SPATIAL AND TEMPORAL CHARACTERISTICS OF PRESCRIBED RANGELAND BURNING: THE NORTHERN FLINT HILLS OF KANSAS

by

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

CHAPTER ONE

Introduction.

Introduction to the problem

The number one agricultural income earner of "Kansas, The Wheat State", is not wheat, but cattle. Of the 5.8 million head of cattle in the state, roughly 900,000 were found within the borders of the Flint Hills, the center of the range cattle industry in the state (U.S.D.A. Census of Agriculture, 1982). The Flint Hills area has 3.0 million acres (1.2 million hectares) of its approximately 4.5 million acres (1.8 million hectares) in rangeland (Barker, 1969). Such heavily utilized areas are often in ecosystems which developed not under a profit-based system of continuous heavy grazing by beef cattle, but under a system of intense, short duration use by native grazers followed by a lengthy period of little or no grazing. For economies based on the cattle industry, like Kansas and the Flint Hills, the sound management of this "growing gold" is an economic necessity which needs accurate information and judicious research, to guarantee success today, that is not at the expense of a rangeland-turned-wasteland tomorrow.

Rangelands occupy 47% of the Earth's terrain (Owensby, 1987). Rangeland is defined as "land on which the native vegetation is predominantly grasses and is suitable for browsing or grazing, including lands revegetated naturally or artificially, to provide a forage cover that is managed like native vegetation" (Society for Range Management, 1974).

The management of grazer-based rangeland resources is a balancing act between the short-term, purely profit motives of increased production of forage, number of grazers and yield from these grazers, and the long-term preservation of productivity, species diversity and ecological stability. This is quite evident in the ranching areas of the world. As profit margins become narrower and narrower, less of a ranch's budget goes toward preserving the fragile balance of soil, water, plants and animals. This often leads to increased pressure on the rangeland to produce more while leaving less for the next generation of plants and animals. The end result is degradation, often in the form of over-grazing, reduction in numbers of desirable plants and increased erosion.

Because of this difficulty in insuring a return while preserving the integrity of the rangeland resource, research into the dynamics of the rangeland's ecosystem is widespread in scope and direction. Any insights into the characteristics of the interaction among the soil, water, air, flora and fauna, and of course, humans, may be the insight which helps resource managers make wiser decisions, while preserving the ability of the land to support grazing.

One of the best tools for use in researching the grassland's complex and vast nature is remote sensing. This geographic tool uses a vantage point not in contact with the rangeland target, and senses specific dynamics of that target through selected portions of the electromagnetic spectrum. Because of remote sensing's advantages and the problems encountered with other types of investigative procedures, it has found widespread acceptance in the rangeland research community. When dealing with large area rangeland studies, remote sensing has been found to be much more efficient in terms of time, money and materials cost than any other type of data gathering procedure (Greeger, 1986).

The merging of remote sensing and the management of the rangeland results in tremendous amounts of useful data. This type of research, however, has often been performed on smaller research or other "control" type of target areas. There has been considerable work on larger areas, but these are generally of semi-arid to arid climatic types. Much research has been performed on humid rangeland areas, but the work here has been concerned primarily with the use of forested rangelands. There exists, therefore, a paucity of research on the sub-humid, tallgrass rangeland ecosystem. This lack of knowledge is even more important in light of the dramatic reduction in acreage of this once vast collection of plants and animals. This reduction is not surprising, because the area's history as a grassland, and its present climate make it ideal for cropland; so ideal in fact, that the only substantial remnant of the once mighty inland ocean of grass, is in a narrow band from southern Nebraska to northern Oklahoma, called the Kansas Flint Hills.

No historical description of Kansas would be complete without a description of the influence of the cattle industry on the State. Since the mid-1860's, when cattle drives from the southwestern U.S. to Abilene, Kansas, began, the raising, fattening, shipping and slaughtering of beef cattle has been an economic mainstay of the state. It is estimated that nearly 16 million acres (6.5 million hectares) of Kansas are in rangeland uses (May, Holko and Anderson, 1983). The contemporary importance of the Kansas cattle industry is just as well known. It is the State's number one agricultural income, higher than any crop, even Kansas' famous wheat (Self, 1978 and Kansas Board of Agriculture, 1986). In 1986 Kansas ranked, on a national basis (Kansas Board of Agriculture, 1986):

> First in red meat production by commercial slaughter plants,
> First in hides/ skins, fats/oils/grease,
> First in live animals/meat.
> First in cattle slaughtered,
> Second in all cattle on farms and
> Third in cattle and calves on grain feed.

This tremendous involvement in the cattle industry is centered in two areas of the state, the southwest where huge feedlots fatten cattle from western states and prepare them for slaughter in nearby packing plants, and the Flint Hills, which had been a finishing and fattening area for transient cattle, but now serves to hold most of the cattle for the entire year, either in steer or cow calf grazing operations (Loper, 1978). The Flint Hills comprise one of eleven physiographic regions in the State of Kansas (Figure 1).

Because of the cherty layers commonly found in the abundant limestones of the upland areas in the regionThe area is called the Flint Hills . The fertile bottomlands and adequate precipitation, about 30 inches (75 cm) per year, made the area attractive for agriculture, but the thin and rocky soil thwarted the attempts to plow the uplands, allowing only a grazing land use. Until late in the last century, the area was foraged by the massive bison herds as they followed the green-up of the rich native flora.

In the 1880's, however, a new type of grazer began to dominate the area; domestic herds of beef cattle. This holds true for the area today. The Flint Hills region is a primary region for the grass fattening of beef cattle in the Midwest. The area includes parts of 20 counties in the east central portion of the state.

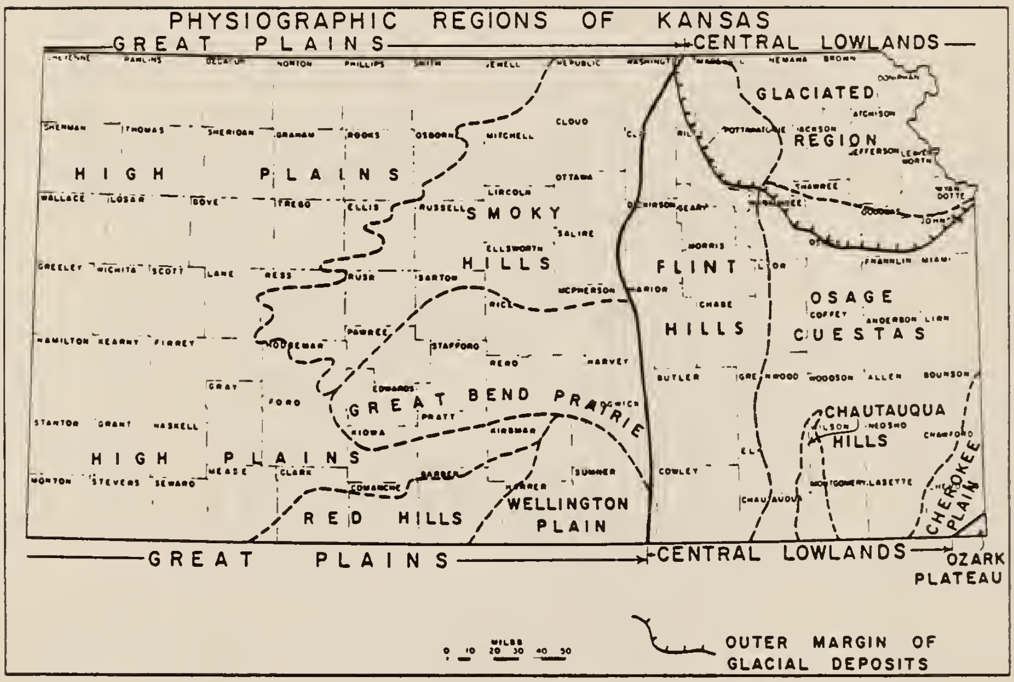


Figure 1 The Physiographic Regions of Kansas
Source: Huber Self, Environment and Man in Kansas. 1978

It is approximately 50 miles (80 kilometers) wide for most of its approximately 200 mile (320 kilometers) north to south transect of the State.

One of the most useful tools available to the ranchers of the area is that of prescribed burning. It is defined as "The use of fire in a (rangeland) management system" (Owensby, 1987). The usefulness of prescribed burning has been solidly confirmed by research and practice, and is widely accepted in the ranching and academic communities. It is of limited geographic acceptance, however, due to its specific characteristics of application benefit, and some opponents feel that all range burns are a detrimental practice, but this opposition has been shown by research to be unwarranted.

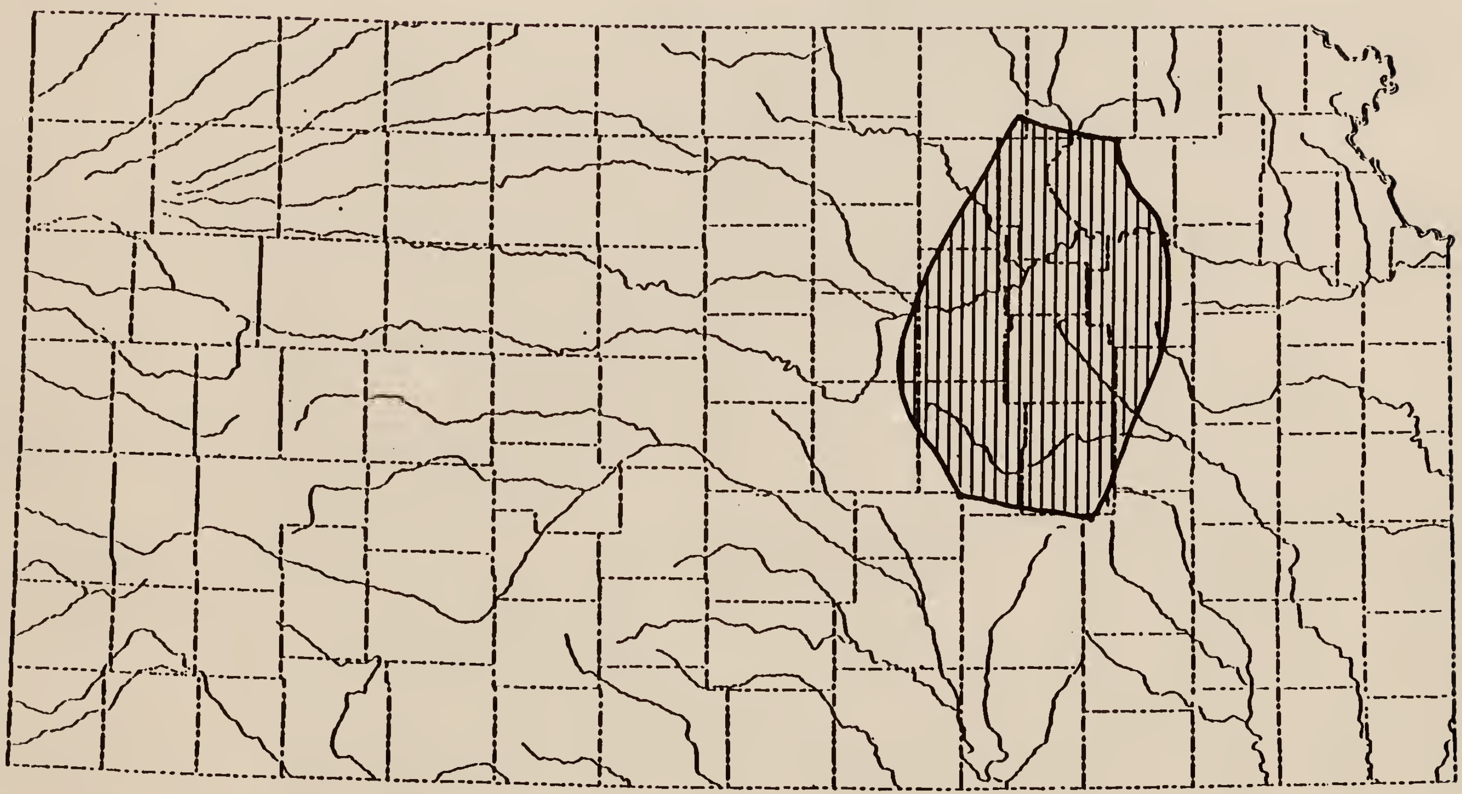
When a rancher sets a burn in the Flint Hills there are three main reasons that will probably explain the effort:

1) to increase the vigor and dominance of the desirable warm season grasses on the range site,
2) to control the invasion of woody species, particularly eastern Red cedar, onto the range site, and
3) to control invader species, weeds and cool season grasses, in a cost effective process.

Burning occurs in the Flint Hills each spring. This is timed so as to maximize the above listed benefits. This dictates that April is recommended as the time for burning in the area, with early April burning recommended in the southern parts of the region, spreading to the northern areas by the third or fourth week of the month (Ohlenbusch and Hodges, 1983). This timing allows the cool season grasses, weeds, and woody species to be adversely affected by the burn, while allowing some of the nutrients from the biomass to be returned to the now black and denuded soil. This increase in nutrients, mainly nitrogen, and increased insolation allows the warm-season grasses to dominate over the affected undesirables, and to increase their vigor and numbers (Owensby, 1987). The benefits of judicious prescribed burning techniques and timing have been well established by the agronomy and range management communities, but the questions of how much area is burned, how much area is repetitively burned, and what are the interactions between soil, slope and these burns, have not, until this study, been investigated.

This study will focus on the area of the Flint Hills shown in Figure 2. This area was chosen for three reasons:

1) prescribed burning is a common management tool throughout the Flint Hills, so no bias was introduced by studying only the northern portion of the area,
2) this area is included on one Landsat image, thereby reducing costs associated with image acquisition,
3) the proximity of the study area to Kansas State University allowed for timely and efficient performance of transects and field observations.



KANSAS

SCALE 0 20 40 MILES

The Study Area

Figure 2 The Study Area

As one of the last large areas of tallgrass prairie in the United States, ranchers in the area realize that management in the area cannot be based solely on economic returns, as they were in the past, but also on the concept of greatest possible economic return while preserving long-term stability of the resource. But decisions which have this high degree of impact and duration need accurate, timely and concise information made available to the decision makers, professors, extension personnel, law makers and most importantly, the ranchers. This Thesis may help to this end.

Problem Statement

The Kansas Flint Hills has traditionally been a beef cattle grazing area, since the time of European settlement. There is no other land use more characteristic of the area than ranching. The economic dependence of the area on ranching has made research into the dynamics of the system desirable, but many problems stand in the way of responsible research. Most evident among these problems are the vast acreages involved, land owners who are sensitive about investigation of their management practices, diverse applications of management tools and techniques and lack of up-to-date and accurate data. All of these hindrances lead to a research platform which does not allow efficient, cost effective research with conventional means.

Remote sensing techniques have been found to be useful when applied to the tasks of documentation, classification and monitoring of rangeland resources. The vast acreages and different approaches to the management of the range resource have long been obstacles to researchers investigating these areas. These problems have been especially evident in the study of prescribed burning, a common management tool in the Flint Hills, which has received considerable attention on small and controlled plots. However, the majority of the burns in the area occur on private, profit-motivated ranches where experimental control conditions are not practical. Therefore, the dynamics of prescribed burning are known, but the monitoring of these dynamics in the field has been limited in scope and area. The opportunistic nature of prescribed burning, based on everchanging weather and atmospheric variables, unpredictable range condition, and rancher perceptions and opinions of burning, all lead to considerable amounts of burning occurring in the few weeks of early spring each year.

Although considerable rangeland research work has been performed in the Flint Hills region, the best available information as to amount of acreage burned in the region is an estimate of "about 30-40% each year" (Owensby, 1987). For this 30-40%, there are no accurate estimates of where this burning occurs, whether it is a repetitive burn, and what are the spatial relationships between soil, slope, weather and the burn characteristics. It is the purpose of this study to provide accurate estimates of the variables of the amount of burning that occurs in the Flint Hills, where this burning occurs in time and space, the repetitive nature of the burns, and the interactions of soil, slope and weather and these burns, through the use of Landsat data, personal observations and aerial reconnaissance.

The findings will present estimates of the:

1) areal extent of burning,
2) spatial distribution of the burns,
3) repetitive nature of the burns,
4) temporal dynamics of the burns and
5) relationships between burned areas and slope, soil and weather.

Justification

As seen by this researcher, the main emphasis of the discipline of geography should be the study of humans and their interactions with their environment. Key to this theme is the concept of land use and resource management. The geographer should be keenly aware of the spatial and temporal dynamics of the subject studied, so as to discover or relate the conditions brought about by the human involvement.

The manner in which this information will be gathered is through the use of remote sensing, one of the most accepted and when used correctly, one of the most accurate tools at the disposal of the geographer.

Without the use of remote sensing, the researcher of very large, difficult to traverse areas of homogeneous nature, with data of dubious accuracy or of sensitive ownership, is left to perform research which will reflect the compromised nature of the project.
With the careful and prudent use of remote sensing and the necessary small scale field checking, however, these obstacles can be all but eliminated.

Methodology

This study has four main research goals. They are to:

1) Determine how much prescribed rangeland burning occurred in the northern Flint Hills for the springs of 1985, 1986, 1987 and 1988,
2) determine when these burns occurred,
3) describe the characteristics of slope, soil and weather, for the burned areas and their relationships to the time and occurrence of burns, and,
4) present the findings in written, tabular, graphic and cartographic forms.

To perform this study Landsat data, in the form of fourteen 1:1,000,000 scale black and white positive transparencies, were used. They were taken from path 28, row 33 from the "Worldwide Referencing System" of geographic coordination used by EOSAT and U.S.G.S., for the Landsat satellite system. Each of these images represents the data taken for a single date, and was centered near the point of North 38 degrees, 54 minutes, West 96 degrees, 57 minutes (Figure 3).

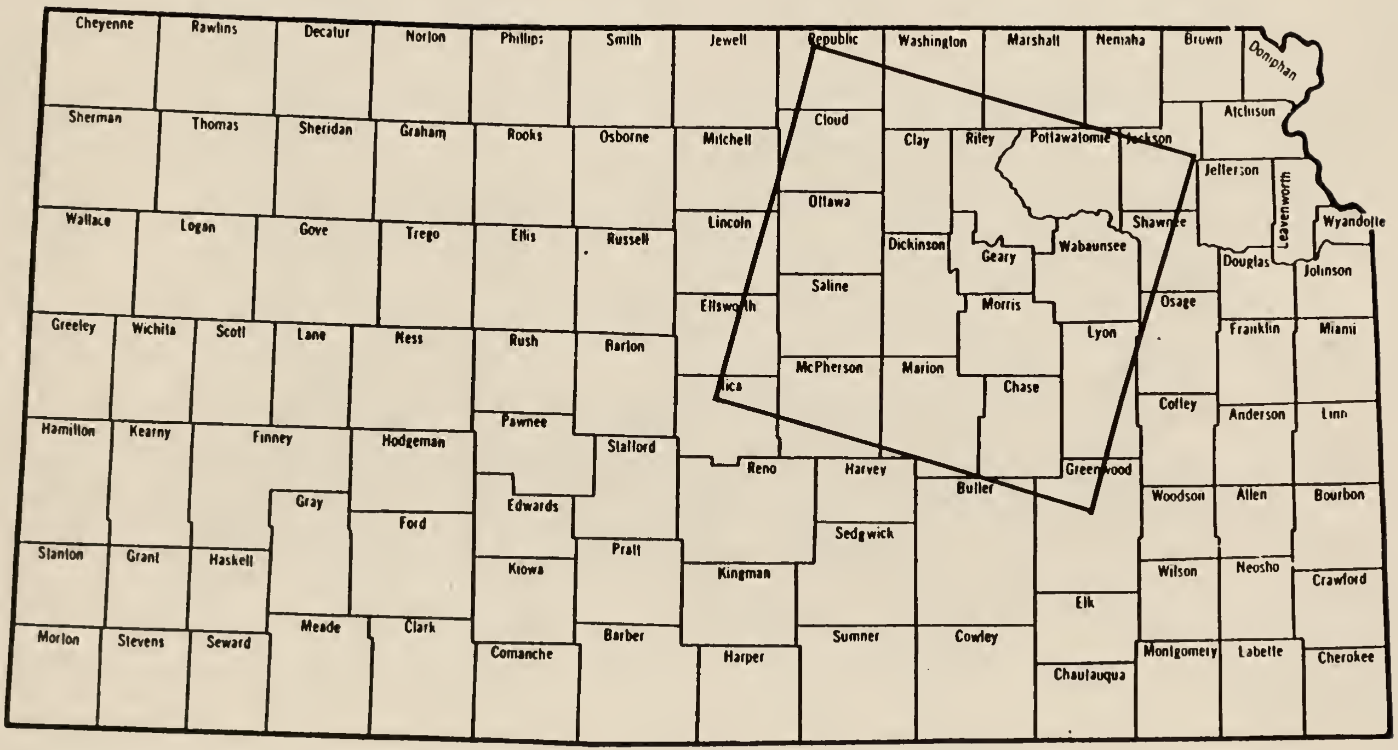


Figure 3 The Location of Landsat Scene Path 28 Row 33

Of the 14 dates, 4 were from each of the three years of the study, 1985, 1986 and 1987. Two were from the 1988 year. The selected dates were 18 March, 03 April, 19 April, and 22 June in 1985; 17 February, 21 March, 14 April, and 22 April in 1986; 09 April, 17 April, 25 April, and 11 May in 1987; and 11 April and 13 May in 1988. The transparencies were, on a Map-o-Graph machine, enlarged to a scale of 1:250,000. A burned area vs. non-burned area classification scheme was designed to guide the interpretation process (Table 1). All areas interpreted as burned were then mapped onto a mylar sheet.

The dates of 22 June 1985, 17 February 1986 and 11 May 1987 were not transferred to mylar sheets due to overpass dates outside the burn schedule or prohibitive cloud cover. The mapping onto mylar procedure was performed on each of the 11 image dates used (Figures 4 through 14). Then, each of the burn images at 1:250,000, was digitized using the "Sigma-Scan" software package for the IBM-PC.[1] This resulted in estimates of area for each of the burned area polygons mapped.

Table 1
Prescribed Burned Area Selective Key

- The polygon is very dark in tone.
- The polygon in question is much darker in tone than the surrounding land use.
- The polygon has visible texture.
- The outside border of the polygon is not dendritic in shape.
- The polygon is located in an upland location.

Prescribed Burned Area Dichotomous Key

```
                  Is the polygon's outside
                 border of dendritic shape?
                   /                    \
        Is the polygon           Is the polygon located
       very dark toned?          in an upland location?
                                     /             \
   Is the polygon's     \      Is it of very     It is not
  tone lighter on        \      dark tone?       rangeland
   its narrow end?        \                  \
                                    |          \
        |           \     Does the map indicate   It is
        |            \    the polygon is a pond? not range
                                   |          \
The polygon is  The polygon  The polygon  The polygon
a reservoir     is a river   is a pond    is
                valley                    recently
                                          burned range
                                          unit
```

For this study of prescribed burning in the Flint Hills of Kansas, Landsat 5 Band 4 data was used. Band 4, which is the longest wave band sensor in the Multi-Spectral Scanner (M.S.S.), sensing from .8 to 1.1 micrometers, was chosen because of its ability to quantify the reflectance values of the target in the near infra-red portion of the electromagnetic spectrum. This occurs because energy in this area of the spectrum is reflected vigorously by healthy green plants.

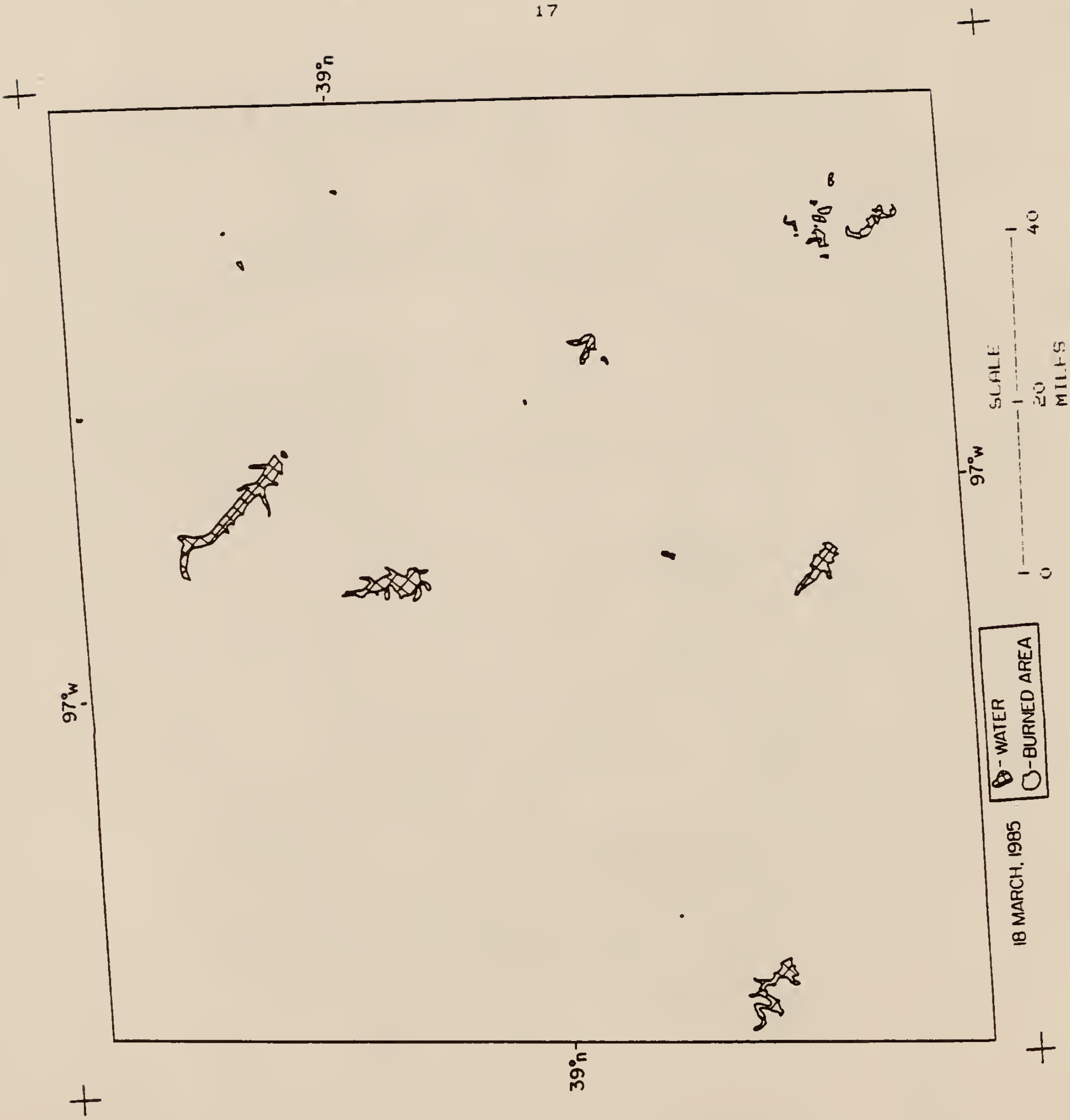


Figure 4 The 18 March, 1985 Burn Map

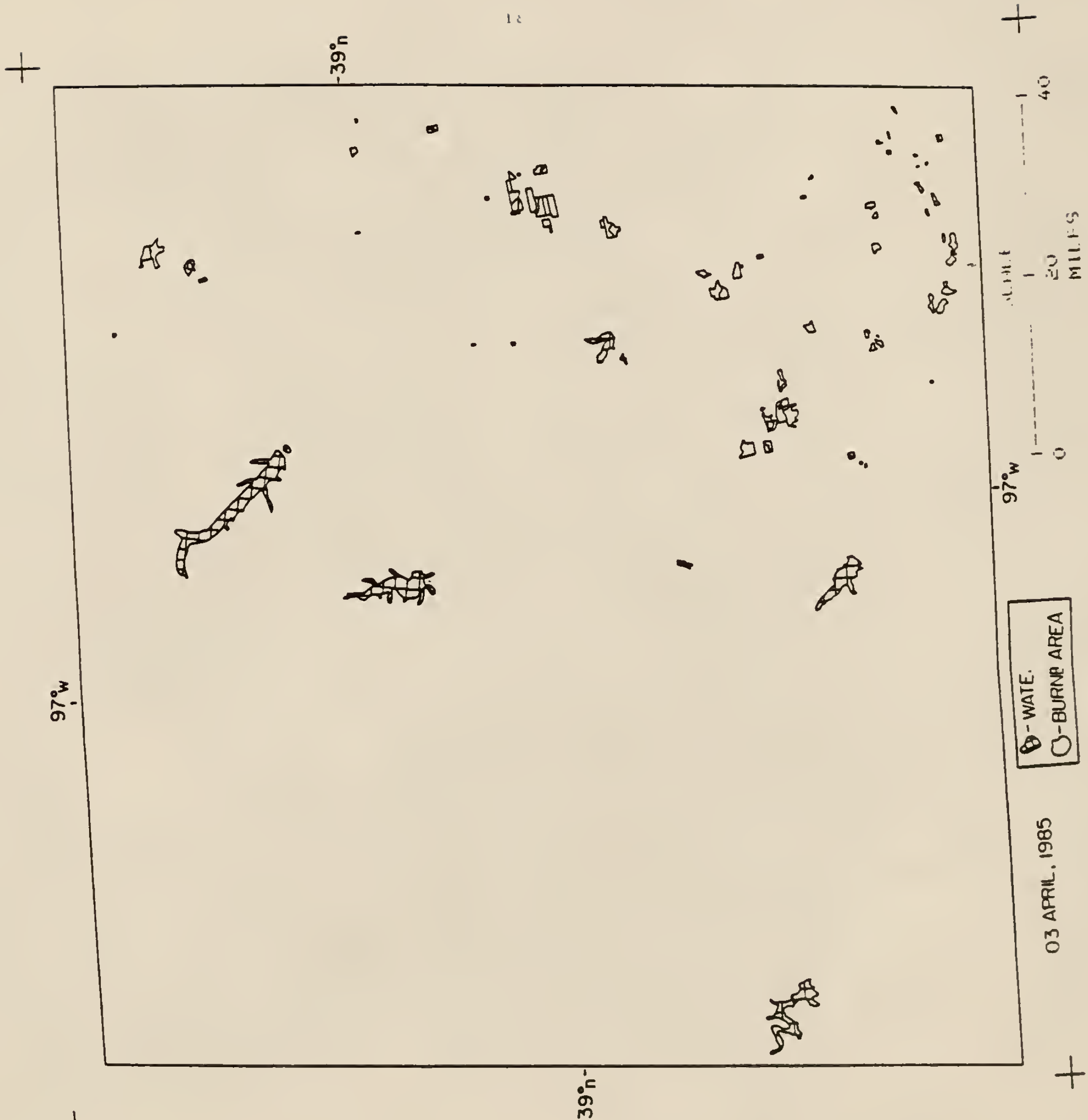


Figure 5 The 03 April, 1985 Burn Map

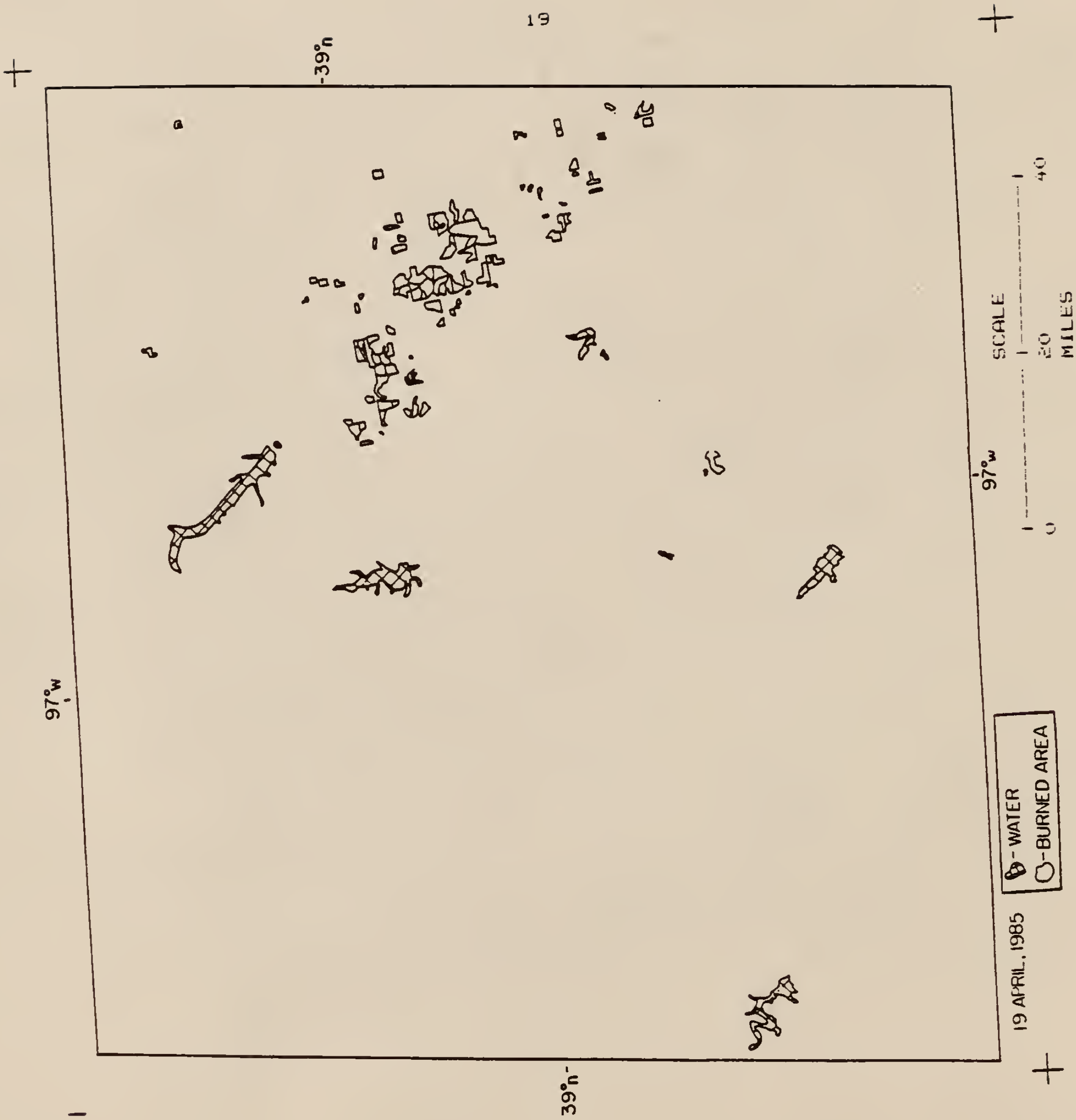


Figure 6 The 19 April, 1985 Burn Map

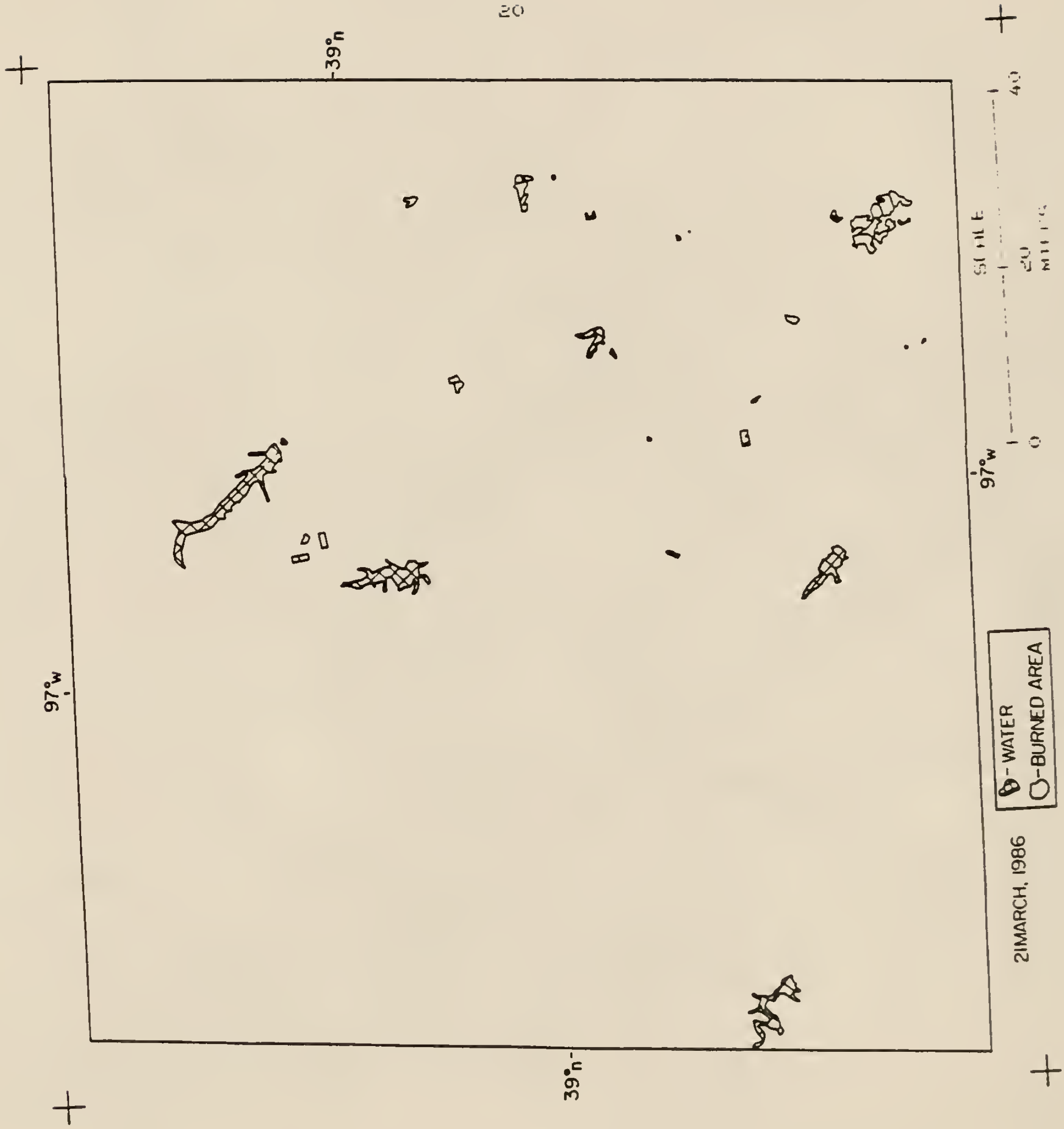


Figure 7 The 21 March, 1985 Burn Map

Figure 8 The 14 April, 1986 Burn Map

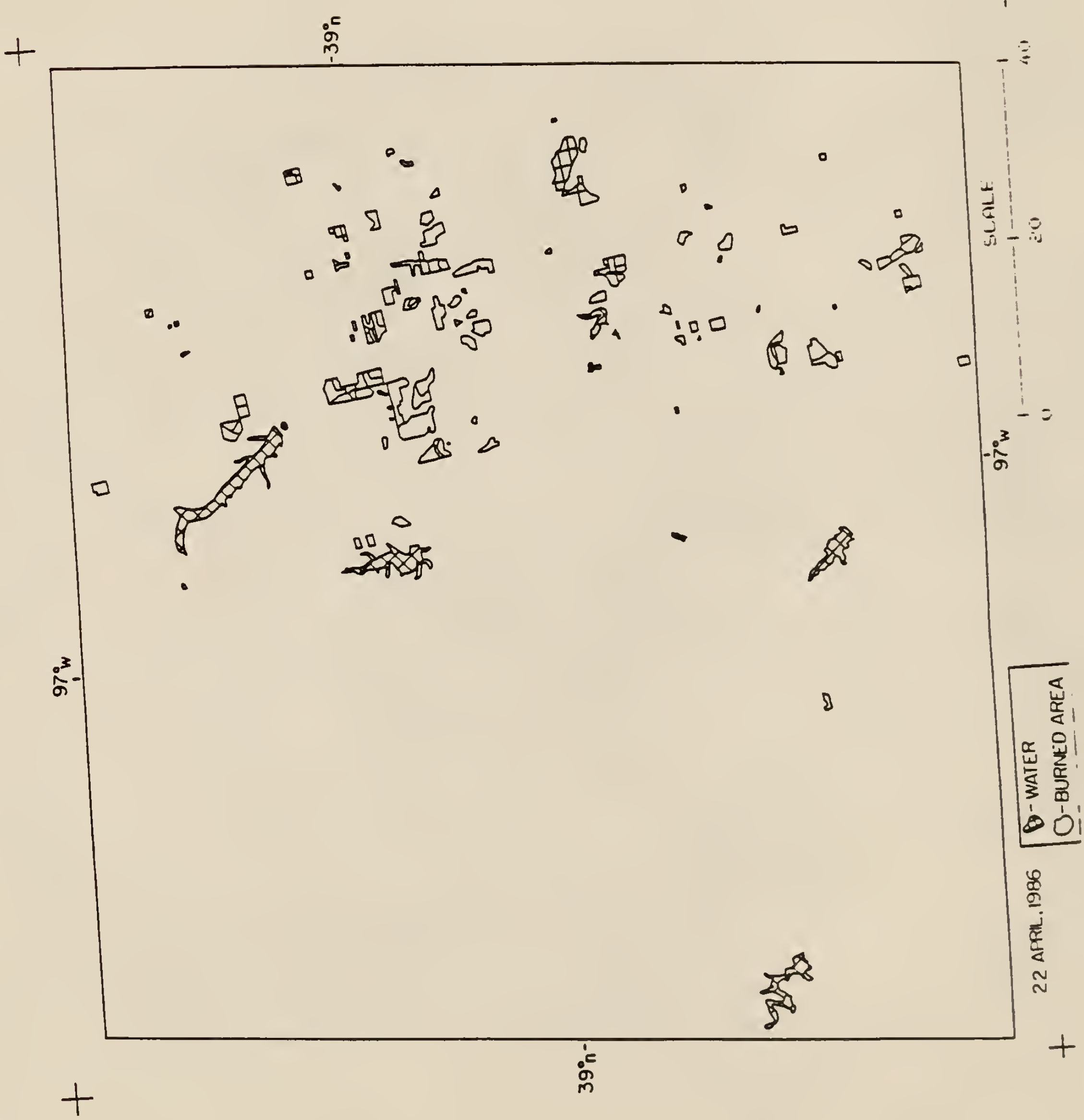


Figure 9 The 22 April, 1986 Burn Map

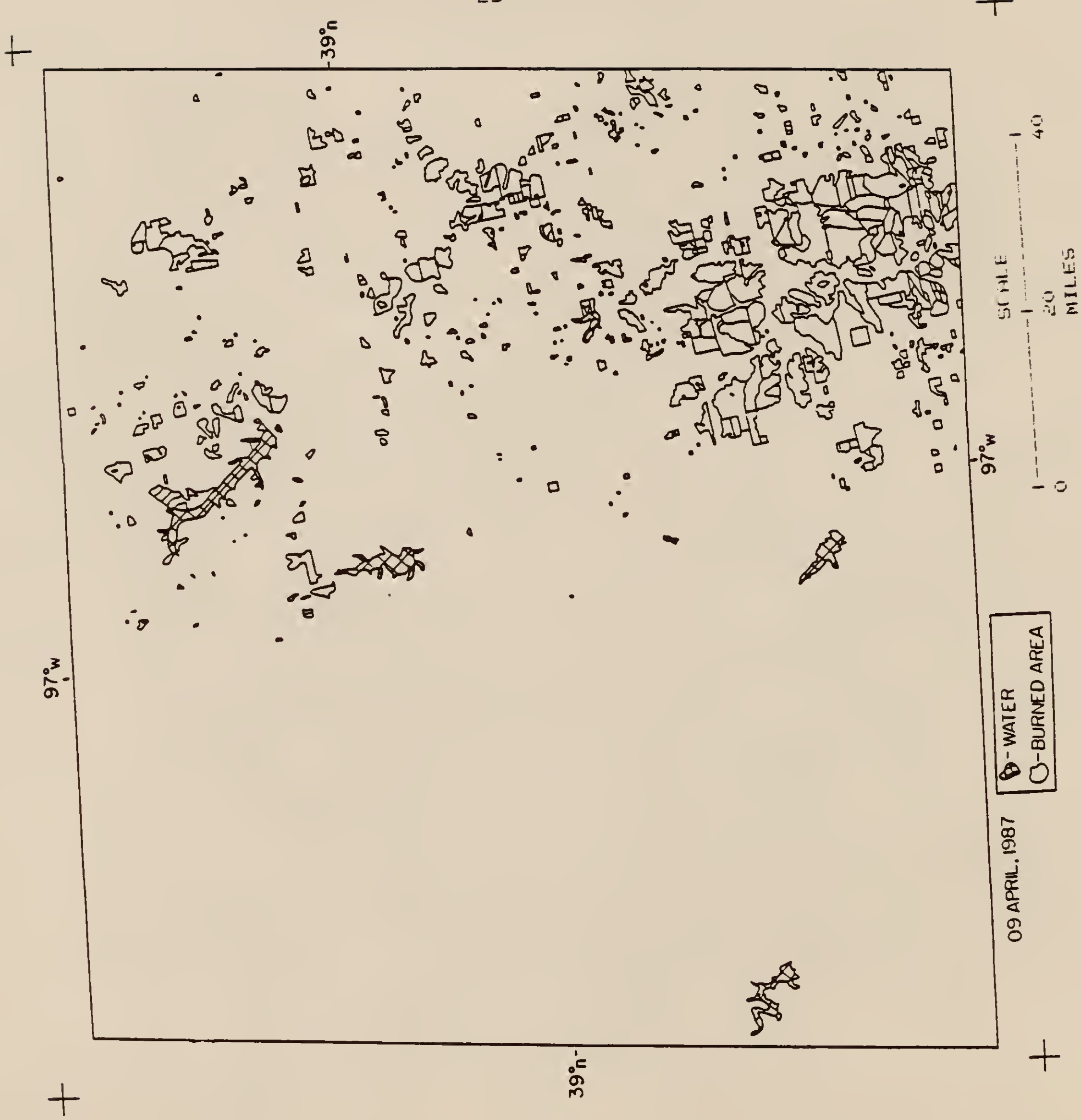


Figure 10 The 09 April, 1987 Burn Map

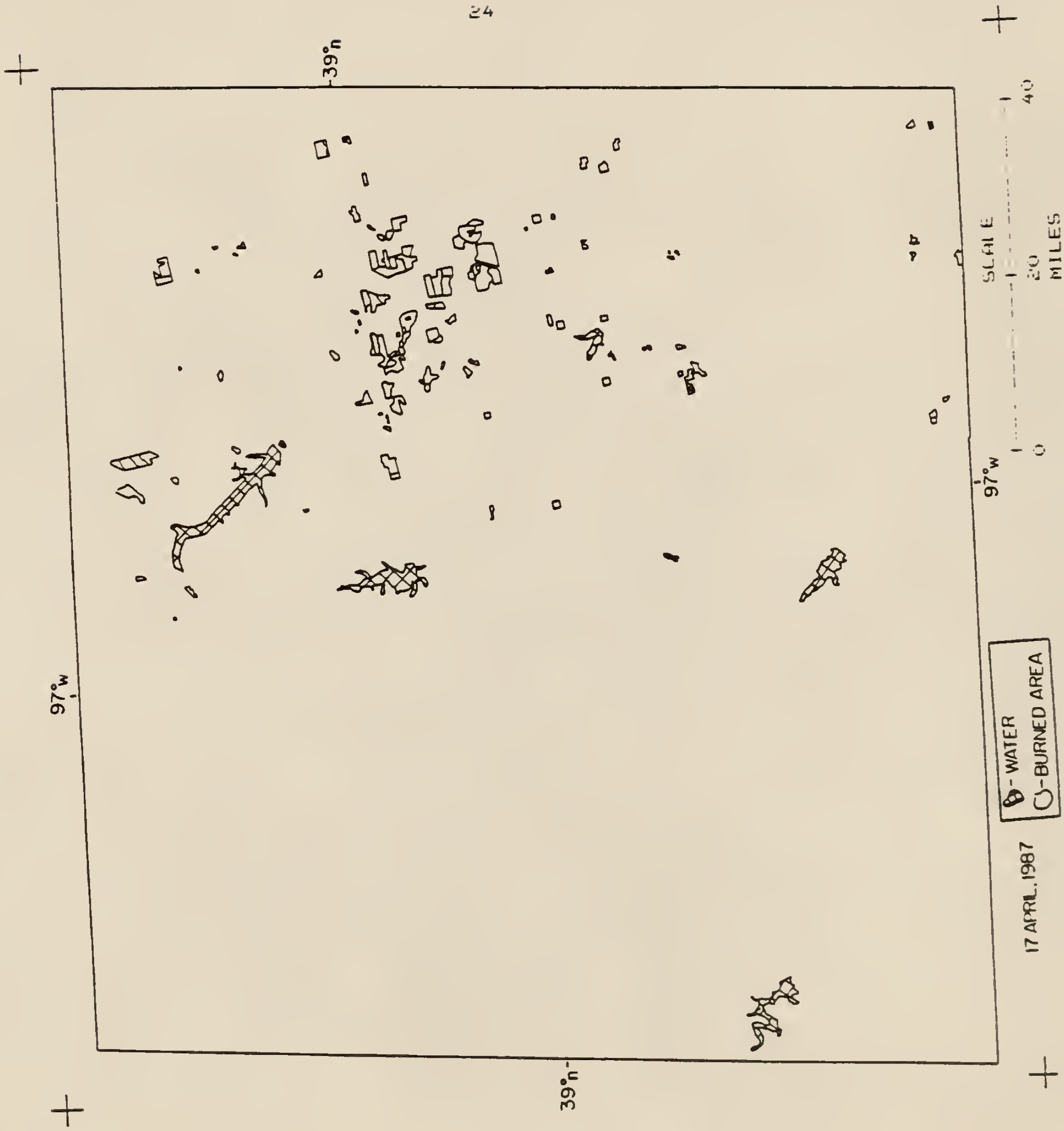


Figure 11 The 17 April, 1987 Burn Map

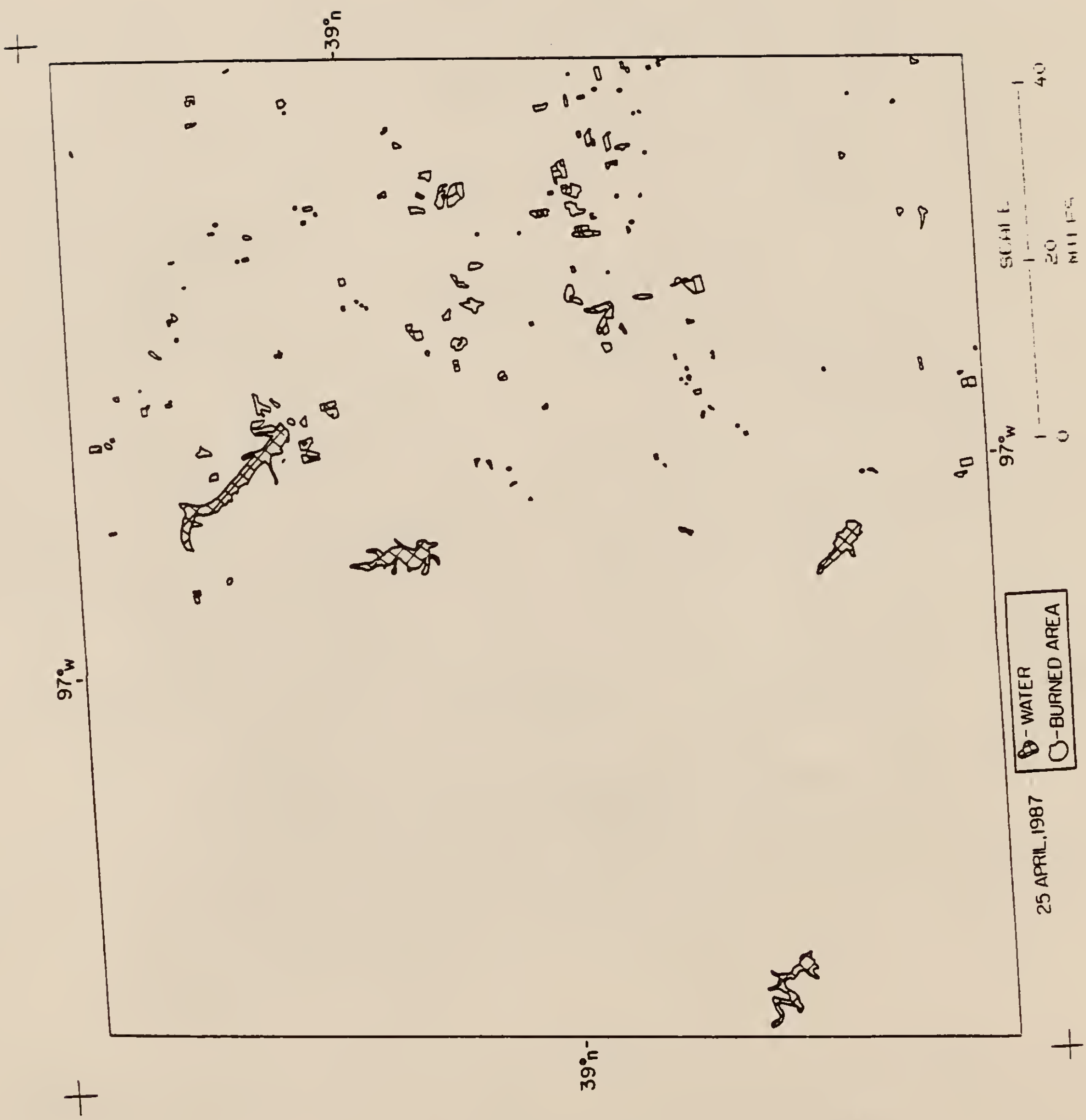


Figure 12 The 25 April, 1987 Burn Map

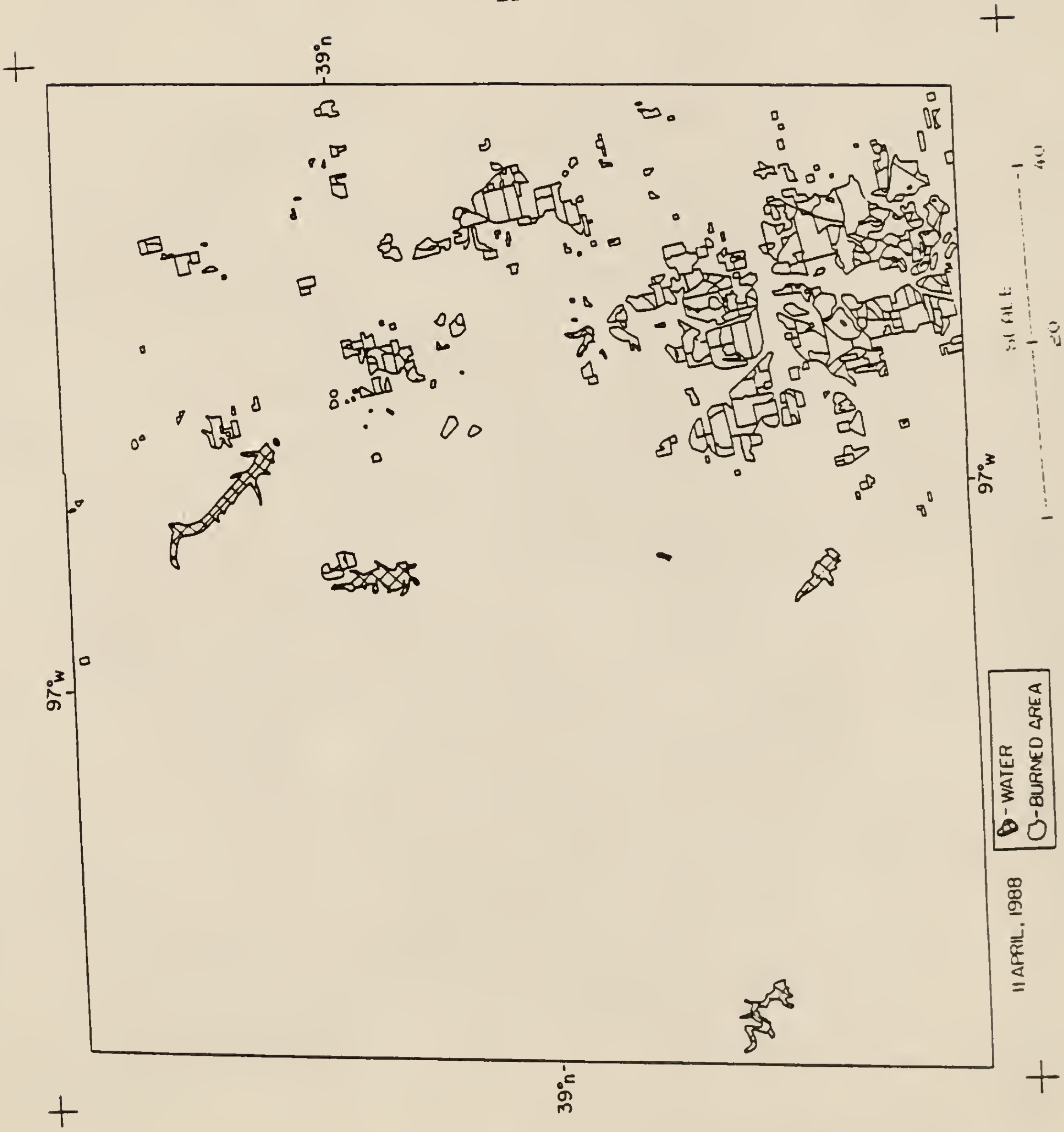


Figure 13 The 11 April, 1988 Burn Map

Figure 14 The 13 May, 1988 Burn Map

The tallgrass prairie in spring is very green with the new growth of the year. When the leaf layer of a plant is altered or eliminated, as occurs with rangeland burning, the resultant reflected energy is dramatically different in response value as compared to the pre-burn leaf. This approach is supported by studies such as Brown (1983), who assessed remotely sensed data for applicability to rangeland management uses; Hass (1975), who developed a method for Landsat M.S.S. data reduction to provide quantitative estimates of green biomass on rangelands; Johnston (1985), who used Landsat M.S.S. spectral response to examine range condition on the Crow Creek Indian Reservation; Rush (1985), who produced, at the lowest possible cost, vegetational maps from Landsat M.S.S. data to distinguish native from non-native plant communities; and Tappan (1981), who estimated the percentage of vegetational cover and green biomass on Kansas Flint Hills rangeland for the 1980 growing season.

Since this Thesis was designed to study areas burned for management of rangelands in the Flint Hills, areas which were mapped but do not lie in the Flint Hills were then eliminated from the burn map sheets and the data sets. Similarly, burns which were mapped within Fort Riley boundaries, were removed from the project. In some instances burns were mapped inside of other burns, in these instances the enclosed polygons were, subtracted from the surrounding polygon and kept in the data set. If the inside polygon was 'nonburned-in-burned' its value was subtracted from the surrounding polygon, then the inside polygon was eliminated from maps and data sets.

The burn maps were then overlaid onto a 1:250,000 soil map created from general soil maps contained in Soil Conservation Service Soil Surveys, and burned polygon vs. soil classification were documented. Slope data were collected from these Soil Conservation Service Soil Surveys and compiled into tables to find slope data for the individual burned polygons (Soil Conservation Service, 1959, 1970, 1974, 1975, 1979, 1980, 1981, 1982, 1983, 1984, 1985, and 1987). Since more than 1,900 burn polygons were mapped, the collection of soil and slope data at the soil series level, the finest detail available, was not feasible. Data were collected at the soil association level. A soil association is "a landscape that has a distinctive proportional pattern of soil" (Soil Conservation Service, 1974). Each of the burned area map sheets was placed over the soil map of the same scale and the soil association under each of the burned areas was noted. The soil associations underlying the burned areas were then researched for information on slope. For each soil association used, the slope value for the dominant soil was used as a value for its slope.

Another important aspect of the project was the determination of the repetitive nature of burns in the study area. This was accomplished by overlaying each of the burn map sheets over each of the burn map sheets of the years that followed. For example 21 March, 1986 was aligned over 18 March, 1985 and any polygon on the 1986 burn map which overlay a majority of an underlying polygon, was determined to be a repetitive burn for that data set. This process was repeated for each possible combination of the burn maps. Sheets from the same year were not overlaid. Since 1985 was the initial year of the study, no repetitive burning was determinable for that year. The combinations of sheet-over-sheet comparisons used are summarized as Table 2.

TABLE 2
REPEAT-BURN OVERLAY SCHEDULE

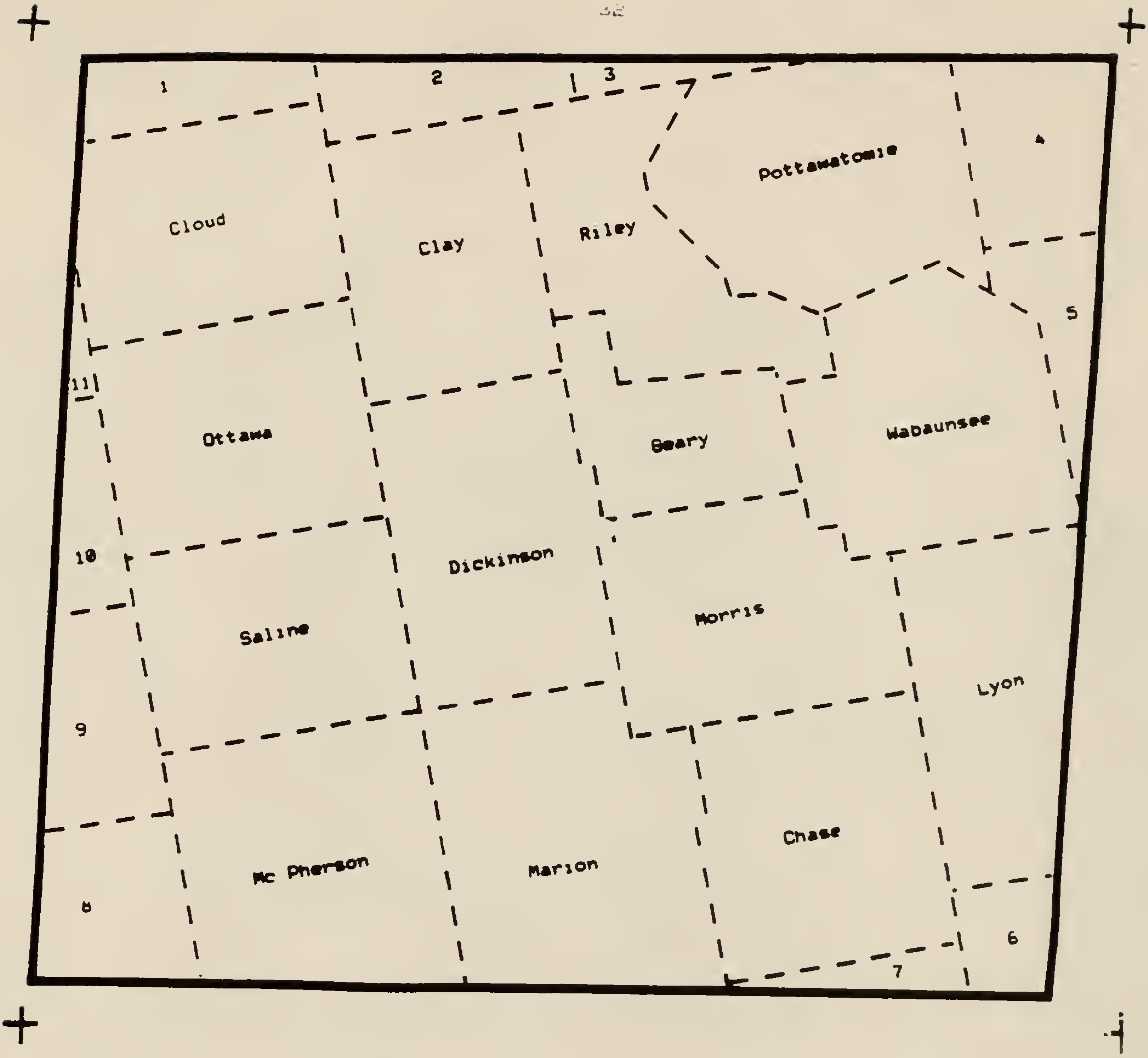
TOP BURN SHEET/ BOTTOM BURN SHEET

21mar86/18mar85,	21mar86/19apr85,	21mar86/03apr85,
14apr86/18mar85,	14apr86/19apr85,	14apr86/03apr85,
22apr86/18mar85,	22apr86/19apr85,	22apr86/03apr85,
09apr87/18mar85,	09apr87/19apr85,	09apr87/03apr85,
17apr87/18mar85,	17apr87/19apr85,	17apr87/03apr85,
25apr87/18mar85,	25apr87/19apr85,	25apr87/03apr85,
11apr88/18mar85,	11apr88/19apr85,	11apr88/03apr85,
13may88/18mar85,	13may88/19apr85,	13may88/03apr85,
09apr87/21mar86,	09apr87/14apr86,	09apr87/22apr86,
17apr87/21mar86,	17apr87/14apr86,	17apr87/22apr86,
25apr87/21mar86,	25apr87/14apr86,	25apr87/22apr86,
11apr88/21mar86,	11apr88/14apr86,	11apr88/22apr86,
13may88/21mar86,	13may88/14apr86,	13may88/22apr86,
11apr88/09apr87,	11apr88/17apr87,	11apr88/25apr87,
13may88/09apr87,	13may88/17apr87,	13may88/25apr87.

Once the repetitive burns were identified, their occurrence was analyzed in terms of spatial and temporal distribution and their relationships with soils and slope.

The goals of the project were also achieved through the use of four 1:1,000,000 scale transparencies which were prepared to demonstrate the relative and absolute placement of the variables of characteristics of soils, county boundaries, and locations of major physical and cultural features at the same 1:1,000,000 scale as the original data (Figures 15, 16, 17, 18). This step was performed prior to the completion of the larger scale products.

An important part of this study involved the two types of field transects, the frontal windshield transect and the aerial reconnaissance (Figure 18). The two windshield surveys were performed in early April 1987 and 1988. The route traveled included the area which best represents the northern Flint Hills, in terms of road pattern through the areas traditionally burned. The total length of the transect route was approximately 180 miles (300 kilometers) for each session. The transect was designed to sample the burn status of plots on the landscape, based on odometer readings, and to act as an aid and reference in the location and identification of burned rangeland units.



COUNTIES IN THE NORTHERN FLINT HILLS

1 Republic
2 Washington
3 Marshall
4 Jackson
5 Shawnee

6 Greenwood
7 Butler
8 Rice
9 Ellsworth
10 Lincoln
11 Mitchell

Figure 15 The Counties in the Landsat Scene

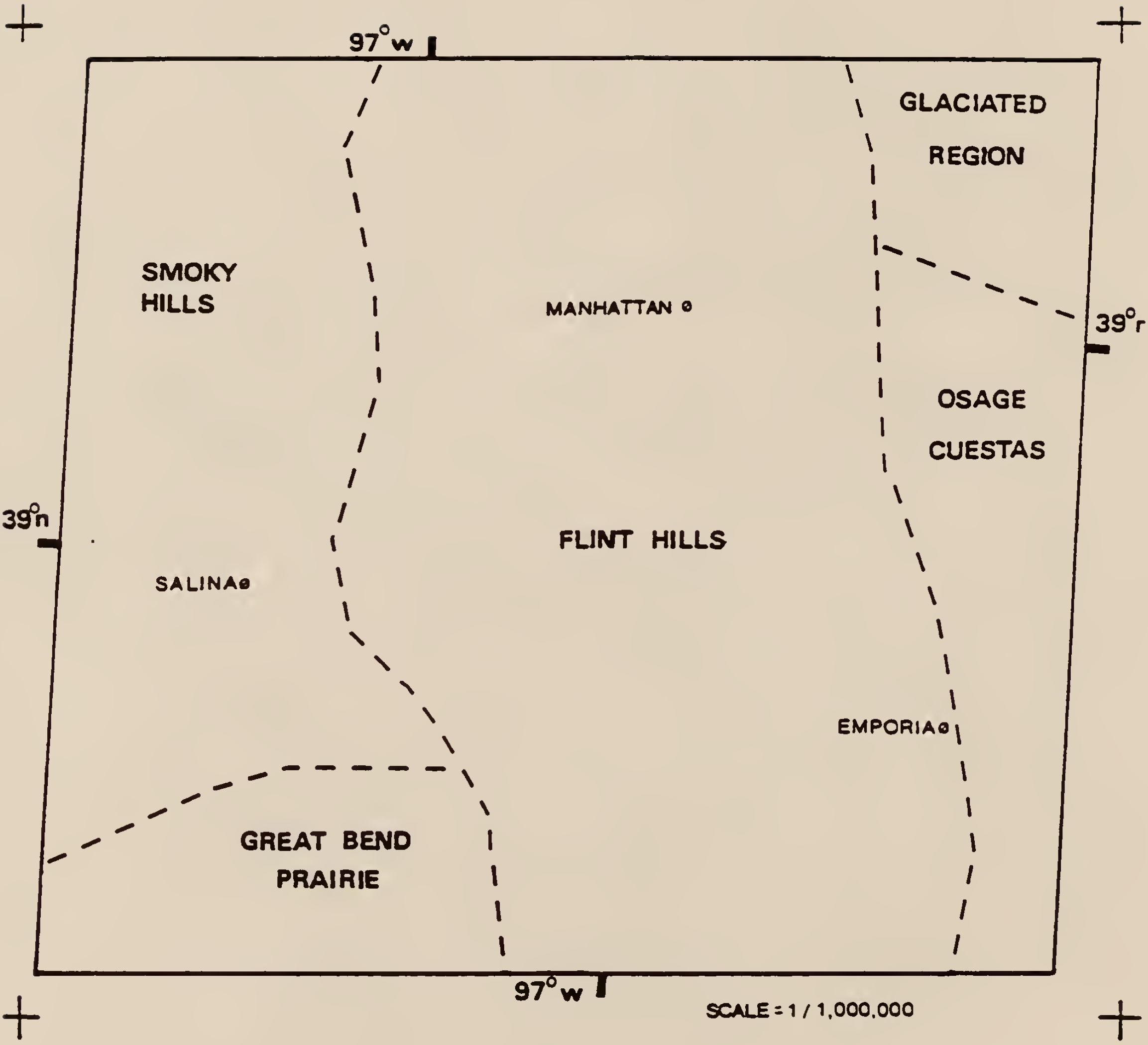


Figure 16 The Physiographic Regions in the Study Area

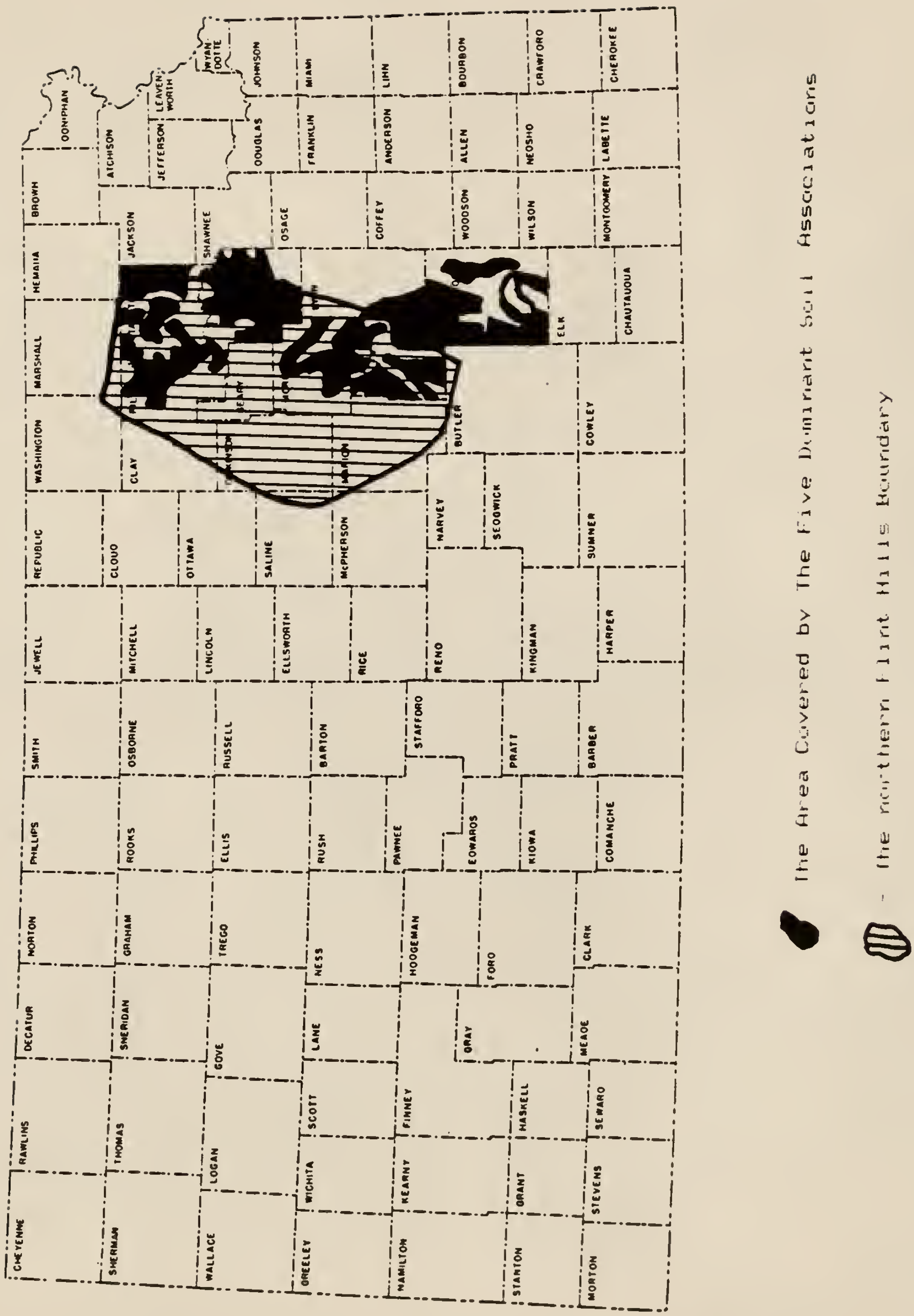
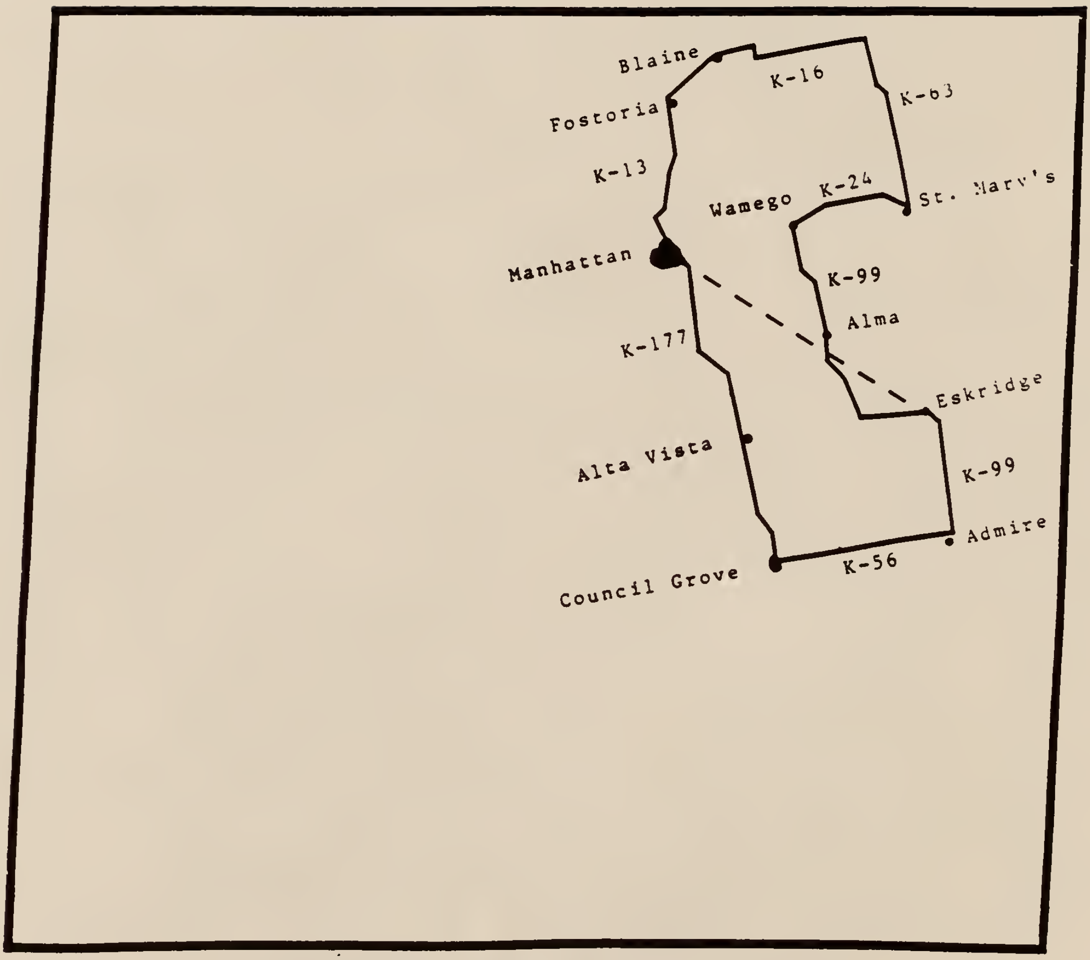


Figure 17 The Major Soil Associations of the Study Area



STUDY TRANSECT, ROADS AND SELECTED TOWNS

scale; 1,000,000

Figure 18 The Transects in the Study Area

——— - Frontal (Surface) Transect

- - - - - - Aerial Transect

Thes transect was then used to assess the accuracy, in terms of placement and position, of the burned area map sheets. These data were also collected from the aerial reconnaissance flown on 21 April, 1988. Visual data were collected with a 35mm camera with color slide film.

Unexpected problems were experienced with the statistical analysis portion of the Sigma-Scan software package. These problems had the end result of making the statistical analysis portion of the software inaccessible. Therefore, the necessary statistical operations were performed on the PC/SAS system. Operations performed were: maximum, minimum, sum, range, N, mean, variance, standard deviation and standard error for the burned areas, by overpass date. These values were also calculated for each of the four years of the study, and for totals of the four years combined.

Also collected was the maximum and minimum temperature and precipitation for the three meteorological stations of Emporia, Cottonwood Falls and Manhattan, for the peak of the burning season, March, April and May, for each of the four years of the study, 1985, 1986, 1987 and 1988. The station at Council Grove was the initial choice for the center station for the study, but missing data from this location station forced the substitution of Cottonwood Falls. These data were compared with the satellite interpreted data to find the relationship between these variables and the temporal occurrence of burning.

During the peak burning season, March through May, every attempt was made to witness as many burns as possible in the study area, and when possible speak with the head of the burn crew. This helped the researcher to experience some of decisions which are made as the burn took place.

The remaining chapters of this study will address "The Study Area and the Role of Prescribed Burning", "The Spatial and Temporal Analysis of Burning in the Flint Hills" and "A Summary of the Study" in chapters two, three and four, respectively.

CHAPTER TWO

The Study Area and the Role of Prescribed Burning.

The Study Area

The Flint Hills Region

"To many of us, who have listened to the heart throb of the prairies and who have felt their strong pulse beating at our senses, our choice of the magic spot 'beloved over all' would be instantly and forever the glorious Flint Hills of Kansas."1

Location

"There are few regions in the United States that are more important and less known than this bluestem pasture region of Kansas."2

The Kansas Flint Hills stand out as a distinct geographic subdivision in terms of 1) natural conditions, (Wibking, 1963), 2) predominant type of grass, climate, methods of agriculture, altitude or a purely arbitrary cartographic line, (Frye and Schowe, 1953) and 3) physiographic nature, i.e., rock structure, landforms and resources available (Self, 1978). In light of these parameters, it is difficult to dispute the claim that the Flint Hills are a physiographic subdivision in their own right. They are also definable in terms of their grazing based land use (Wibking, 1963). The characteristics which define and describe the Flint Hills in relation to themselves and their surroundings will be the focus of this chapter.

The generally regarded boundaries of the Flint Hills are on the east,3 a distinct rocky escarpment several hundred feet high which forms the border with the Osage Cuesta subdivision, and on the west,4 an indistinct line indicated by the local relief change and soil and vegetation transition into the Smoky Hills, Great Bend Prairie and Wellington Plain (Self, 1978, Frye and Schowe, 1953). The Flint Hills are narrowest in Washington and Marshall counties, about 12 miles (19 kilometers) east to west. Their width increases towards the south until about 197 miles (317 kilometers) south of the Nebraska border, they encompass parts of Saline, Dickinson, Morris and Lyon counties, at a width of about 62 miles (100 kilometers). The total area within the subdivision is approximately 4.5 million acres (1.8 million hectares) (Barker, 1969).

The northern Flint Hills, as studied in this research, will be defined as the area traditionally delineated as the Flint Hills, and from the Nebraska border south to the Cottonwood River. This area includes all or part of the following counties; Washington, Marshall, Clay, Riley, Pottawatomie, Dickinson, Geary, Wabaunsee, Marion, Morris, Lyon and Chase.

<u>Topography</u>

The Flint Hills offer the most rugged relief features in the State of Kansas. Most of the high points in the region are at about 1200 to 1500 feet, (365 to 456 meters) above sea level. The highest areas are in southern Morris and eastern Wabaunsee counties;

the lowest, in the Kansas River valley.

The stream and river beds in the north, are at less than 1000 feet (304 meters) and in the south, about 1200 feet (365 38 meters) giving local relief of up to 350 feet (106 meters). Most of the area however exhibits relief of a lesser degree (Schowe, 1949). This rolling plateau is often marked with out-crops of limestone which roughly follow the form of contour lines.

The region is well drained, with many streams, small and large, varying in valley width from one quarter of a mile to four miles. The major watercourses of the region are the Kansas, Republican, Big Blue, Vermillion, Neosho and Cottonwood rivers. Two northern courses, the Kansas and Republican, flow in a west to east direction. Two others, the Big Blue and Vermillion, flow from north to south. The southern courses, like the Marais de Cygnes, Neosho, and Verdigris, flow from northwest to southeast. The southwestern streams flow almost due south, they are the Walnut, Grouse Creek, and Big Caney Creek. The only system to bisect the Flint Hills is the Kansas River, the others start in the region and work their way down-slope and out of the area.

Geology

The geologic history of the Flint Hills is an active one, spanning more than 200 million years. The present surface geology of the Flint Hills is almost exclusively sedimentary material. There are limited intrusions of igneous rocks which reach the surface,[5] but they are very limited in size and number. The boundary of the Flint Hills is defined, in geologic terms, by the out-cropping of alternate layers of flint,[6] flint-bearing Permian limestones and shales (Figure 19). The area's west-dipping escarpments are topped by weather-resistant strata of these limestones. These limestone layers are separated by layers of less resistant shales. This gives the area its characteristic limestone "breaks" where these layers are exposed at the surface, and they surround layers of shale which have been removed by weathering. In northern parts of the region, the Threemile member, and Fort Riley limestone member are the top layers, while in central Kansas, the Florence limestone member takes their place. And in the south the Wreford limestone is dominant.

Summit elevations in the Flint Hills average about 1,500 to 1,600 feet above sea level (Self, 1978). The area's bench and slope or cuesta landforms exhibits a slope, rising from the west, which is contrary to the east to west rise for the rest of the State. The northern Flint Hills have a relief of up to 500 feet, (152 meters) whereas most of the Flint Hills an average local relief of less than 350 feet (106 meters) (Wibking, 1963). The vertical dimension of the area is

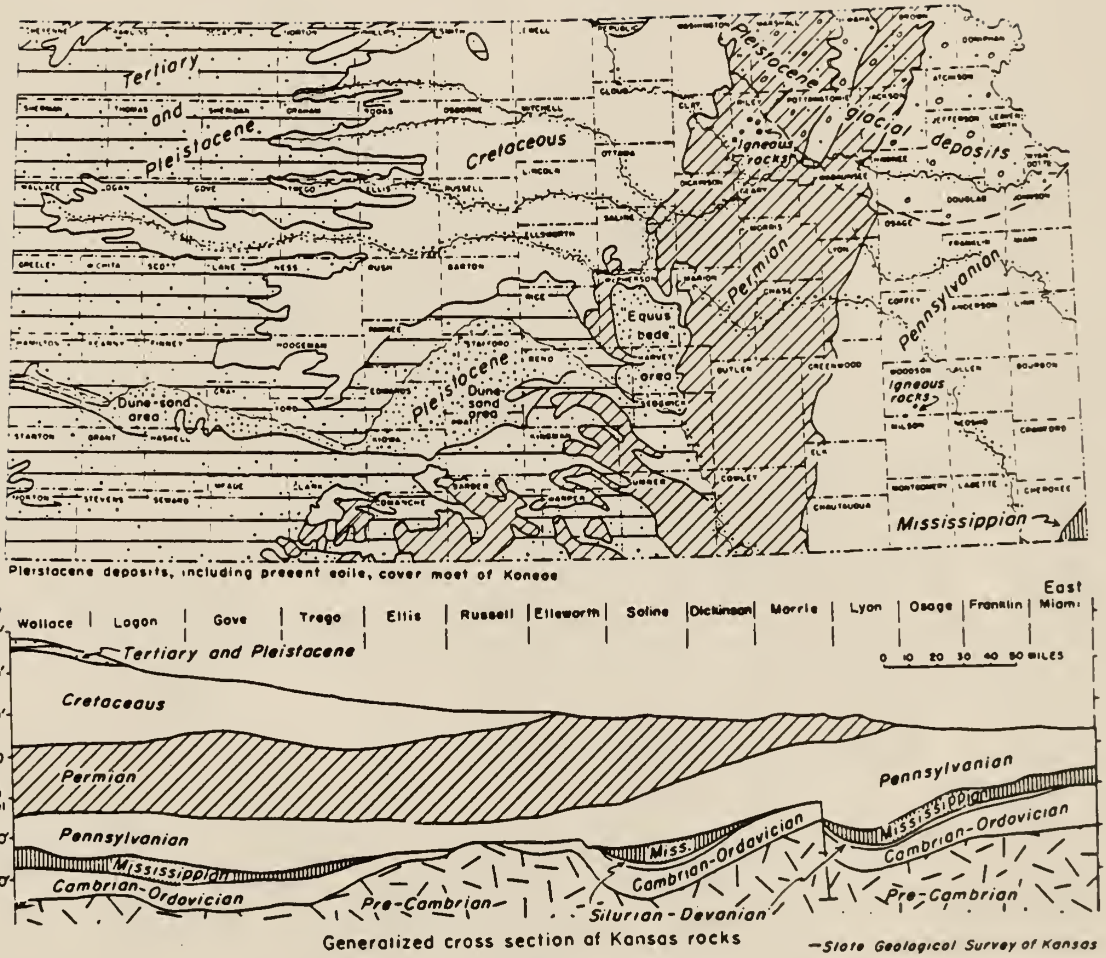


Figure 19 The Generalized Geology of Kansas
Source: Huber Self, Environment and Man in Kansas, 1978

attributable to the weathering of the soil and shale complex, while the more resistant strata hold fast to their elevation. Also adding to the ruggedness is the presence of a small underground granitic arch, closely associated with the Nemaha anticline.

In the northernmost area of the Flint Hills, north of the Kansas River, the less rugged nature of the surface is a reflection of the Pleistocene glaciation which, in a geologic time frame, just recently spread glacial till and eolian deposits across the area.

The Permian background of the area south of the Kansas river is reflected in the domination of the area by two related groups of limestones of the Wolfcampian series, the Council Grove and the Chase. It is their high degree of resistance to weathering and westward dip which allows the formation of the characteristic steps or benches in the region. They are also responsible for the rolling nature of the topography in the area, for they allow the soil beneath them to be protected, while the soil not so protected is weathered away. The steps develop when the resistant limestones, stacked like overlying shingles, remain after the erosion of weaker shales. Many streams have dissected the benches and scarps, forming areas of considerable relief.
These stream beds, littered with chert and flint fragments, open up into much more gentle slopes when the weaker shale areas are reached.

When all of the above are considered, the geology of the Kansas Flint Hills stand out as one of the State's most interesting and influential physiographic subdivisions.

Climate

The Flint Hills occur in Kansas roughly along the 96 degrees west longitude line and 38 degrees 30 minutes north latitude. This part of Kansas is classified by Koeppen as Cfa (humid subtropical) (Wibking, 1963), by Thornthwaite as CBr (subhumid mesothermal, rainfall abundant all seasons) (Wibking, 1963) and by Trewartha as Dfa (humid continental, hot summer, rainfall all year) in the northern portion and as Cfa (humid subtropical) in the southern portion (Self, 1978).

Kansas is more than five hundred miles from the Gulf of Mexico, the nearest water body of climatic influence. This continental influence of the Flint Hills position is often manifested in the extremes of temperature that the area experiences on a daily and seasonal basis. Also, there are no physiographic barriers of significance to limit the moisture available from the source area, the Gulf of Mexico. Therefore when storm centers approach Kansas from the north or west, they often encounter moisture-laden Gulf air and the stage is set for extreme or even violent weather phenomenon, such as tornadoes, blizzards or droughts.

The average annual temperature of the coldest month for all the stations in Kansas is 32 degrees F (0 degrees C.), the warmest, 80 degrees F. (27 degrees C.) This indicates an average annual range of 48 degrees F. (9 degrees C.) This is, again, a reflection of the continentality of the area. The range in highest and lowest recorded temperatures is 161 degrees F. (72 degrees C.). Manhattan, Kansas, in the northern Flint Hills is typical of the climatic experience for the area, its average monthly temperature and precipitation are shown in Table 3.

Table 3
Average Climatic Data for Manhattan, Kansas
1951-1988

Month	Temperature F.	Precipitation In.
Jan.	27.1	0.83
Feb.	33.2	0.95
March	42.5	2.08
April	55.5	2.79
May	65.4	4.50
June	74.8	5.29
July	79.9	3.96
August	78.4	3.18
Sept.	69.3	4.04
Oct.	58.2	2.89
Nov.	43.8	1.46
Dec.	32.7	0.91
Year	55.1	32.88

(Dept. of Commerce, 1987)

This information lends itself well to an interpretation of the average annual growing season for the State, which ranges from less than 150 days in the extreme northwest to more than 200 days in the extreme southeast. For the northern Flint Hills these values vary from approximately 165 days along the Nebraska border to more than 185 days along the Oklahoma border.

Another key factor in the understanding of climate in the region is precipitation. The average precipitation for the State varies from less than 18 inches (44 cm), in the west, to more than 40 inches (101 cm), in the southeast. The "center line" of the Flint Hills follows very closely the 34 inch isohyet (approximately 90 cm) of precipitation per year (Figure 20). This precipitation is not, however, a reliable 35 inches, for the very nature of the continental climate in the area provides an over-abundance of water in some years with droughts being a common factor as well. The high summer temperatures of the area result in high evaporation values. Tests in pastures near Manhattan, showed that 45 to 55 inches of water evaporate from a free surface during the summer (Kansas Board of Agriculture, 1949).

Each of these climatic factors, when considered individually, is a very powerful agent in shaping the prairie ecosystem. Nowhere are the effects of climate more apparent than in the soils, vegetation and land use of the area in question.

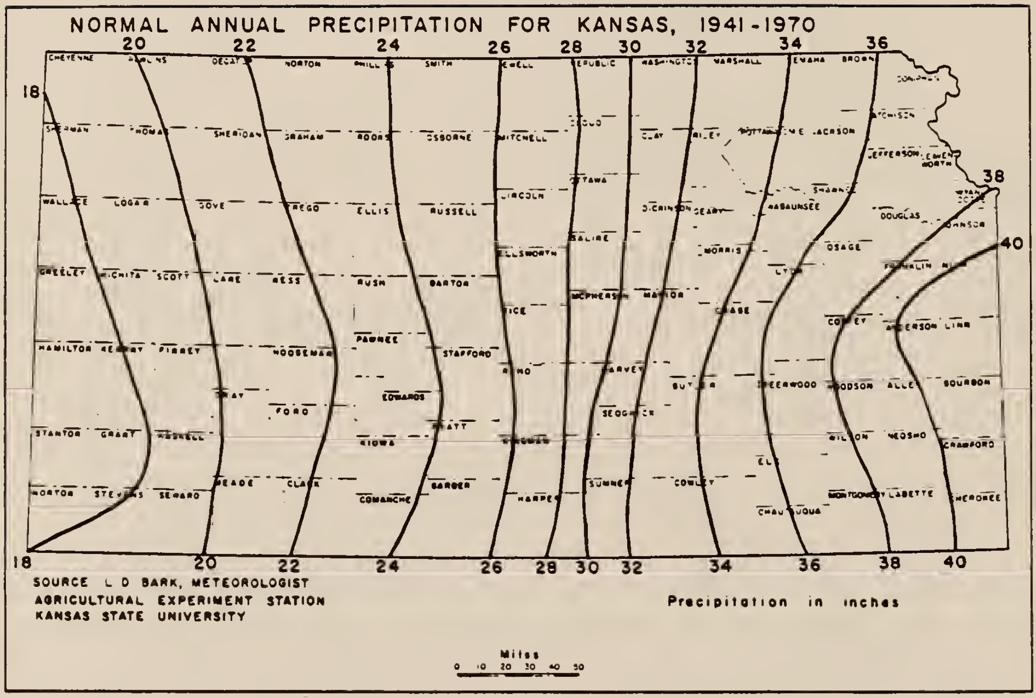


Figure 20 The Average Kansas Yearly Precipitation
Source: Huber Self, Environment and Man in Kansas, 19[illegible]

Soils

The majority of soils of the Flint Hills region are classified in the Mollisol order, Ustoll suborder, Udic subgroup (Self, 1978). These types of soil have formed under grassland vegetation, with a hot summer, cold winter, subhumid climate with about (40 inches) 100 cm annual precipitation, coming primarily in spring and summer. They occupy a belt of the Great Plains from northern Texas through central Oklahoma, Kansas, Nebraska into southeastern South Dakota. These soils are characterized by deep, moderately deep, and shallow dark grayish-brown, and very dark grayish-brown silt loams, silty clay loams and silty clays. They have a depth to secondary carbonates of more than 36 inches (89 cm). They are known for their high capabilities for production, both in crop and rangeland uses. This comes about from their development under grassland ecosystems. The perennial grasses which dominated the area, and in rangeland use still do, return a considerable amount of their above ground biomass to the soil each year. In just several plant generations this amount of returned biomass can be staggering. The return of these prodigious amounts of nutrients and biomass allows the soil to develop adequate drainage, good permeability and, perhaps most importantly, an ability to absorb and retain nutrients.

There are several associations that are dominant in the soils of the northern Flint Hills. Associations are groups of soils which exhibit similar characteristics in terms of slope, texture, and subsoil.

The characteristics of soil associations found in the study area can be summarized as follows;

Soils located on river bottoms consist primarily of alluvial material. They are composed of larger textural components than their upland counterparts and often receive new inputs of alluvium by way of flood events. They are highly productive and easily worked; so, as expected, their predominant use is for cropland. Examples are Clime-Sogn, Florence-Labette and Chase-Osage associations.

Important to the discussion of soils and their involvement with rangelands is the concept of range site. It is defined as "a distinctive kind of rangeland that produces a characteristic natural plant community that differs from the natural plant communities on other range sites in kind, amount and proportion of range plants" (Figure 21). Range sites found throughout the study area include; lowland claypan sites, loamy upland sites, flint ridges, breaks and clay upland sites. Range sites influence the vegetation which grows on them in several ways: moisture supply, depth to bedrock, salt content and seasonal water tables.

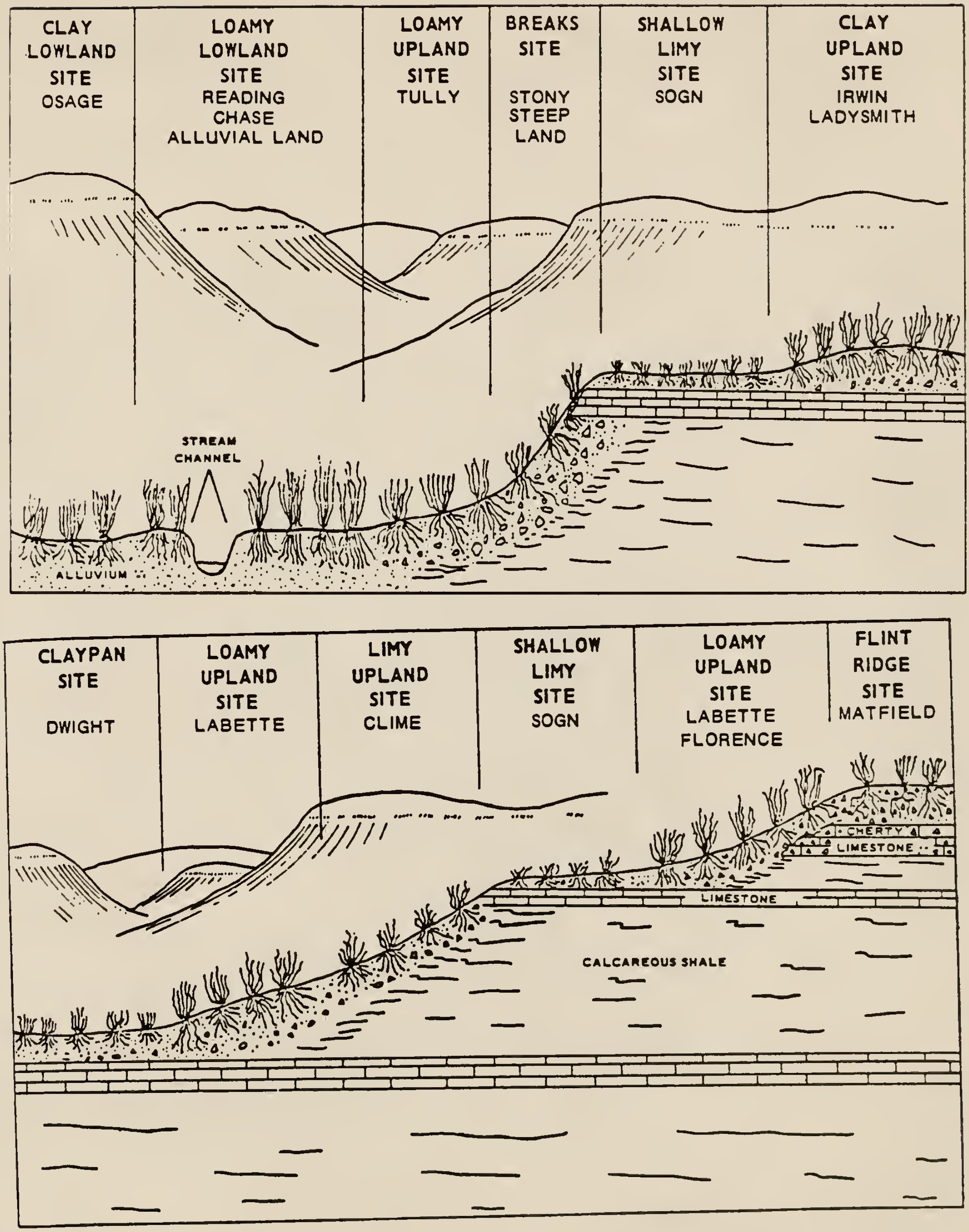


Figure 21 Range Sites

Source: U.S.D.A., S.C.S., Chase County Soil Survey, 1974

Soils from upland locations are generally formed from weathering of the area's sedimentary bedrock. This genesis is found with the cherty limestone-based Florence soil association. Bates soils are formed by the weathering of sandstone. Clime and Martin are formed from the weathering of shale. These soils are primarily used for rangeland because the amount of chert found in them is often prohibitive for plowing. There are also problems in regards to steep slopes and claypan layers.

Older soils, such as Ladysmith and Martin soil associations, have soluble carbonates well leached away, and a well developed illuvial clay level which can cause drainage problems, often limiting the soil to rangeland uses. Soils found on summits are likely to be very shallow, excessively drained or flinty, allowing only the rangeland use. Examples include Wymore-Pawnee and Labette-Florence associations.

Soils have many far reaching effects on their surroundings. One of the most direct contacts is with the vegetation they support.

Vegetation

Kansas is part of the prairie grassland province of the United States. The dominant native vegetative cover of all but the most eastern sections of the state is grass. Historically, these climax communities were short grass in the western third of the State, mixed tall and short grass in the central third of the State, and tallgrass in the eastern third, except for the extreme eastern edge of the state where deciduous trees begin to dominate (Figure 22). Today, approximately one-third of the State is covered with grasses (Self, 1978).

The native vegetation of the Flint Hills is the bluestem tallgrass and its associates. These grasses were, and remain today, so plentiful in the region that the area was once called the "Bluestem Pasture Region". These grasses are primarily warm season grasses; that is, they perform the majority of their growth during the summer. The key temperature for the start of this growth seems to be about 60 to 65 degrees F. (16 to 18 degrees C.) (U.S.D.A. Soil Conservation Service Agricultural Handbook # 389, 1976). Grasses are grouped into two categories, annuals and perennials. Annuals grow from seed each year, while a perennial grows each year from axillary buds at basal nodes or from seeds.

Some of the most prevalent and economically important grasses for the Flint Hills are;

1) Big bluestem, (Andropogon gerardi), a warm season perennial. Big Bluestem is the dominant grass on lowlands and on slopes where moisture is available. It produces abundant foliage in late spring from buds and rhizomes. Seedheads appear when the plant is about 4 inches above the ground. Its growth cycle is about 4

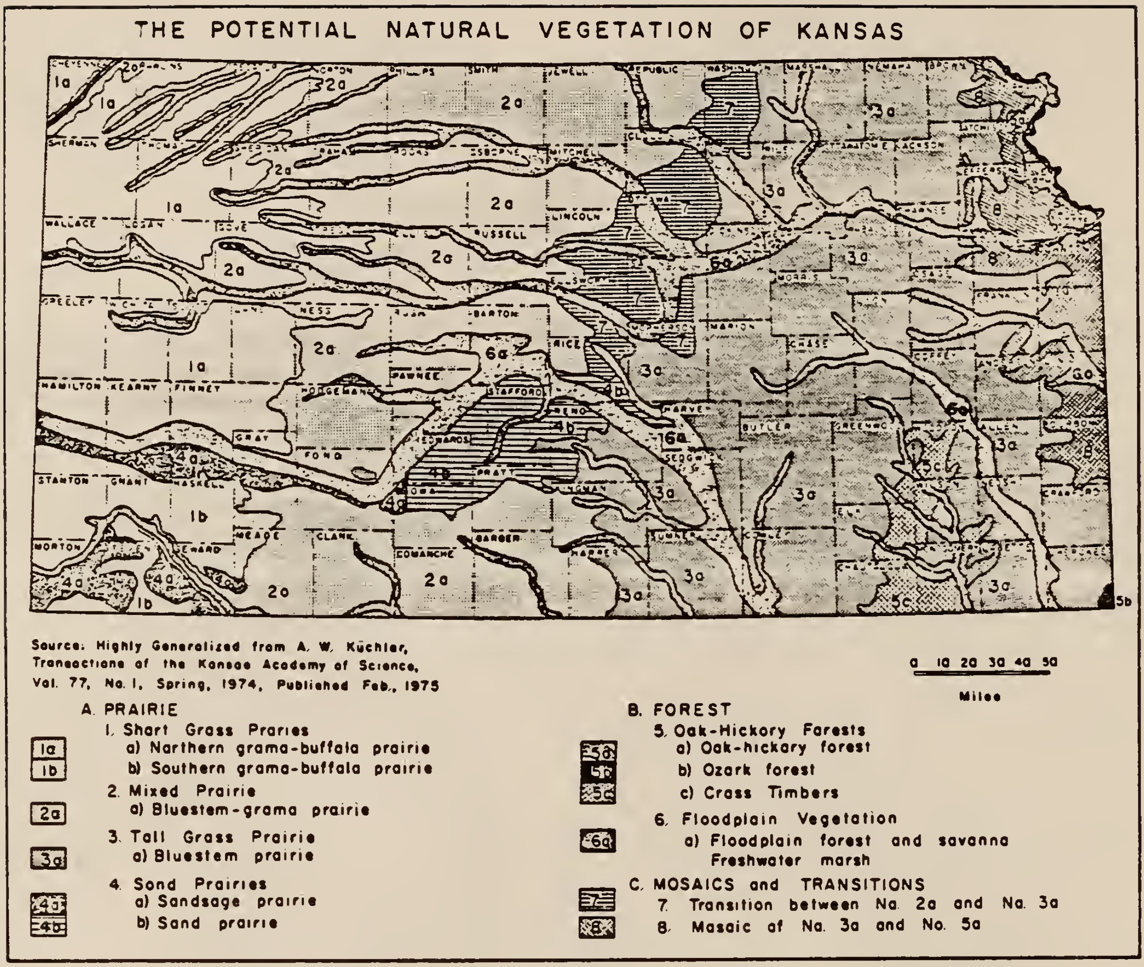


Figure 22 Potential Vegetation of Kansas
Source: Huber Self, Man and The Environment , 1978.

months. At the end of the growth cycle the ungrazed leaves fall from the plants and form a dense mat of thatch which quickly decomposes to form very rich and erosion-resistant soils. Elk and livestock prefer big bluestem to associated grasses. It can grown as forage or as a hay crop. It grows to a height of 6 feet (1.8 meters).

2) Little Bluestem, (Andropogon scoparius), is a warm season perennial. It has many of the same characteristics of "big blue" except that it is a bunch grass. This means that its growth pattern is very dense with a tremendous amount of plant material in a small amount of space. This density is also present in its root system, allowing it to grow on dry upland areas and ridges. It grows to a height of 2 to 4 feet (.6 to 1.2 meters) and is cut for hay or grazed.

3) Switchgrass, (Panicum virgatum) is a warm season, perennial grass which prefers lowland locations. It is tolerant of very low temperatures, -25 to -35 degrees F. It is used for hay and forage. It grows up to 6 feet (1.82 meters) tall.

4) Indiangrass, (Sorghastrum nutans) is a warm season perennial grass. It grows best in deep, moist soils from clays to sands. It produces good quality forage, is readily grazed, and grows up to 7 feet (2.13 meters) in height.

5) Sideoats Grama, (Bouteloua curtipendula) is a warm season perennial which grows to a height of 20 inches (51 mm) and tolerates well the shallow, rocky or alkaline soils which are prevalent on the summits of the region. It is readily consumed by wild and domestic grazers alike. It is a good grass to rehabilitate an over-used range (U.S.D.A. Soil Conservation Service Agricultural Handbook # 389, 1976).

These grasses are by far the dominant components on the rangelands of the Flint Hills. The bluestem grasses alone often account for over 40 percent of the plants on a Flint Hills range (Wibking, 1963). The ideal situation for grazing enterprises is to have a rangeland composed of 95 percent grasses and 5 percent forbs (Wibking, 1963). This is rarely achieved in a working ranch because of the pressures of selective grazing and overstocking, and the time-lag between detecting a range problem and bringing about a solution.

The vegetation of the Flint Hills is very conducive to summer grazing. This is based on the cycles of growth in the native vegetation. The dominant warm season grasses are in their peak growth stages in the warmest parts of the year.

At the same time the warm season grasses are gearing up for prodigious growth, the cool-season grasses have spent their energy and are now entering dormancy. This, combined with the grazer's preference for succulent young grass, makes the choice of warm or cool season grass an easy decision for the range manager to make.

To bring about the seemingly opposed goals of maximum production from the grass resource without deteriorating its productivity, the range manager has many tools and techniques at his disposal; one of the most useful is prescribed burning.

Current Land Use

The Flint Hills are dominated by agricultural land use. This agricultural dominance is manifested in the valleys with cropped land, and on the cherty, rocky or thin-soiled areas, with range land uses. The unusual soil conditions of the Flint Hills dictate a greater than average portion of the area to be used for range and pasture. Selected counties in the area and their dependence on rangeland are shown in Table 4.

Table 4

Selected Counties and Rangeland Percentage

County	Percent Rangeland
Pottawatomie	52
Morris	57
Chase	80
Riley	50
Lyon	45

(U.S.D.A. Soil Survey, 1974, 1975, 1981 and 1987)

This rangeland use is primarily involved with cow-calf operations and steer grazing. Table 5 is a summary of livestock value figures for the counties of the northern Flint Hills.

Table 5

Kansas Counties and Livestock Production Values

County	1986 Livestock value in dollars*
Pottawatomie	25,190,100
Riley	14,228,700
Chase	12,108,000
Geary	10,710,000
Morris	18,561,000
Wabaunsee	20,579,000
Total	101,376,800

* Includes meat animals, chickens, eggs, turkeys and wool. (U.S.D.A., Kansas State Board of Agriculture, Kansas Farm Facts, 1986.)

Second to rangeland in the northern Flint Hills is cropland. The areas capable of cultivation are almost exclusively in bottomlands. The area used, by county, for cropland averages about 30 percent of total land area, but in the high rangeland acreage counties, such as Chase, the cropland acreage is considerably less.

Four counties of the study area have very little economic activity other than agricultural interests; Morris county, with the county seat, Council Grove, (1980 population of 2381 persons) has two plastic plants and a milk processing plant. Pottawatomie county, with Westmoreland as its county seat, (1980 population of 598) has limited development in the southern portion of the county, especially in the Wamego area, with a tractor implement manufacturing plant. The Jeffries Energy center is a major employer in the county.

The western third of Pottawatomie county has experienced a considerable amount of suburban development from the neighboring city of Manhattan, especially in the past ten years. Wabaunsee county, with the county seat of Alma, (1980 population, 925 persons) has limited development with a cheese factory. Chase county, with the county seat of Cottonwood Falls, (1980 population of 951) has a mower manufacturing plant.

Three counties of the area are more developed, Lyon, with the county seat of Emporia, (with a population in 1980 of 25,287) Riley, with the county seat of Manhattan, (with a 1980 population of 32,644) and Geary with the county seat of Junction City (with a 1980 population of 19,305). The land near the cities is much more developed, but just a short distance from these urban areas, the land use changes to the familiar cropped bottomlands and grazed uplands (U.S. Department of Census, 1980).

The Role of Prescribed Burning

"Fires favor grass and grass favors fire."
(Owensby, 1987)

Purpose and Goals

The True Prairie, of which the Flint Hills are a part, have had a history of fire. It developed under a system of repeated burning from natural causes (Owensby, 1987). Lightning induced fires had few barriers to stop their race across hundreds of miles of prairie. These fires increased the vigor of the grass, providing more fuel for the next fire. This formed a very close bond between the grassland ecosystem and fire. Native Americans discovered this relationship and would introduce fires to areas to attract bison to graze the highly palatable new growth. This was the first use of fire as a management tool, or prescribed burning.

Prescribed burning is the use of fire in a controlled rangeland management scheme, and is used to bring about specific goals for productivity, vegetational composition and grazing plans. It is a common tool for the range manager in the tallgrass-dominated Flint Hills. The use of burning decreases as one moves out of the Flint Hills area. To the west, the transition from tallgrass to mixed short and tallgrass does not provide sufficient biomass on the surface to allow the regular burning of the area without irreparable damage to the range. To the east, soils allow much more cropping, the dominant vegetation becomes deciduous trees, so area of rangeland are less common, and when they do occur, they are of smaller acreages and are more dispersed.

Prescribed burning has several goals, they are;

1) Woody plant control
2) Control of weedy forbs and grasses
3) Increase forage quality
4) Increase grazing distribution
5) Removal of excess old growth
6) Reduction in height of browse for wildlife
7) Management of wildlife habitat (Owensby, 1987)

Prescribed burning brings about these goals by burning away, or at least damaging, the parts of plants above the soil. This process affects grasses, forbs, weeds and woody plants alike. When the burn is correctly timed, the desired grasses, which are warm season perennials about 1 to 1.5 inches (25.4 to 38.1 mm) tall, will be seriously harmed by the burn, but since they are in their very high growth period, the grass plant is quick to recover. The forbs, weeds and trees are not in such "upward movement of energy" state and are not able to tolerate the damage. This, coupled with the fact that up to 95 percent of the biomass of a grass plant is in the roots, and is protected from the fire by soil, has the net effect of causing a short-term stress to the grass, while virtually eliminating the undesired weeds, forbs and trees. Cool season grasses are affected because they are, at the time of a late-spring burn, in their lowest point of their food reserves, whereas the warm season grasses are at their high point. Any damage that occurs to a cool season at this time, could prove to be fatal. The warm season grass is only temporarily set back.

The effects of burns on soils are well documented. The overall effect of burning on soils has been thoroughly researched. Some of the conclusions reached are as follows;

-burning causes no detectable change in overall organic matter, (Owensby and Wyrill, 1973),
-burning causes no detectable change in total soil nitrogen, (Owensby and Wyrill, 1973),
-burning increases post-burning event soil temperatures, allowing quicker growth of desired species, (Sharrow and Wright, 1977),
-burning causes a loss of moisture in the post-burn soil, with the earliest burns causing the greatest loss of moisture (Anderson, 1965).
-burning can, with proper timing, moisture and vegetation increase herbage yield, (Wright, 1972).
-timing of the burn is the critical management factor, with late spring burns increased grass production, and favored warm-season grasses, winter and early spring burns favoring others species. The long-term effects were determined not to be detrimental to production, composition, and basal cover (Towne and Owensby, 1984).

A common goal for the range manager in the Flint Hills is the elimination of woody invaders, primarily Eastern Red cedar (Juniperus virginiana L.). This task is efficiently accomplished with prescribed burning (Ohlenbusch and Hodges, 1983). These softwood trees are considered a pest because they are prodigious consumers of water, are difficult to control, create an unsightly range and are of little forage value, and they have traditionally been viewed a sign of a poorly kept range.

The value of prescribed burning has been proven by many years of research, with the most critical variable in the success of a burn found to be timing.

Timing

To favor a species, the range should be burned just after initial growth following dormancy. Prescribed burning in the Flint Hills is designed to favor the warm season perennial grasses. Research has shown increases from 2300 lbs/ ac., with a March 20 burn, to 3240 lbs/ac., with no burn (Ohlenbusch and Hodges, 1983). The best results have been achieved with late spring burning (Anderson, et al. 1970).

Throughout most of the Flint Hills, the recommended optimum date for range burning is about April 23, (+ or - 10 days, depending on growing conditions). This optimum date is not closely followed in the field for a number of reasons, most important, being immediate weather factors. A prescribed burn requires a fairly narrow set of atmospheric conditions, such as low to medium velocity, steady wind, moderate to high temperature, and moderate levels of humidity. Not only must these conditions be present at the start of the burn, but must remain for its duration. If these conditions are not present, the burn is usually cancelled.

To eliminate a species, the range should be burned when the species is at its lowest flow of energy. For most cool season grasses, forbs and trees, this period occurs when the warm season grasses are just beginning their growth, that is they are entering their highest period of energy flow. This works well for the range manager, for it allows control of both the desired and undesired species.

Frequency

It is estimated from historical evidence that the prairie, under natural conditions, burned one out of every four years (Briggs, 1987). Owensby 1987, stated that the vigor of sprouting species may be reduced by one fire, but if no fire is applied the next growing season, they will attain their previous stature. There seems to be a consensus among range managers that annual burning is best for the goals outlined above, and there seems to be no evidence that, for the short term, annual burning is any more detrimental than other burning schedules. Evidence from the Konza Prairie Research area in southern Riley and Geary counties suggests that annual burning is not harmful until it has been practiced for several decades (Briggs, 1987).

The strong emphasis on grazer-based land uses in the northern Flint Hills requires the use of sound rangeland management techniques. Rangeland burning is just such a tool, and it is commonly employed in the Flint Hills, but there is no precise estimate of the acreages involved with this practice. The purpose of the next chapter is to determine this and other characteristics of the Flint Hills and their relationship with prescribed burning.

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1 Grace E. Muilenburg, Where east meets west-in Kansas The Prairie Scout, Vol. 5, The Kansas Corral of Westerners, Inc. Abilene, Kansas 1985

2 James C. Malin, "An Introduction to the History of the Bluestem Pasture Region of Kansas," Vol. XI, No. 1, Kansas Historical Quarterly Topeka: State Printer, 1942.

3 Approximately 96 degrees 15 minutes west

4 Approximately 96 degrees 30 minutes west

5 These outcrops are probably of Cretaceous age, and are located in just two counties of the state, Riley and Woodson.

6 The terms "flint" and "chert" are used here interchangeably for the local varieties of quartz with conchoidal fracture. Flint is generally regarded to be the darker form of the two, with chert occurring in lighter tones.

CHAPTER THREE

The Reporting of Temporal/Spatial Analysis of Burning

Introduction to the Analysis

Several problems were encountered in the execution of this project, some of which required change in the initial approach to addressing the questions involved in the study. The first problem encountered in the project was the limited availability of cloud-free imagery for the part of the desired study period. The 11 May, 1987 date had limited cloud cover, but there was little burning evidenced on the image, so the cloud cover was not prohibitive. Cloud cover was prohibitive on only 2 dates, 19 April, 1985, and 14 April, 1986. Since these dates are in the crucial burning month of April, the data on them had to be obtained, but intense burning areas were obscured by cloud cover. Additionally, polygons were found which could not be positively identified as burns or cloud shadows. Every attempt was made in these instances to determine the identity of the polygon in question, but when this was not possible the polygon was deleted from the study.

The next problem encountered was that of the Map-o-Graph machine, used to enlarge the 1:1,000,000 scale transparencies to 1:250,000. To enlarge the 7.2 inch imaged area of the transparency to the required 28.8 inches, the Map-o-Graph was pushed to its limits. In most cases, the burned area polygons were dark enough to stand out well against the unburned background. In the very early and very late season burns, however, this dichotomy in response was reduced to a minimum where the burned areas were not on the landscape, as in very early dates, or where the burned areas had sufficient time to grow enough green cover to lose their burned response, as in the very late burn dates. Every effort was made to check and recheck polygon shape and size with the Map-o-Graph and with the imagery in hand. As a precursor to the analysis section of the study, checks were made using the transect data collected in 1988. These field data indicated that, on the three levels of observation used, satellite, airborne camera and surface, the accuracy of three platforms was acceptable in terms of placement, areal extent and boundary line demarcation.

Spatial Relationships of the Original-Burns

One of the major goals of this study was to analyze the relationships of the burns and the space they occupy. The general spatial characteristics of the burns, by date of satellite overpass, are summarized below;

The burn of 18 March, 1985 (Figure 4) was a primarily southern burn. There was some clustering in Chase county with a few burns well into the northern portion of the study area. The 21 March, 1986

(Figure 7) and 19 April, 1985 (Figure 6) burns were heavily concentrated on Wabaunsee county while some burns occurred in Riley and Lyon counties. The 14 April, 1986 (Figure 8) and 11 April, 1988 (Figure 13) burns were very heavy burn dates. Clustering of the burns occurred near the southern border of the study area, with a large group of burns in Chase county. The cluster continued north to the Neosho River, where it was broken. The clustering then continued in Morris county into northwest Lyon county, then north and west into central Wabaunsee and central Geary counties. This general distribution also occurred with the 18 March, 1985 burns, but with fewer burns involved. The 22 April, 1986 (Figure 9) burns were evenly dispersed throughout the study area, with loose clustering in Chase, Morris, Lyon and Wabaunsee counties. Some scattered burns also occurred in Geary and Pottawatomie counties. The 09 April, 1987 (Figure 10) burns were the most numerous of the study, and clustering was very strong. The burns followed the same general pattern as the 14 April, 1986 and 11 April, 1988 maps, but the 1987 burn map showed a greater number of burns in the northern portion of the study area. The 17 April, 1987 (Figure 11) burn area map was very similar to the 19 April, 1985 burn area map, with most of its burns occurring in Wabaunsee county, and some scattered burns in Pottawatomie, Lyon, Chase, Morris and Geary

Counties. The 03 April, 1985 (Figure 5) burns were loosely dispersed throughout Chase, Greenwood, Wabaunsee, Lyon and Pottawatomie counties. They were similar to the 25 April, 1987 burn map, a loosely dispersed burn date, with two clusters, one in southern Riley county and the other in northwest Lyon county. The 13 May, 1988 (Figure 14) burned area map showed light burning activity. There were six burns south of Council Grove, and 14 burns in Pottawatomie, Riley and Geary counties.

For each of the study dates, occurrences of burns, by county, were calculated. These data were then condensed into yearly summaries, (Table 6), and a total original-burn county occurrence table, (Table 7).

Table 6
Yearly Summaries for Original-Burn County Occurrences

Year	County	Occurrences	Percentage
1985	Wabaunsee	82	38.0
	Chase	54	25.0
	Lyon	32	15.0
	Riley	13	6.0
	Pottawatomie	9	4.0
	Greenwood	9	4.0
	Geary	7	3.0
	Marion	4	2.0
	Morris	3	1.0
	Marshall	1	0.0**
	Shawnee	1	0.0**
	Jackson	1	0.0**

			98.0*
	Total	216	

1986	Chase	210	44.0
	Wabaunsee	87	18.0
	Lyon	53	11.0
	Morris	49	10.0
	Riley	29	6.0
	Geary	27	6.0
	Greenwood	11	2.0
	Shawnee	4	1.0
	Pottawatomie	2	0.0**
			98.0
	Total	472	
1987	Wabaunsee	160	19.0
	Chase	159	19.0
	Lyon	137	16.0
	Pottawatomie	116	14.0
	Morris	92	11.0
	Riley	63	7.0
	Greenwood	39	5.0
	Geary	38	4.0
	Marion	32	4.0
	Shawnee	11	1.0
	Jackson	5	1.0
	Marshall	4	0.0**
	Dickinson	1	0.0**
			101.0
	Total	857	
1988	Chase	174	42.0
	Wabaunsee	54	13.0
	Lyon	48	12.0
	Morris	31	7.0
	Greenwood	26	6.0
	Pottawatomie	26	6.0
	Riley	19	5.0
	Marion	18	4.0
	Geary	15	4.0
	Marshall	3	1.0
	Shawnee	3	1.0
			101.0*
	Total	417	

* = Error Due to Rounding   ** = Actual values > 0.01.

These tables highlight the spatial domination of the burning phenomenon by the counties of Wabaunsee, Chase and Lyon. They accounted for 78 percent of the 1985 burns, 73 percent of the 1986 burns, 54 percent of the 1987 burns and 68 percent of the 1988 burns. For the four years of the study, Chase county was number one in terms of burn occurrences twice, with Wabaunsee in second place, while in the other two years Wabaunsee lead, with Chase second. The reduction in percentage for the Chase, Lyon, Wabaunsee group, for the 1986 year is best explained by 1986 having more burns than any other year, by reason of undetermined management decisions in the area and more counties hosting those burns, so the percentages of occurrence for counties were reduced.

The data from the yearly summaries were compiled to make Table 7.

Table 7
Total County Occurrences

All Years	County	Occurrence	Percentage
	Chase	597	30.0
	Wabaunsee	383	20.0
	Lyon	270	14.0
	Morris	175	9.0
	Pottawatomie	153	8.0
	Riley	124	6.0
	Geary	87	4.0
	Greenwood	85	4.0
	Marion	54	3.0
	Shawnee	19	1.0
	Marshall	8	0.0**
	Jackson	6	0.0**
	Dickinson	1	0.0**
			99.0*
	Total	1,962	

* = Error Due to Rounding ** = Actual values > 0.01.

Here again the Chase, Lyon, Wabaunsee domination can be seen. These three counties account for 64 percent of the total burns for the four years of the study. This is not surprising since the area of Chase and Lyon counties is seen as the heart of the Flint Hills range burning area. Wabaunsee county, although not in the heart of the Flint Hills, is also highly oriented to the range land use. After these three counties, the occurrence and resultant percentage values of prescribed burns diminishes drastically, with a group of values in the 100's (Riley, Morris and Pottawatomie counties, all moving away from the heart of the Flint Hills region) and, as distance from the big three counties increases, the occurrences of burns falls off very quickly.

These tables show the dramatic domination of rangeland burning by the burning area core of the counties of Chase, Lyon and Wabaunsee. These counties are dominated by the range land use, with Chase county having over 80 percent of its land in range, and the resultant use of prescribed burning on the tremendous amounts of land found here is responsible for much of the burning that takes place in the Flint Hills each year.

The spatial distribution of the burns was found to follow several distinct patterns;

1) burns were found to occupy space in a very loose and dispersed manner throughout the study area,

2) very close association in an area about the size of a county, in the south central portion of the study area, with a small number of isolated burns,
3) large numbers of burns in close association, extending from the southern boundary north and east, breaking for the Neosho River, then continuing north and becoming less concentrated in number and association, in the northern portion of the study area,
4) a few small isolated associations, with a small number of burns spread out through most of the study area.

Several generalizations can be made from inspection of the burn maps;

1) Early burn dates showed clustering of burns in the southern portion of the study area;
2) The vast majority of prescribed burning shown in the scenes took place east of a line passing through Tuttle Creek Reservoir and Marion Reservoir;
3) The burn shapes showed a close adherence to township and range lines;
4) the burns often clustered in isolated groups,
5) when several groups were in close proximity, they were often separated by a sinuous area of non-burned status.

Several factors are responsible for the above characteristics;

1) Since prescribed burning is somewhat weather dependent, burning moves from south to north, appearing first in mid-March in the southern portion of the study area, with a few scattered, small burns throughout the area.

2) Since prescribed burning is also vegetationally dependent, it is found only where vegetation exists which can support this management technique. This

condition occurs east of a line from approximately Tuttle Creek Reservoir south to Marion Reservoir and beyond into Butler County. The 'frame' of the Landsat transparencies used for this study is bounded on the east by the traditional boundary of the Flint Hills, and therefore little burning was expected to the east of the study area.

3) Prescribed burning occurs in areas used primarily for grazing by steers and cow-calf operations, and the ranches involved are divided and defined by fences, usually placed on township and range lines. The resultant effect of these fences on the shape of burns is easily seen on the burn maps (Figures 4-14).

4) Burn clusters are often separated by sinuous areas of non-burned status, which were often found to be cropland or other higher yielding land use.

Temporal Relationships of the Original-Burns

The occurrence of prescribed burns in the study area over time is shown in Table 8. The year 1985 had a small number of burns in the first date, then more in the second and more still in the final date. The year 1986, however, peaked in the second date, with a small number in the first, and an increase in number for the third. The year 1987 began with a tremendous number of burns in the first date, about 1/4 of this number in the second then a small increase in the third. The year 1988 began with a very large number of burns in the first and had a very small number of burns in the second, and final, date for the year.

Table 8
Temporal Occurrence of Rangeland Burning

Date	# of Burns
18 March, 1985	25
03 April, 1985	89
19 April, 1985*	102
Total 1985	216
21 March, 1986	34
14 April, 1986*	293
22 April, 1986	145
Total 1986	472
09 April, 1987	553
17 April, 1987	128
25 April, 1987	176
Total 1987	857
11 April, 1988	396
13 May, 1988	21
Total 1988	417

*-scenes with some prohibitive cloud cover

There was a possibility that the summaries for 1987 and 1988 would have been more closely related if late season 1988 data had been available.

Upon closer inspection this table reveals that the temporal occurrence of prescribed burning is governed by three variables; the condition of the range, and the calendar. The former also takes into account the weather variable. In each of the years of the study, there were early burns and there were late burns. The condition of the range is seen as a guide from the viewpoint that these early burns and late burns took place at those times for they then met the criteria set-out by the range manager. The calendars influence can be seen in the distribution of the burns around the first week of April. This was the most concentrated time for burning. This was true for all the years. The increase of post-1 April burns over pre-1 April burns was 356 percent for 1985 and 861 percent for 1986. Percentage increases were not available for 1987 and 1988 because there were no pre-1 April scenes available for those dates without prohibitive cloud cover. There were only 60 pre-1 April burns recorded for the study. The years of 1987 and 1988, however, had no pre-1 April scenes, so any burning which occurred prior to these dates and still retained a burned appearance, was recorded on that first of the year burn map (Figures 10 and 13). The dates closest to 1 April for these two years show tremendous numbers of burns, however. The 09 April, 1987 date had the largest number of burns in the study with 553, and 11 April, 1988 had the second largest number of burns, with 396.

Since this domination of the burning season by the first week of April was present in each of the four years of the study, regardless of weather considerations, it is clear that range managers in the study area were using their calendars to decide when they should burn their ranges.

Burned Area Estimates

In the four years of the study, very small values were found for the total area burned for some of the dates: 14.57 sq., miles for 13 May, 1988. Some very large areas were found, with 14 April, 1986 at 482.36 sq. miles. The year 1985 showed the least amount of area burned: 144.86 sq. miles, followed by 1988 with 429.22, 1987 with 581.62 and the year with the largest amount of burned area was 1986 with 638.31 sq. miles.

After the Landsat transparencies had been transferred to mylar sheets, the burn polygons were digitized using the Sigma-Scan software package. This P.C. based scientific measurement package is designed to take a variety of measurements and perform various manipulations on the data collected. Its primary use was to obtain area measurements for each of the nearly 2,000 burn polygons. The results of this operation are shown in Table 9.

Table 9
Summary of Prescribed Burning Area Estimates
(All Data in Sq. Miles)

Date	Number of Burns	Area Burned
18 March, 1985	25	12.12
03 April, 1985	89	51.10
19 April, 1985	102	81.64
Total 1985	216	144.86
21 March, 1986	34	32.71
14 April, 1986	293	482.36
22 April, 1986	145	123.24
Total 1986	472	638.31
09 April, 1987	553	391.99
17 April, 1987	128	113.10
25 April, 1987	176	76.53
Total 1987	857	581.62

11 April, 1988	396	414.65
13 May, 1988	21	14.57
Total 1988	417	429.22

The tremendous amount of data generated by the digitizing of the polygons necessitated the use of a computer based system for system for statistical data collection. Since the statistical analysis portion of the study was designed to investigate the characteristics of the burn polygons area data set, it was deemed by the researcher, that the most appropriate operations would be values for maximum, minimum, number of observations, sum, mean, variance, standard deviation, and standard error. This information was collected for data sets by date of overpass, year and total. (Table 10)

Table 10
Summary of Burned-Area Statistics
(Data in Sq. Miles)

Date	Number of Areas	Max.	Min.	Sum	Std. Dev	Mean
3-18-85	25	1.85	0.04	12.12	0.47	0.48
4-03-85	89	2.49	0.04	51.10	0.59	0.57
4-19-85	102	2.63	0.06	81.64	0.66	0.80
1985	216	2.63	0.04	144.9	0.62	0.67
3-21-86	34	3.33	0.11	32.71	0.93	0.96
4-14-86	293	5.26	0.04	482.3	1.18	1.65
4-22-86	145	2.85	0.05	123.2	0.67	0.85
1986	472	5.26	0.04	575.6	1.10	1.35
4-09-87	553	4.21	0.00*	391.9	0.75	0.71
4-17-87	128	4.58	0.06	113.1	1.01	0.88
4-25-87	176	2.07	0.02	76.53	0.45	0.43
1987	857	4.21	0.00*	575.6	0.71	0.67

4-11-88	396	5.24	0.01	414.6	0.83	1.05
5-13-88	21	1.58	0.02	14.57	0.57	0.69
1988	417	5.24	0.01	429.2	0.83	1.03
Total	1,962	5.26	0.00*	1794.0	0.90	0.91

*0.0017

There were nearly 2,000 polygons used in the study. They totalled, for the four years involved, 1,794 sq. miles (1.15 million acres) of burned area. The polygons ranged from 0.0017 sq. miles (1.1 acres) to 5.24 sq. miles (3,354 acres). These extreme values are of suspect nature when first viewed, but the minimum value is the smallest area detectable with the Landsat M.S.S. system and 5.24 sq. miles which is well within the largest size generally accepted for a prescribed burn of 15 sq. miles (approx. 10,000 acres) (Owensby, 1988). The means for the study range from 0.43 sq. miles (275.2 acres) to 1.65 (1,056 acres). These values are well within what most experts feel to be the average size for a prescribed burn, approximately one sq. mile (640 acres) (Owensby, 1988).

The standard deviations of the yearly burns ranged from 0.62 (397 acres) for 1985 to 1.1 (704 acres) for 1986. The standard deviation of a data set measures the variance of the data set about the mean, in terms of square miles, and is a measure of the variance of the values in the data set. Therefore, those dates with low standard deviations have data set members which more closely resemble each other, (fewer outlying values), and conversely, those with large standard deviation values have large numbers of outlying data set members. Desirable (low) standard deviation scores were found for small number of polygon dates, large number of polygon dates, both early and late dates, as well as yearly values. This deviation of data set members from the value of the mean is to be expected with a natural resource such as rangeland burning which is not quickly or easily contained in terms of extent or configuration. The major pattern which develops upon inspection of standard deviation values is that 1985 and 1988 have relatively consistent values for all the burn dates in the respective year. This means that the polygons mapped for these years are relatively uniform in size (Figures 4, 5, 6, 7, 8, 9). The years of 1986 and 1987, however, have standard deviations ranging from 0.67 to 1.18. This variation is best explained by three factors;

1) the lack of available imagery at the critical time in the burning schedule
2) weather, and
3) inaccuracies in the transfer process, caused by cloud cover.

For 1986, imagery with suitable cloud cover was not available for the first week of April, when the majority of the burning in the area is suspected to have taken place. The imagery which was available was too early, 21 March, or too late, 14 April. This disparity allowed the burned grasses to green-up and become very difficult to distinguish from other burned area polygons. The weather was warmer than usual, allowing quick regeneration of the burned areas.

The large standard deviation values for 1987 are primarily a result of factors 2 and 3 above. The weather for the 1987 burning season was average to warm, but wet. This allowed the burned areas to quickly green over and lose their characteristic burned response, leading to increased inaccuracy in the interpretation process. Careful checking of the burn maps was performed using the original transparencies as guides, but the interpretation process was very difficult on some of the images.

The percentage of the Flint Hills burned each year can be calculated by using the figure of 2,500 sq. miles (7,300 sq. km.), the amount of land in the study area, (about 53 percent of the Flint Hills' 4,700 sq. miles (12,032 sq.km.)), and the figures for the area burned per year.

Table 11
Percentage Burned of Total Area, By Year.
(All Data in Sq. Miles)

Year	Area Burned	Area Available	Percentage
1985	144.86	2,500	6
1986	638.30	2,500	26
1987	575.61	2,500	23
1988	429.22	2,500	17

These figures are considerably lower than the estimates of 30-40 percent by Owensby, 1987. Possible explanations for the difference are;

1) overestimation of burned area by Owensby,
2) underestimation in this study,
   caused by; A. less burned area on the landscape,
   B. errors in interpretation, transfer, or digitizing.
3) inexact area of rangeland reference.

The variation among the years can be partially explained by the weather during the burning season of the year in question. The year 1985 was a late burn year, only 25 burns were recorded for the first image date, 89 for the second, and 102 for the third. These numbers indicate very slow burning activity in the early portion of the burn season. The variables of maximum and minimum temperature and precipitation do not adequately explain this lack of burning activity. Wind direction and duration can be critical factors in the execution of a burn, and were desirable for this study, but were unavailable. The last image date for 1985 was 19 April, and this date was expected to reflect the lateness of the burning for that year. The study area was, however, at this date, under a scattered cloud layer. Cloud coverage for the study area was about 40 percent. This cloud cover prohibited interpretation of much of the rangeland target below. This lowered the number of burns cataloged. 1986 and 1987 were close to Owensby's estimate. The months in the burning season were average to warm in temperature, with several dry months, but with exceedingly wet months before each of the dry periods. In the Landsat scene of 14 April, 1986, about 40 percent of the study area was hidden under heavy cloud cover. The area under the clouds was in the northern portion of the study area, but since 1986 was an early burn year, the adverse impacts of this cloud cover were minimized. The year 1986 had the largest amount of burning of all the years studied. There were three dates in 1986, 09 April had some cloud cover, but its effect on the interpretation process was minimal. The weather for 1987 was about normal, but fewer burns were mapped than for 1986. In 1988 there were only two useable scenes, 11 April and 13 May. Cloud cover was prohibitive for the rest of the burning season. The lateness of the two dates used for 1988 forced most of the burns to be mapped on the first date. There were very few burns on the second date. The year 1988 had a good burn season weather wise, but the overall occurrence of burns was lower than for 1987, which had a very dry burning season. This dryness combined with gusty spring winds would have compromised the safety and effectiveness of many burn dates, possibly resulting in the lower figures for the burned area for 1988. It is this type of management decision which was determined to be the major force behind the yearly variations. There was not enough evidence present in the weather data to explain the wide variations in number of burns, total area of burns, and to explain the variations in timing of the burns.

Characteristics of Soil

The management practice of prescribed burning, being a manipulation of vegetation, is directly dependent on soil, slope and weather conditions. This study set out to document the characteristics and influences of these variables in terms of their association with prescribed burning.

The Flint Hills are dominated by soils which have tremendous potential for agricultural land uses. They are often, however, very flinty, often shallow or droughty. When these conditions occur, the land use shifts from the economically desirable cropland to the less economically viable rangeland.

The soils under the burns were very productive Mollisol soils. They can be characterized by their genesis in the underlying limestones, shales and glacial tills of the area. They are primarily upland soils, occupying ridgetops or side slopes, since these are the soils most likely to have shallowness, rockyness or are too quickly drained to be used for the more lucrative cropped land use. Some lowland soils are found under burns. They are most likely used in a hay or pasture setting rather than native grass rangeland. They are typically clayey or silty clay loams on the surface with clayey or silty subsoils. The soil associations found under the burn polygons are shown in Table 12.

Table 12
Soil Classification, By County, with Dominant Soil and Percentage.

COUNTY	SOIL ASSOCIATION	DOMINANT SOIL	PERCENTAGE OF ASSOCIATION
MARSHALL	WYMORE-PAWNEE	WYMORE	44
	KIPSON-TULLY	KIPSON	50
MARION	IRWIN-LADYSMITH	IRWIN	65
	LABETTE-TULLY-SOGN	LABETTE	34
	WELLS-VERDIGRIS	WELLS	47
POTTAWATOMIE	CLIME-TULLY-BENFIELD	CLIME	25
	PAWNEE-WYMORE	PAWNEE	46
	KENNEBEC-CHASE-WABASH	KENNEBEC	40
	WAMEGO-ELMONT	WAMEGO	42
	MORRIL-ORTELLO	MORRILL	42
LYON	CHASE-OSAGE	CHASE	37
	CLIME-SOGN	CLIME	55
	KENOMA-MARTIN-ELMONT	KENOMA	30
	KENOMA-LADYSMITH	KENOMA	50
	TULLY-FLORENCE	TULLY	20
MORRIS	LABETTE-FLORENCE	LABETTE	26
	IRWIN-LADYSMITH	IRWIN	51
	MASON-TULLY-READING	MASON	30
	IRWIN-KIPSON-SOGN	IRWIN	30
CHASE	LABETTE-IRWIN	LABETTE	40
	FLORENCE-LABETTE	FLORENCE	28
	READING-TULLY	READING	50
	CHASE-OSAGE	CHASE	30
	CLIME-SOGN	CLIME	45
	LADYSMITH-MARTIN	LADYSMITH	25
RILEY	EUDORA-HAYNIE-SARPY	EUDORA	21
	READING-KENNEBEC-IVAN	READING	50
	SMOLAN-GEARY	SMOLAN	51
	WYMORE-IRWIN	WYMORE	45
	CLIME-SOGN	CLIME	33
	BENFIELD-FLORENCE	BENFIELD	38

GEARY	TULLY-MUIR-HOBBS	TULLY	NA
	SHELLABARGER-FARNUM-DERBY	SHELLABARGER	NA
	CRETE	CRETE	NA
	SOGN-FLORENCE	SOGN	NA
	DWIGHT	DWIGHT	NA
	IRWIN	IRWIN	NA
	LADYSMITH-IRWIN	LADYSMITH	NA
SHAWNEE	READING-WABASH	READING	50
	EUDORA-MUIR	EUDORA	33
	PAWNEE-SHELBY-MORRILL	PAWNEE	70
	LADYSMITH-PAWNEE	LADYSMITH	56
	MARTIN-LADYSMITH	MARTIN	29
	GYMER-SHELBY-SHARPSBURG	GYMER	29
	MARTIN-SOGN	MARTIN	36
JACKSON	PAWNEE-SHELBY-BURCHARD	PAWNEE	42
	MARTIN-PAWNEE-SOGN	MARTIN	36
GREENWOOD	FLORENCE-LABETTE	FLORENCE	60
	CLIME-SOGN-MARTIN	CLIME	50
	ERAM-LABETTE-KENOMA	ERAM	20
	READING-IVAN-CHASE	READING	52
WABAUNSEE	CLIME-SOGN-MARTIN	CLIME	NA
	FLORENCE-IRWIN-LABETTE	FLORENCE	NA
	IRWIN-MARTIN-LADYSMITH	IRWIN	NA
	CHASE-IVAN-READING	CHASE	NA
	MARTIN-WAMEGO-ELMONT	MARTIN	NA
	PAWNEE-MARTIN-WYMORE	PAWNEE	NA
DICKINSON	IRWIN-CLIME-SOGN	IRWIN	55

The soil associations underlying the majority of the burned areas were found to be the Florence-Labette, Clime-Sogn-Martin, Florence-Irwin-Labette, Clime-Sogn, Labette-Florence, and the Clime-Tully-Benfield associations. Table 13 shows these major associations of the study area and their respective percentages of coverage for each of the years of the study.

Table 13
Major Soil Associations and Percent Occurrence, by Year.

Year	Soil Association	Percent of Occurrence
1985 (N=216)	Florence-Labette	14.8
	Clime-Sogn-Martin	14.4
	Florence-Irwin-Labette	13.4
	Clime-Sogn	13.0
1986 (N=472)	Florence-Labette	27.3
	Clime-Sogn	13.9
	Florence-Irwin-Labette	9.9
	Labette-Florence	9.1
1987 (N=857)	Clime-Tully-Benfield	11.1
	Florence-Labette	9.7
	Labette-Florence	9.2
	Clime-Sogn-Martin	9.2
1988 (N=457)	Florence-Labette	32.4
	Clime-Sogn	11.0
	Labette-Florence	7.4
	Florence-Irwin-Labette	6.5

These associations and their percentage of occurrence for the study period are shown in Table 14.

Table 14
Soil Association Percentage Table, for All Years.
(N=1,962)

Soil Association	Percentage of Occurrence
Florence-Labette	19.4
Clime-Sogn	10.0
Florence-Irwin-Labette	8.7
Labette-Florence	7.8
Clime-Sogn-Martin	7.7
Clime-Tully-Benfield	6.4

The soil associations found to lie under the majority of the burned areas can be classified into three groups;

1) the Florence, Labette, Irwin classification,
2) the Clime, Sogn, Martin classification and
3) the Clime, Tully, Benfield classification.

Florence-Labette was by far the dominant association. It underlay a greater percentage of the burn than any other association in three of the four years; it was second only once, and was the leader in the final summary. It is comprised primarily of the Florence soil series, with a minority of Labette soil series occurring with close association. The Florence soils are dark, grayish brown cherty silt loam, approximately one foot thick, underlain by cherty limestone, and well drained.

The Labette soil series is very similar to the Florence, except the surface layer is a shallower silty clay loam about ten inches deep, and has slow permeability. The land use of the Florence-Labette is almost exclusively rangeland. Some small fields are cultivated, but the stony and shallow nature of the soil is generally prohibitive to cultivation.

The Labette-Florence association was found to be the third dominant association in two of the years, fourth dominant in one year, and fourth most dominant in the overall summary. It is comprised of the same soils as the Florence-Labette, but with the dominance switched between the two. It, too, is dominated by rangeland uses.

Closely related to the these two associations, is the Florence-Irwin-Labette. It was found to be the third dominant association in two of the years, fourth dominant in one of the years, and third dominant in the overall summary. It is essentially the same association as the Florence-Labette or the Labette-Florence, but with the Irwin soil series being common enough to warrant its inclusion. It is found exclusively in Wabaunsee county.

The Clime-Sogn association was second most dominant in the yearly summaries twice, and fourth once. It was second on the overall summary. The Clime-Sogn-Martin association was on two of the yearly summaries, in second and fourth places, and occupied the fifth place position in one of the years. These association are composed primarily of the Clime soil series, with a dark, grayish brown, calcareous silty clay surface layer, with a silty clay subsoil and moderately slow permeability. The secondary soil is Sogn, a soil found over limestone outcrops, with a surface layer of dark, grayish brown silty clay loam, approximately six inches thick. The tertiary soil of the classification is Martin, it is formed in residuum, on lower side slopes, and have a surface layer of black silty clay loam, about one foot thick.

The Clime-Tully-Benfield association was found on only one of the yearly summaries, (1987) and was sixth in the overall occurrence list. It is found on ridgetops, sideslopes and foot slopes. The Clime soils are essentially the same as those in the Clime, Sogn, Martin classification, with the addition of the secondary Tully and tertiary Benfield soil series. The Tully soils are based on local alluvium and have a surface layer that is black, silty clay loam with a depth of about one foot. The Benfield soils are based on the weathering of calcareous shale. They have a surface layer of very dark brown silty clay loam about six inches (15 cm) deep and are found on ridgetops and upper side slopes. The dominance of these associations is best explained by two factors;

1) These associations are dominated by rangeland uses, more so than most of the other associations in the study area, and
2) These associations are found primarily on upland and side slope locations, which are the topographic locations best suited to rangeland uses and consequently, range burning.

In a temporal scope, the earliest burns were concentrated on the southern portion of the area, mainly the Florence-Labette, and Clime-Sogn associations. As the burning season progressed, the burning moved northward into the Clime-Sogn-Martin, Labette-Florence, and continuing in the Florence-Labette and Clime-Sogn associations. The end of the season burns, concentrated in the northern portion of the study area, was primarily burned on the Labette-Florence, Florence-Labette, Clime-Sogn, and Clime-Tully-Benfield associations. This temporal movement was a result of the changes in dominant soil association encountered as the burning activity moved from the southern end of the study area to the northern end.

Characteristics of Slope

One of the key characteristics investigated in this study was that of slope. Slope categories were taken from Soil Survey and then correlated to the soil category data collected in the soil section of the study. The data collected are shown in Table 15.

Table 15
Slope Classification Table

SLOPE CATEGORIES	SLOPE	ASSIGNED VALUE
NEARLY LEVEL	0 TO 2 PERCENT	1
GENTLY SLOPING	2 TO 5 PERCENT	2
MODERATELY SLOPING	5 TO 8 PERCENT	3
STRONGLY SLOPING	8 TO 12 PERCENT	4
MODERATELY STEEP	12 TO 20 PERCENT	5
STEEP	20 TO 25+ PERCENT	6

COUNTY	SOIL ASSOCIATION	SLOPE VALUE
MARSHALL	WYMORE-PAWNEE	1-2
	KIPSON-TULLY	3-6
MARION	IRWIN-LADYSMITH	1-2
	LABETTE-TULLY-SOGN	1-2
	WELLS-VERDIGRIS	1-3
POTTAWATOMIE	CLIME-TULLY-BENFIELD	6
	PAWNEE-WYMORE	1-3
	KENNEBEC-CHASE-WABASH	1
	WAMEGO-ELMONT	2-5
	MORRIL-ORTELLO	2-5
LYON	CHASE-OSAGE	1
	CLIME-SOGN	2-3
	KENOMA-MARTIN-ELMONT	1-3
	KENOMA-LADYSMITH	1-3
	TULLY-FLORENCE	1-3
MORRIS	LABETTE-FLORENCE	1-2
	IRWIN-LADYSMITH	1-2
	MASON-TULLY-READING	1
	IRWIN-KIPSON-SOGN	1-2

CHASE	LABETTE-IRWIN	1
	FLORENCE-LABETTE	2-5
	READING-TULLY	1-2
	CHASE-OSAGE	1
	CLIME-SOGN	2-6
	LADYSMITH-MARTIN	1-2
RILEY	EUDORA-HAYNIE-SARPY	1
	READING-KENNEBEC-IVAN	1-2
	SMOLAN-GEARY	1-3
	WYMORE-IRWIN	1-3
	CLIME-SOGN	3-5
	BENFIELD-FLORENCE	3-5
GEARY	TULLY-MUIR-HOBBS	2
	SHELLABARGER-FARNUM-DERBY	3
	CRETE	1-3
	SOGN-FLORENCE	1-3
	DWIGHT	1
	IRWIN	2
	LADYSMITH-IRWIN	1
SHAWNEE	READING-WABASH	1
	EUDORA-MUIR	1
	PAWNEE-SHELBY-MORRILL	1-4
	LADYSMITH-PAWNEE	1
	MARTIN-LADYSMITH	1-4
	GYMER-SHELBY-SHARPSBURG	2-3
	MARTIN-SOGN	1-4
JACKSON	PAWNEE-SHELBY-BURCHARD	1-3
	MARTIN-PAWNEE-SOGN	2-3
GREENWOOD	FLORENCE-LABETTE	1-4
	CLIME-SOGN-MARTIN	1-6
	ERAM-LABETTE-KANOMA	1-3
	READING-IVAN-CHASE	1
WABAUNSEE	CLIME-SOGN-MARTIN	3-6
	FLORENCE-IRWIN-LABETTE	2-4
	IRWIN-MARTIN-LADYSMITH	1-3
	CHASE-IVAN-READING	1
	MARTIN-WAMEGO-ELMONT	3-4
	PAWNEE-MARTIN-WYMORE	2-3
DICKINSON	IRWIN-CLIME-SOGN	1-3

There were 56 soil associations categorized. For each of the soil associations the dominant soil was determined from the Soil Conservation Services' Soil survey for the appropriate counties, and its slope value was ascertained. These slope values, taken from the A.S.C.S. Soil Surveys, ranged from one to six, (Table 15) based on slopes from 0 to 25+ percent.

The most slope values occurred in the 1 and 1-3 values with 13 each, followed by 1-2, with nine occurrences. The 1- 4 and 2-3 values each had four occurrences, The values of 2, 3-5 and 3-6 each had two occurrences. The values of 1-6, 2- 4, 2-6, 3, 3-4 and 6 each had one occurrence. The percentage of occurrence is shown in Table 16.

Table 16
Study Area Slope Occurrence and Percentage

Slope Value	Occurrences	Categories	Percent
1	13	56	23.2
1-2	9	56	16.0
1-3	13	56	23.2
1-4	4	56	7.0
1-6	1	56	2.0
2	2	56	3.5
2-3	4	56	7.0
2-4	1	56	2.0
2-5	3	56	5.3
2-6	1	56	2.0
3	1	56	2.0
3-4	1	56	2.0
3-5	2	56	3.5
3-6	2	56	3.5
6	1	56	2.0
			104.2*

* error due to rounding

The burns were concentrated on nearly level, 0 to 2 percent slope, gently sloping, 2 to 5 percent slope, and moderately sloping soils, 5 to 8 percent slope. These categories account for about 63% of the associations found under burns in the study. There are several explanations for the affinity of burns for shallow slopes. The topography of the Flint Hills is dominated by large, open ridgetops and uplands, separated from lowlands by narrow limestone breaks, steps and benches. It is in these breaks where the steepest slopes of the area occur. They are very steep, 8 to 40 or more percent slope, but they occur over small, narrow areas. The soils on these breaks, steps and benches are poorly developed and are not able to support the richness and density of upland or lowland sites. As a result, these breaks support fewer vigorous communities of grasses than a well-soiled upland or lowland site. This reduced level of productivity adversely impacts the ability of the break to be burned. The less-dense vegetation does not carry a fire as well as a densely vegetated upland or lowland area. Since rangeland burning is an economic activity, these marginal areas are not of primary concern to the range manager when range areas are being considered for burning. As they are not capable of high levels of production, they are not first in line to get the time and effort needed to produce a good burn.

<u>Characteristics of Weather</u>

Weather is an important parameter for decisions made in the use of range burning. Data collected for the study were in the form of maximum, minimum, and precipitation date and amount values. Wind direction and velocity are important parameters in the application of prescribed burning techniques. These data were not, however, available as a routinely collected atmospheric variable, and were, therefore, not addressed in the study.

The high and low temperature weather data collected for the study averaged one to three degrees lower in Manhattan than in Cottonwood Falls and Emporia. The precipitation figures for the study period were comparable for the three stations.

The weather characteristics affected the burns in several ways; The year 1985 had a warm burning season; since range burning can be triggered by warm weather, this allowed the season to begin early in the southern portion of the study area and progress northward at a rapid rate. The year 1986 was a warm year as well, with less than adequate precipitation in the early and late portions of the burning season, with average precipitation in April, allowing early growth and a rapid northward spread of the burning practice.
The year 1987 had weather which affected the burns by having average temperatures for the period, but with a

wet March, a dry April and a wet May. The year 1988 was of average temperatures, but March and May were very dry.

The overall effects of weather on the burned areas of this study can be summarized here:

1) All of the study years were of at least normal temperature. This had the effect of moving burns to the early portion of the burning season, and

2) There were variations in precipitation from the very wet months of April 1986, March 1987 and May 1987, to the very dry months of April 1985, March 1986, May 1986, April 1987, March 1988 and May 1988.

These factors seemed to have little effect on the time of burning, with very dry conditions possibly causing some range managers to wait for safer conditions, and heavy rains delaying some burns. In both cases, however, the delays were likely to be for only a few days, a time scale too small to affect the outcome of the burning season.

Repetitive Nature of the Burns

As a major point of the study, considerable effort was put into determining the characteristics of repetitive burning in the project area. Data were collected and analyzed for each of the burn dates, each combination of burn dates, each year, and total area of repeat-burns.

Spatial Relationships of the Repeat-Burns

The data collected for this section of the study were gathered in the same manner as the spatial distribution data for the original-burns. The county in which a burn was found to lie was used as that burn's county of occurrence. Since repeat-burns are the product of a base year burn and then repetition of the burn phenomenon, comparisons of two years must be used. The county occurrences for the repeat-burn data are shown in Table 17.

Table 17
Yearly Comparisons of Repeat-Burn County Occurrence

	County	Number of Occurrences	Total Number	Percentage
1985/1988	Wabaunsee	9	29	31.0
	Chase	6	29	21.0
	Lyon	4	29	14.0
	Riley	3	29	10.0
	Pottawatomie	2	29	7.0
	Geary	2	29	7.0
	Morris	1	29	3.0
	Marion	1	29	3.0
	Greenwood	1	29	3.0
				99.0*
1986/1987	Chase	49	124	40.0
	Wabaunsee	30	124	24.0
	Lyon	21	124	17.0
	Morris	10	124	8.0
	Riley	4	124	3.0
	Geary	4	124	3.0
	Marion	3	124	2.0
	Greenwood	2	124	2.0
	Pottawatomie	1	124	1.0
				100.0
1985/1986	Chase	22	42	52.0
	Wabaunsee	12	42	29.0
	Lyon	5	42	12.0
	Geary	2	42	5.0
	Morris	1	42	2.0
				100.0

1985/1987	Wabaunsee	24	59	41.0
	Chase	15	59	25.0
	Lyon	9	59	15.0
	Geary	4	59	7.0
	Greenwood	3	59	5.0
	Riley	3	59	5.0
	Pottawatomie	1	59	2.0

				100.0
1986/1988	Chase	87	138	63.0
	Wabaunsee	16	138	12.0
	Lyon	10	138	7.0
	Morris	10	138	7.0
	Riley	6	138	4.0
	Greenwood	5	138	4.0
	Pottawatomie	2	138	1.0
	Marion	1	138	1.0
	Shawnee	1	138	1.0

				100.0
1987/1988	Chase	17	168	54.0
	Wabaunsee	17	168	10.0
	Lyon	16	168	10.0
	Morris	16	168	10.0
	Pottawatomie	10	168	6.0
	Greenwood	7	168	4.0
	Riley	5	168	3.0
	Marion	4	168	2.0
	Geary	3	168	2.0

				101.0*

* = Error Due to Rounding

As with the original-burns, the repeat-burns are dominated by the three counties of Chase, Wabaunsee and Lyon, but to a greater degree. Approximately 93 percent of the repeat-burns from 1985/1986 were in these three counties; 81 percent of the 1985/1987 repeat-burns were found there; 66 percent of the 1985/1988 burns were in these counties as well; 74 percent of the 1987/1988 repeat-burns were in this three county area; 81 percent of the 1986/1987 repeat-burns were in these counties;

and 82 percent of the 1986/1988 were found in these counties. These values are higher than those for the original-burn data. This indicates that the repeat-burns occurred at a higher rate in these areas than were the original-burns. This occurs because the burning in the Flint Hills is concentrated in this three county area, and repeat-burns must be burned on areas that have already burned. Since it is necessary for repeat-burns to occur in areas where this phenomenon was already a part of the landscape, areas of greater burning occurrence are able in subsequent years to receive more repeat-burns.

Temporal Relationships of the Repeat-Burns

The domination of repeat-burning's temporal distribution by the first week of April is quite evident in Table 19. In each year of the study the largest values were found to occur just after the first of April. The pre-1 April repeat-burns total only 6.54 sq. miles. As with the original-burns, it would have been desirable to have had imagery for the week before, during and after the first week of April, but this was not possible for this study period due to cloud cover. Grouped by years, the repeat-burning data are shown in Table 18.

Table 18
Repeat-Burn Area Comparisons for Year to Year
(All Data in Sq. Miles)

Year of Comparison	Area of Repeat-Burns
1985-1986	91.19
1985-1987	73.28
1985-1988	34.38
1986-1987	135.52
1986-1988	171.00
1987-1988	193.45
Total	698.82

The presentation of these yearly summaries shows a range in values from 34.38 sq. miles to 193.45 sq. miles. The 1986 and 1987 values are comparable, being in the mid to high 100's. The 1985 comparisons are considerably lower. The explanation for this is that for an area to be repeat-burned it must have first been burned. Of the original-burns, 1985 was, by far, the lowest value at 144.86 sq. miles, with the years of 1986, 1987 and 1988 having original-burn area values of 638.31, 581.62 and 429.22 sq. miles, respectively. This small amount of original-burned area in 1985 limited the amount of repeat-burns that were possible.

The lowest value of all, the 1985-1988 value of 34.38 sq. miles, was very low by virtue of having few non-repeat burns in 1985, then having what could have been repeat-burns in the large repeat-burn year of 1988 occur in locations which did not make them repeat-burns.

Conversely, the very large repeat-burn values of 1986-1987, 1986-1988 and 1987- 1988, came about because of the large number of original-burns in the first year of the comparison and a large amount of burns in the second year, many of which occurred on the site of the original-burns, making them repeat-burns.

The increase from one year to the next was consistent with the increase from 1985-1986 to 1986-1987 at 48.4 percent, and the increase from 1986-1987 to 1987-1988 at 43.0 percent. This steady growth resulted from the addition each year of new repeat-burns and new original-burns which tended to moderate any large changes in the data on these yearly comparisons.

Although the one-year-to-the-next comparisons were consistent and predictable, this was not the case for the other comparisons. For 1985, as the time between the compared years increased, the number of repeat-burns decreased. The values declined from roughly 91 sq. miles in 1986 to approximately 73 sq. miles in 1987 to slightly more than 34 sq. miles in 1988. There was, however, an increase from about 136 sq. miles for 1986-1987 to approximately 171 sq. miles for the 1986-1988 comparison. The 1987-1988 comparison has no companion year by which it could be judged.

The 1985 behavior can be best explained by the fact that original-burn areas declined from 1986 through 1988 from approximately 638 sq. miles to about 430 sq. miles.

This meant that there was simply less original-burned area to be repeat-burned. The decrease in the amount of repeat-burned area from 1986 to 1988 was about 70 percent, while the reduction in the amount of original-burns for the same period was approximately 68 percent.

The behavior of 1986-1987 and 1986-1988 does not follow that of the 1985 repeat-burns. There was a 9 percent reduction in the original-burned area from 1986 to 1987, a 23 percent reduction from 1987 to 1988, and a 33 percent reduction from 1986 to 1988, but an increase of almost 26 percent in the amount of reburned area from 1986 to 1988. There were more original-burns in 1986 than in either 1987 or 1988, but, the amount of area repeat-burned increased from 1986 to 1987 to 1988.

Repeat-Burned Area Estimates

To fully investigate the dynamics of the repeat-burning occurrence in the study area, it was necessary to analyze the repeat-burned area for each of the individual study dates. These data, along with yearly totals, are shown in Table 19.

Table 19
Repeat-Burn Date/Year Comparisons
(All Data Sq. Miles)

Date/Year	Area Repeat-Burned
21 March, 1986/1985	6.54
14 April, 1986/1985	70.32
22 April, 1986/1985	14.33
Total 1986	91.19

09 April, 1987/1985	41.17
09 April, 1987/1986	94.28
17 April, 1987/1985	29.91
17 April, 1987/1986	26.29
25 April, 1987/1985	2.20
25 April, 1987/1986	14.95
Total 1987	208.8
11 April, 1988/1985	34.38
11 April, 1988/1986	170.82
11 April, 1988/1987	192.30
13 May, 1988/1985	none
13 May, 1988/1986	0.18
13 May, 1988/1987	1.15
Total 1988	398.83

This table was created by totalling, by date, the amount of repeat-burned area from the overlay comparisons for each of the three years that repeat-burning occurred. It, therefore, shows the total amount of repeat-burning that occurred in the four years of the study, for a particular study date. The dates are grouped according to the year over which the burn maps were overlaid. This grouping allows the values for the dates to be categorized without listing each of the 45 burn-map comparisons.

The values shown here vary greatly, from a low of no repeat-burns for 13 May, 1988/1985 to 192.30 for 11 April, 1988/1987. The remainder of the values are more moderate, with a mean value of 46.59 sq. miles. These data show a large increase in the amount of total repeat-burned area from 1986 to 1987 and an even larger increase from 1987 to 1988. This is misleading, however, since the lowest area figure, 1986, is comprised of burns that were repeated from the 1985 season only. The figure of 208.80 sq. miles for 1987 has the years of 1985 and 1986 summed. Likewise, 1988 has the years of 1985, 1986 and 1987 added together to give it the figure of 398.83 sq. miles. Table 20 shows these characteristics in percentage form.

Table 20
Repetitive Percentage of Burns from Year/Year
(All Data area in Sq. Miles)

Year/Year	Repeat-Burn Area/Total Area Burned	% Repeat
1985-1986	91.19/144.86	62.9
1985-1987	73.28/144.86	50.6
1985-1988	34.38/144.86	23.7
1986-1987	135.52/638.31	21.2
1986-1988	171.00/638.31	26.8
1987-1988	193.45/581.62	33.3
Total	698.82	Average 37.6%

The greatest percentage of repeat-burn occurrence was in the 1985-1986 comparison. This took place because of the low area of original-burns in 1985, and the relatively large area of repeat-burns that occurred on them in the following years.

The large increase in original-burns for the 1986 comparisons reduced percent coverages dramatically from the 1985 values. Although the repeat-burn area had increased, it had not done so as dramatically as had the original-burn area. The comparisons of 1986-1987, 1986-1988 and 1987-1988 all show an increasing percentage of repeat-burns. Some of this is attributable to the reduced original-burns of the 1988 season, but the increase from 21.2 percent of 1986-1987 to 26.1 percent of 1986-1988 was the result of increased levels of repeat-burning, which this researcher can only attribute to decisions, not in the scope of this study, made by the range managers of the area to increase the repeat-burns of the range sites.

In terms of size the means for the repeat-burns and the original-burns are comparable. These values are shown in Table 21.

Table 21
Original-Burn and Repeat-Burn Mean Comparison
(All Data in Sq. Miles)

Year	N	Original-Burns	N	Repeat-Burns
1986	472	1.35	53	1.32
1987	857	0.67	218	0.74
1988	417	1.03	341	0.60
Total	1,746	0.91	612	0.89

In terms of mean size of polygons the two groups are essentially the same. There is a disparity in the 1988 comparison. The original-burns had a mean of 1.03 sq. miles, and the repeat-burns had a smaller mean of 0.60 sq. miles. The reduction in the size of the mean for the repeat-burns is due to the fact that there were six repeat-burn dates which had no burns, so a value of 0 was entered into the calculation for the mean.

Characteristics of Soil

The soils underlying the repeat-burns were found to be essentially the same soils as those found under the original-burns. Table 22 compares the two soil occurrences.

Table 22
Repeat-Burn and Original-Burn
Soil Association Percentage Comparison Table
All Years.

Soil Association	Original-Burn %	Repeat-Burn %
Florence-Labette	19.4	33.0
Clime-Sogn	10.0	9.0
Florence-Irwin-Labette	8.7	16.8
Labette-Florence	7.8	6.2
Clime-Sogn-Martin	7.7	4.2
Clime-Tully-Benfield	6.4	3.1

The most frequently occurring soil in the original and repeat-burn groups was the Florence-Labette. The next four soils were found in both groups, but in different rankings. Florence-Irwin-Labette occurred second on the repeat list, third on the original, Clime-Sogn was found to be third on the repeat list, second on the original. Labette-Florence placed fifth on the repeat, fourth on the original, and Clime-Sogn-Martin was ranked sixth on the repeat list and fifth on the original list. The only soil listed in the top six on the repeat list which was not on the top six of the original-burn soils list was Tully-Florence, which occurred twelfth on the original-burn list. Tully-Florence is a soil association found in Lyon county, on narrow ridgetops and sideslopes, with dissected stream channels, primarily in the northwestern corner of the county. It is this location which brought the association in to the top six of the repeat list, for the area is one that experienced heavy repeat-burning, with more than one-quarter of the Tully-Florence repeat-burns occurring on the 09 April, 1987/14 April, 1986 comparison.

Characteristics of Slope

To analyze the characteristics of the slope found under the repeat-burns, data were collected in the same manner as for the original-burns. Slope categories were found for all the soils associations on which repeat-burns occurred. These data were then grouped together by number of occurrences, and percentage of occurrence was calculated. The results of these steps are shown in Tables 23 and 24.

Table 23
Repeat-Burn Soil Classification and Slope Table

Slope Categories	Slope Percent	Value
Nearly Level	0 to 2	1
Gently Sloping	3 to 5	2
Moderately Sloping	6 to 8	3
Strongly Sloping	9 to 12	4
Moderately Steep	13 to 20	5
Steep	21 +	6

Soil Association(county)	Dominant Soil-% of Assoc.	Slope Value
Benfield-Florence (Rl)	Benfield- 38	3-5
Chase-Osage (Ly)	Chase - 37	1
Chase-Ivan-Reading(Wa)	Chase - na	1
Clime-Sogn (Ly)	Clime - 55	2-3
Clime-Sogn-Martin (Gw)	Clime - 50	1-6
Clime-Tully-Benfield(Pt)	Clime - 25	6
Eram-Labette-Kenoma(Gw)	Eram - 20	1-3
Eudora-Muir (Sn)	Eudora - 33	1
Florence-Irwin-Labette(Wa)	Florence- na	2-4
Florence-Labette (Gw)	Florence- 60	1-4
Irwin-Ladysmith (Mr)	Irwin - 65	1-2
Irwin-Martin-Ladysmith(Wa)	Irwin - na	1-3

Kenoma-Martin-Elmont(Ly)	Kenoma - 30	1-3
Labette-Florence (Mo)	Labette - 26	1-2
Labette-Irwin (Cs)	Labette - 40	1
Labette-Tully-Sogn(Mr)	Labette - 34	1-2
Ladysmith-Irwin (Ge)	Ladysmith-na	1
Ladysmith-Martin (Cs)	Ladysmith-25	1-2
Martin-Wamego-Elmont(Wa)	Martin - na	3-4
Mason-Tully-Reading(Mo)	Mason - 30	1
Pawnee-Martin-Wymore(Wa)	Pawnee - na	2-3
Reading-Tully (Cs)	Reading - 50	1-2
Sogn-Florence (Ge)	Sogn - na	1-3
Tully-Florence (Ly)	Tully - 20	1-3
Wymore-Irwin (Rl)	Wymore - 45	1-3

With these data the percentages of occurrence can be calculated, as in Table 24.

Table 24
Repeat-Burn Slope Occurrence and Percentage

Slope Value	Occurrences	Categories	Percentage
1	6	25	24.0
1-2	5	25	20.0
1-3	6	25	24.0
1-4	1	25	4.0
1-6	1	25	4.0
2-3	2	25	8.0
2-4	1	25	4.0
3-4	1	25	4.0
3-5	1	25	4.0
6	1	25	4.0
			100.0

As with the original-burns, the repeat-burns were found to lie predominantly on the lesser slopes. Some 68 percent of the repeat-burns were found in slope category one, two, and three, compared with a little more than 63 percent of the original-burns. The remainder of the repeat-burns were dispersed throughout the lower end of the range, with a distinct absence in the four and five values as was the case in the original-burns.

Characteristics of Weather

As was the case with the original-burns, the repeat-burns seemed to be set more by historical precedent than by the weathervane. Repeat-burns were very scarce until the first of April had passed. This was true in years of less than normal precipitation, greater than normal precipitation, higher than normal temperatures and lower than normal temperatures. The movement northward of the burning season was evidenced in the repeat-burns, as it was in the original-burns, but the effect of weather on the burning dynamics of the area, at least at the temporal scale of several months, was found to be negligible.

Findings

The results of the analysis of this chapter can be summarized into 8 statements:

1) The amount of land area which was prescribe burned was found to be less than that of previous estimates.

2) The area of prescribed burning which occurred in the northern Flint Hills in 1985, 1986, 1987 and 1988 varied considerably (from 145 sq. miles in 1985 to 638 sq. miles in 1986).

3) Prescribed burns were concentrated in Chase, Wabaunsee and Lyon Counties.

4) The historical precedence of burning in the first week of April was found to govern the temporal distribution of range burning in the study area.

5) The weather variables used in the study were found to have little effect on the temporal distribution of the burning phenomenon.

6) Four soil associations were found to underlie 46 percent of the study area.

7) 63 percent of the burns were found to occur on slopes of less than 8 percent.

8) Repeat-burns were found to exhibit much the same behavior as original-burns, in terms of the characteristics examined in this study.

CHAPTER FOUR

Summary and Conclusions

Summary

The Flint Hills of Kansas comprise an area based on a ranching economy. The decisions that go into the operation of a ranch in the area are challenged by pressures ranging from adverse weather to misinformation about rangeland and its management, to, especially in the last five years, a sagging agricultural economy. In this light it is important to understand as much as possible about the tools available to range managers in the area. To this end this study was undertaken.

It was the purpose of this study to investigate the temporal and spatial dynamics of prescribed range burning in the northern portion of the Flint Hills of Kansas. These goals were accomplished using data collected by 14 overpasses of the Landsat earth resources satellite and the resulting images in transparency form were interpreted for burn area polygons. These transparencies were obtained for the burn season (March, April and May) for the years of 1985, 1986, 1987 and 1988. Data were collected from published and unpublished soil surveys, field and aerial transects as well as from Landsat data. Prescribed burn maps were developed from these sources. The interpreted burn maps were then compared with each other to determine the repetitive nature of burns in the area. The dynamics of soil, slope and weather, and their involvement with the burns were also investigated.

The amount of rangeland burned in the four years of the study, 1985-1988, varied from a low of 144.86 sq. miles for 1985, to 429.22 for 1988, to 581.62 for 1987, to a high of 638.31 sq. miles for 1986. The variation found here is best explained by the cloud cover on some of the satellite images, which lead to variability in the number of burns available for interpretation, overall variability in the number of burns taking place, and to a limited degree, the weather.

Burns were concentrated in the counties of Chase, Wabaunsee and Lyon, with 64 percent of the burns in these counties. These counties are highly range-oriented in terms of land use and they are possibly utilized by larger operators and managers who may be more liberal in their use of prescribed burning.

The temporal distribution of prescribed burns was found to be governed almost exclusively by the calendar, with the first week of April as the period when the vast majority of burns taking place. Small amounts of burning occurred before the first week of April, then a large "bloom" of burns were begun, then the burning trickled out, ending by the second week of May.

The effects of weather on the prescribed burns in the area was found to be minimal. Weather data gathered was in the form of daily high and low temperature, and precipitation date and amount. These data were found to have little effect on the overall burn phenomenon, with some effect detected on the time of burn. Very warm periods accelerating burning somewhat, but no effect determinable on the amount or placement of the burns. The temporal scale used in the study allowed little correlation between weather and burns. An investigation sampling burning activity on a much more compressed time scale may find the interactions which probably exist between range burning and the weather data used for this study.

The interactions between soil, slope and burns were investigated. The soils underlying the burns were found to be primarily Florence-Labette, Clime-Sogn, Florence-Irwin-Labette and Labette-Florence soil associations. These associations accounted for 45.9 percent of the soils underlying the burned area polygons. They are predominantly upland soils, with dark, silty clay or silty clay loam surface soils, overlying limestone, some areas contain considerable amounts of chert or flint. Their backgrounds are all in their local colluvium and alluvium, and their usefulness is usually limited to rangeland, for they are subject to droughtyness and are difficult or impossible to plow.

The slopes under the burns were found to be mostly shallow with 63 percent of the study's burned areas having a slope of less than eight percent. This domination is a reflection of the large area in the Flint Hills which utilizes the hilltops, ridges, and upland areas. Most of the relief in the area comes from narrow breaks, leaving the rest of the area in less slope.

The analysis of the repeat-burns found that they were very similar to the original-burns in terms of soils, slope and temporal and spatial distribution.

The area of repeat-burns was found to vary from 91.19 sq. miles for 1985-1986 to 193.45 for 1987-1988. This variation can be explained by two factors:

(1) In the years following a large-area burn, there is more area available for repeat-burning; and
(2) repeat-burns were more prevalent in 1987 than can be explained by the variables in this study.

Soils underlying repeat-burns were the same as with the originals, but they occupied 51.4 versus 45.9 percent. The repeat-burns were found to occupy shallow slopes to slightly more than the original-burns, with 68 percent of the repeats found on slopes of less than 8 percent, versus 63 percent for the originals. The repeat-burns were distributed in a manner similar to the originals, with 67 percent of the burns located in Chase, Wabaunsee and Lyon Counties, compared to 64 percent for the originals. Cumulative repeat-burns increased from 91.19 sq. miles in 1986 to 208.8

in 1987, to 398.82 in 1988.

The area of original-burns increased from 1985 to 1986, peaked in 1986 and decreased for 1987 and 1988. Repeat-burning increased as well, from 1985-1986 to 1986-1987 as a result of the increased amount of land burned. The reduction of original-burns from 1986 to 1987, and 1987-1988 did not, however, lead to reductions in repeat-burns; but rather, repeat-burns increased for these time periods. There was simply more repeat-burning on less originally burned land. Range managers had made decisions which were not investigated in this study, and remain unknown.

This study's goals of estimating the amount of land burned for each of the four years of the study were accomplished, as well as were estimates of the repetitive nature of the burning phenomenon. The interactions between soil, slope, weather and the burns were assessed.

Conclusions

Many problems were encountered in the completion of the project. Every attempt was made to anticipate these problems, but some were unavoidable, given the uncontrollable nature of atmospheric variables, the cost of the project and computer breakdowns. Two controllable areas could have used to improve accuracy and efficiency of the study; 1) the purchasing of Landsat prints at the study scale of 1:250,000 (more expensive) than at the transparency scale of 1:1,000,000 (less expensive). This would have eliminated the lengthy and tedious transfer process, which was a source of possible error and 2) the use of a vector based, (since soil and slope data are in irregular polygon shapes) G.I.S. system for geo-referencing, polygon location statistical analysis, and image processing. The computer driven capabilities of G.I.S. systems, such as IDRISI, and ERDAS, would have lead to increased accuracy, and flexibility in the study, but at increased cost.

In terms of future studies, this researcher feels that an interesting follow-up to this study would be an in-depth look at the dynamics of prescribed burning in Chase, Lyon and Wabaunsee counties. These counties dominated the burning phenomenon in this study, and it would be interesting to investigate, at a much more detailed level, the characteristics chosen for this study, in this most active area of the range burning scene in Kansas.

The future of the Kansas Flint Hills lies in the future of the beef cattle industry. If feed and petroleum prices remain low for the next several decades, there will likely be a reduction in the ranching activities in the Flint Hills, due to the cost advantage experienced by the large feedlots in the western portion of the state. If these input prices should increase, the low maintenance and low cost of range fed beef will increase the use and therefore the management, of the rangeland in the Flint Hills. It is just this management activity which needs intelligent, far-sighted, economically acceptable and environmentally sound decisions. It was the goal of this project to contribute to this decision making process.

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SPATIAL AND TEMPORAL CHARACTERISTICS OF PRESCRIBED RANGELAND BURNING; THE NORTHERN FLINT HILLS OF KANSAS

by

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ABSTRACT

The Land use of the Kansas Flint Hills is dominated by range and pasture. The management of these resources is of key importance to the economic stability of the area. As one of the primary tools used by range managers in the area, prescribed burning was investigated to understand more fully the complex interrelationships between the prescribed burning which occurs in the area, and its environment. The area of rangeland burning was found to be less than that of previous estimates. The rangeland burned areas were concentrated on shallow slopes and a small number of soil associations. Annual rangeland burn timing was found to be most affected by historic practice, as little correlation was determined to exist between weather conditions and burn timing. The spatial pattern of repetitive burns was similar to those of all burns in the study area.