Range improvement research progress report. Okla. Agri. Exp. Sta. Pro. Series 596. 11 p.

McMurphy, W. E. 1970. Fertilization and deferment of a native hay meadow in north central Oklahoma. Oklahoma State University Agri. Exp. Sta. Bull. 678.

Meyer, B. S., D. B. Anderson, R. H. Bohning and D. G. Fratianne. 1973. Introduction to plant physiology. D. Van Nostrand Co., New York. 565 p.

Owensby, C. E., R. M. Hyde and K. L. Anderson. 1970. Effects of clipping and supplemental nitrogen and water on loamy upland bluestem range. J. Range Manage. 23:341-346.

Owensby, C. E. and J. L. Launchbaugh. 1971. Acidifying nitrogen compounds and range fertilization. J. Range Manage. 24:203-206.

Owensby, C. E., E. F. Smith and D. L. Anderson. 1973. Deferred-rotation grazing with steers in the Kansas Flint Hills. J. Range Manage. 26:393-395.

Pechanec, J. F. and G. D. Pickford. 1937. A weight estimate method for the determination of range or pasture production. Amer. Soc. Agron. J. 29:894-904.

Powell, J. 1974. Soil factors affect herbage production on Lake Carl Blackwell rangeland grazing area. Okla. Agri. Exp. Sta. Res. Rept. P-695. pp. 36-38.

Rhykerd, C. L. and C. H. Noller. 1973. The role of nitrogen in forage production. pp. 416-424. In: M. E. Heath, D. S. Metcalf and R. E. Barnes, Eds. 3rd Ed. Forages: The science of grassland and agriculture. Iowa State University Press, Ames, IA.

Sampson, A. W. 1914. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. U.S.D.A. J. of Agri. Res. 3(2):93-148.

Simms, P. L. 1970. Grazing management systems. Colorado State University Range Sci. Dept., Ft. Collins, CO. Vol. 1, No. 2.

Simms, P. L. and D. D. Dwyer. 1965. Pattern of retrogression of native vegetation in north central Oklahoma. J. Range Manage. 18:20-25.

Smika, D. E., H. J. Haas and J. F. Power. 1965. Effects of moisture and nitrogen fertilizer on growth and water use by native grass. Agron. J. 57:483-486.

Staten, H. W. 1949. Palatability trials of winter pasture crops, and effect of phosphate fertilizers on palatability. Okla. Agri. Exp. Sta. Tech. Bull. 35. 10 p.

Thompson, L. F. and C. C. Schaller. 1960. Effect of fertilization and date of planting on establishment of perennial summer grasses in south central Oklahoma. J. Range Manage. 13:70-72.

Tisdale, S. L. and W. L. Nelson. 1966. Soil fertility and fertilizers. 2nd Ed. Macmillan Co., New York. 694 p.

U.S. Dept. of Agriculture, Soil Conservation Service. 1961. Range site technical descriptions. Soil Conservation Service, Stillwater, Okla. 167 p.

U.S. Dept. of Commerce. 1965. Climatography of the U.S., No. 86-30. Climatic summary of the U.S. Supplement for 1951-1960, Oklahoma.

Vallentine, J. F. 1971. Range developments and improvements. Brigham Young University Press, Provo, Utah. 516 p.

Weed Science Society of America, Subcommittee on Standardization of Common and Botanical Names of Weeds. 1971. Composite list of weeds. Weed Sci. 19:435-476.

Woodhouse, W. W., Jr. and W. K. Griffith. 1973. Soil fertility and fertilization of forages. pp. 403-415. In: M. E. Heath, D. S. Metcalf and R. E. Barnes, Eds. 3rd Ed. Forages: The science of grassland agriculture. Iowa State University Press, Ames, IA.

Woolfold, J. S., E. F. Smith, R. R. Schalles, B. E. Brent, L. H. Harbers and C. E. Owensby. 1975. Effects of nitrogen fertilization and late-spring burning of bluestem range on diet and performance of steers. J. Range Manage. 28:190-193.

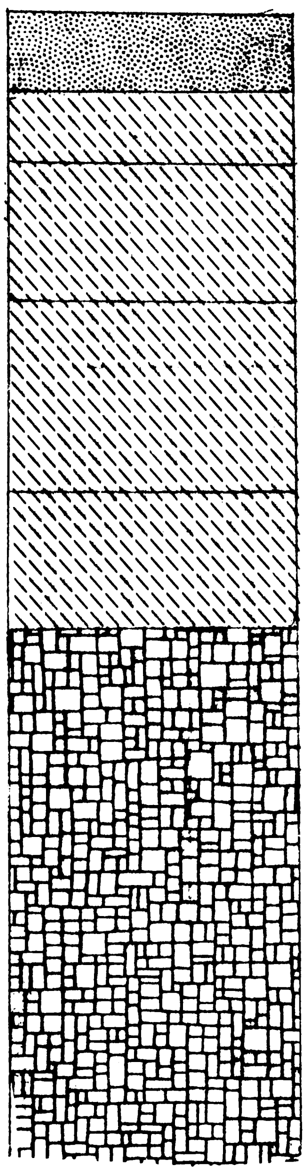
APPENDIX A

SOIL PROFILE DESCRIPTIONS

GRAINOLA SOIL PROFILE

Fine, mixed, thermic Vertic Hap Lustalf

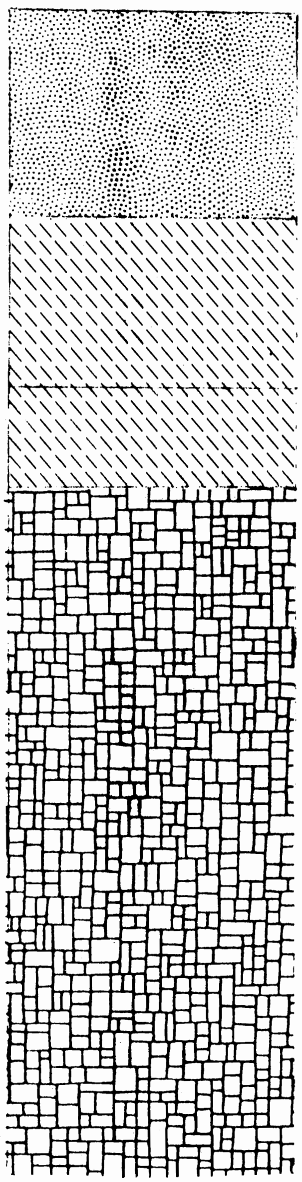
Shallow Prairie Range Site



Ap 0-10 cm.	Dark reddish brown (5YR 3/4) silt Loam; granules.
B1 10-23 cm.	Reddish brown (2.5YR 4/4) silt Loam; Subangular blocky.
B21t 23-46 cm.	Reddish brown (2.5YR 4/4) silty Clay; Blocky.
B22t 46-71 cm.	Red (2.5YR 4/6) silty Clay; Blocky.
B3t 71-96 cm.	Yellowish red (5YR 5/6) silty Clay Loam; Blocky.
Cr 96 + cm.	Bedded shale, siltstone and sandstone that varies from gray to red in color.

GRAINOLA-LUCIEN COMPLEX PROFILE

Shallow Prairie Range Site

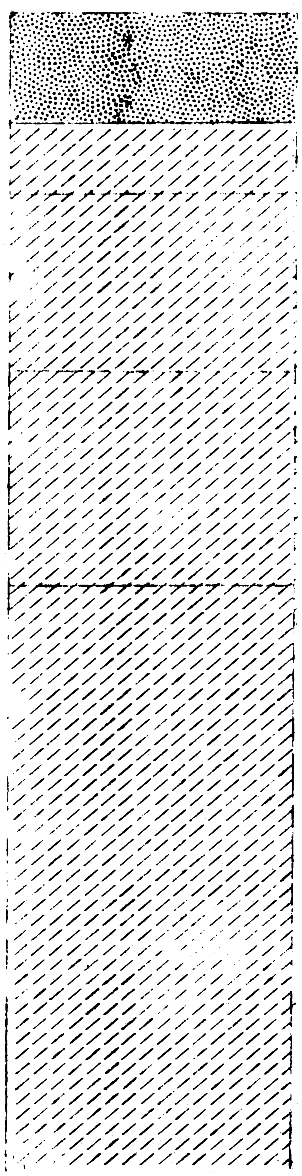


A1	0-13 cm.	Dark reddish brown (5 YR 3/3.5) Loam; Granules.
B2	13-23 cm.	Reddish brown (5YR 4/4) Loam; Subangular blocky.
B3	23-28 cm.	60% yellowish red (5YR 4/4) Loam; Subangular blocky.
Cr	28 + cm.	Paralithic bedded brown and reddish brown sandstone.

KIRKLAND SOIL PROFILE

Fine, mixed, thermic Udertic Paleustoll

Loamy Prairie Range Site

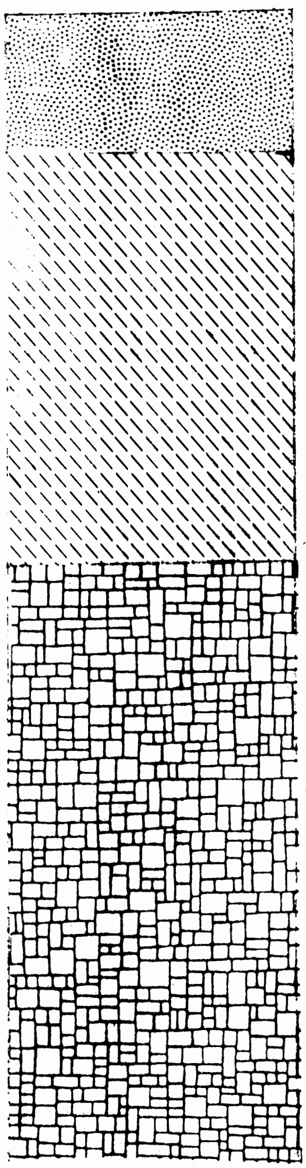


A1	0-30 cm.	Dark brown (7.5YR 3/2) silt Loam; granular.
B21t	30-43 cm.	Dark brown (7.5YR 3/2) silty clay; Subangular blocky.
B22t	43-96 cm.	Dark grayish brown (10YR 3/2) silty Clay; blocky.
B23t	96-147 cm.	Grayish brown (10YR 5/2) silty Clay; few fine distinct yellowish brown (10YR 5/6) mottles; blocky.
B24t	147-216 cm.	Coarsely mottled dark gray (10YR 4/1), grayish brown (10YR 5/2), yellowish brown (10YR 5/4, 5/6), silty clay; blocky.

LUCIEN SOIL PROFILE

Loamy, mixed, thermic, shallow Udic Haplustoll

Shallow Prairie Range Site



Ap 0-10 cm. Dark brown (10YR 4/3) Loam; granules.

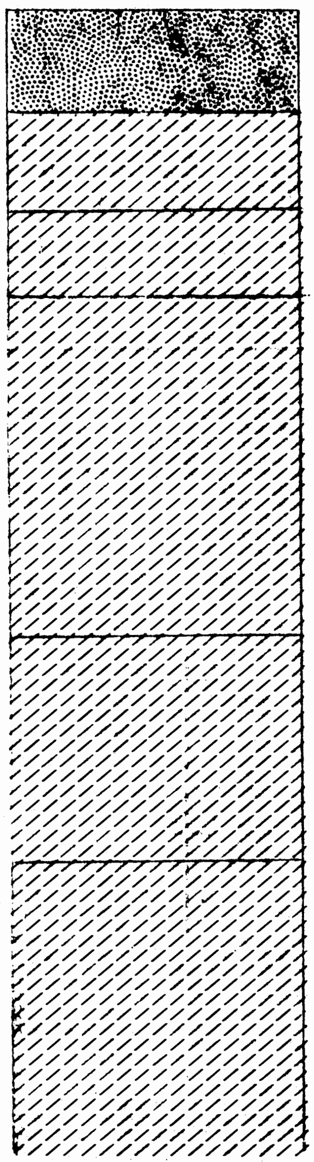
B2 10-38 cm. Reddish brown (5YR 4/4) Loam; Subangular blocky.

Cr 38-80 cm. Bedded paralithic sandstone.

NORGE SOIL PROFILE

Fine-silty, mixed, thermic Udic Paleustoll

Loamy Prairie Range Site

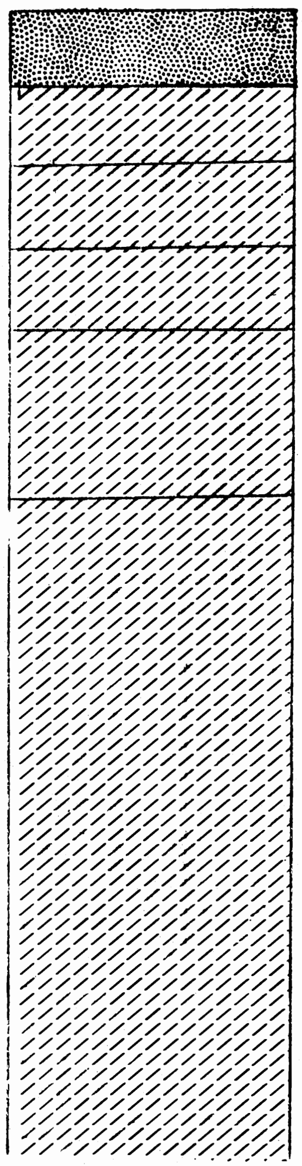


A1 0-25 cm.	Dark reddish brown (5YR 3/3) Loam; granules.
B1 25-43 cm.	Dark reddish brown (5YR 3/3) Loam; subangular blocky.
B21t 43-66 cm.	Dark reddish brown (2.5YR 3/4) Clay Loam; subangular blocky.
B22t 66-104 cm.	Reddish brown (2.5YR 4/4) Clay Loam; subangular blocky.
B23t 104-152 cm.	Reddish brown (2.5YR 4/4) Loam; subangular blocky.
B3 152-204 cm.	Red (2.4YR 4/5) Loam; Prismatic.

TELLER SOIL PROFILE

Fine-Loamy, mixed, thermic Udic Argiustoll

Loamy Prairie Range Site

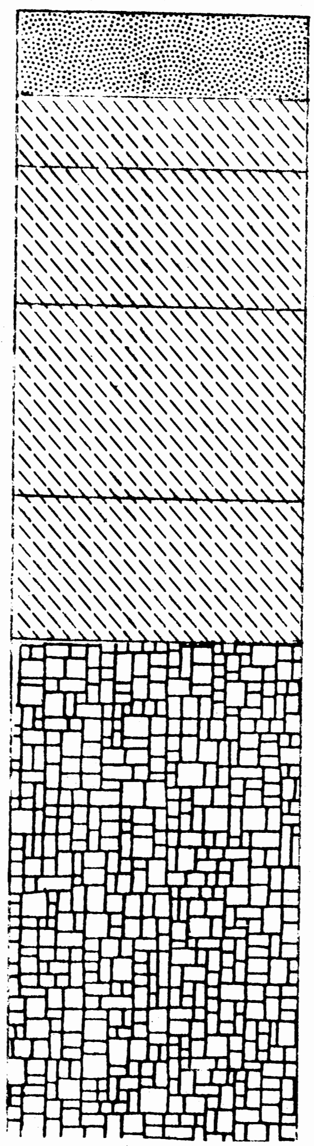


A1 0-20 cm.	Dark reddish brown (5YR 3.5/3) Loam; granules.
B1 20-43 cm.	Dark reddish brown (5YR 3/3) Loam; granules.
B21t 43-89 cm.	Reddish brown (2.5YR 4/4) Loam; Subangular blocky.
B22t 89-135 cm.	Reddish brown (2.5YR 4/4) Loam; Subangular blocky.
B31 135-193 cm.	Reddish brown (2.5YR 4/4) Loam; Prismatic.
II B32t 193-229 cm.	Reddish brown (2.5YR 4/4) Loam; Subangular blocky.

ZANEIS SOIL PROFILE

Fine-Loamy, mixed, thermic Udic Argiustoll

Loamy Prairie Range Site



Ap 0-20 cm.	Dark brown (7.5YR 3/2) Loam; Granules.
B1t 20-43 cm.	Dark reddish brown (5YR 3/3.5) Light Clay Loam; Subangular blocky.
B21t 43-76 cm.	Reddish brown (5YR 4/4) Clay Loam; Subangular blocky.
B22t 76-102 cm.	Yellowish red (5YR 4/6) sandy Clay Loam; Subangular blocky.
B3t 102-122 cm.	Yellowish red (5YR 4/8) sandy Clay Loam; Subangular blocky.
Cr 122-147 cm.	Weathered bedded yellowish red (5YR 4/6) sandstone that crushes to heavy Loam.

APPENDIX B

PLANT SPECIES ON STUDY AREA

PLANT SPECIES ON STUDY AREA

Common Name	Scientific Name
GRASSES AND GRASSLIKE	
Big Bluestem	Andropogon gerardii Vitman
Splitbeard bluestem	Andropogon ternarius Michx.
Broomsedge	Andropogon virginicus L.
Threeawn grasses	Aristida spp.
Silver bluestem	Bothriochola saccharoides Rydb.
Sideoats grama	Bouteloua curtipendula (Michx.) Torr.
Blue grama	Bouteloua gracilis (Willd. ex H.B.K.) Lag. ex Griffiths
Hairy grama	Bouteloua hirsuta Lag.
Japanese brome	Bromus japonicus Thunb.
Buffalograss	Buchloe dactyloides (Nutt.) Engelm.
Sedges	Carex spp.
Windmillgrass	Chloris verticilata Nutt.
Bermudagrass	Cynodon dactylon (L.) Pers.
Crabgrass	Digitaria sanguinalis (L.) Scop.
Lovegrasses	Eragrostis spp.
Little barley	Hordeum pusillum Nutt.
Fall witchgrass	Leptoloma cognatum (Schultes) Chase
Scribner's panicum	Panicum scribnerianum Nash.
Switchgrass	Panicum virgatum L.
Tumblegrass	Schedonnardus paniculatus (Nutt.) Trel.
Little bluestem	Schizachyrium scoparium Nash.
Indiangrass	Sorghastrum nutans (L.) Nash.
Dropseed	Sporobolus spp.

Common Name	Scientific Name
Purpletop	Tridens flavus (L.) Hitchc.
FORBS	
Prairie acacia	Acacia angustissima (Mill.) Kuntze
Western yarrow	Achillea lanulosa Nutt.
Western ragweed	Ambrosia psilostachya DC.
Lead plant	Amorpha canescens Pursh.
Louisiana sagewort	Artemisia ludoviciana Nutt.
Milkweed	Asclepiodora spp.
Heath aster	Aster ericoides L.
Wild indigo	Baptisia spp.
Showy partridgepea	Cassia fasciculata Michx.
Thistles	Cirsium spp.
Texas Croton	Croton texenus (Klotzsch) Muell. Arg.
Illinois bundleflower	Desmanthus illinoensis (Michx.) MacM.
Tick clover	Desmodium spp.
Mare's tail	Erigeron canadensis L.
Daisy fleabane	Erigeron strigosus Muhl. ex Willd.
Geranium	Geranium spp.
Annual broomweed	Gutierrezia dracunculoides (DC.) Blake
Sunflower	Helianthus spp.
Hawkweed	Hieracium longipilum Torr.
Virginia pepperweed	Lepidium virginicum L.
Lespedeza	Lespedeza spp.
Dotted gayfeather	Liatris punctata Hooker
Wooly plantain	Plantago purshii R. & S.

Common Name	Scientific Name
Scurfpea	*Psoralea tenuiflora* Pursh.
Sumac	*Rhus* spp.
Rose	*Rosa* spp.
Blackeyed Susan	*Rudbeckia hirta* L.
Prairie rosegentian	*Sabatia campestris* Nuttall
Catclaw sensitive brier	*Schrankia uncinata* Willd. (S. *Nuttallii*)
Carolina horsenettle	*Solanum carolinense* L.
Silver nightshade	*Solanum elaeagnifolium* Cav.
Goldenrod	*Solidago* spp.
Buckbrush	*Symphoricarpos orbiculatus* Moench
Western ironweed	*Vernonia baldwinii* Torr.

VITA 2

Patrick James Broyles

Candidate for the Degree of

Master of Science

Thesis: OKLAHOMA TALLGRASS PRAIRIE SPECIES COMPOSITION AND PRODUCTION RESPONSES TO ROTATION FERTILIZATION ON DIFFERENT RANGE SITES

Major Field: Agronomy

Biographical:

Personal Data: Born in Columbus, Ohio, July 5, 1950, the son of Mr. and Mrs. Nick Broyles.

Education: Graduated from Memorial High School, Tulsa, Oklahoma, in May, 1968; received Bachelor of Science degree in Agriculture from Oklahoma State University in 1975; completed requirements for the Master of Science degree at Oklahoma State University in May, 1978.

Professional Experience: U.S.D.A. Soil Conservation Service Student Trainee, 1974; graduate teaching assistant, Oklahoma State University, Agronomy Department, 1975-1977. U.S.D.A. Soil Conservation Service Range Conservationist for Osage County, 1977.