RURAL LAND USE CHANGES AND LOCAL CLIMATE IN THE CROSS TIMBERS OF OKLAHOMA

By

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CHAPTER I

INTRODUCTION

The issue of climatic change is receiving increased attention in the geographic literature. More specifically, human-induced climatic change has become a very important topic. As world population increases, the impact of human activities on the natural environment becomes more and more apparent. Increasing atmospheric carbon dioxide concentrations and depletion of the ozone layer, for example, have been tentatively linked to anthropogenic activities and also to large-scale climatic fluctuations (Kellogg, 1987 and Thompson, 1989).

Another aspect of climatic change currently being studied is that of land surface modification. Land altered from its natural state has shown significant influence on local climate in the form of urban heat islands (Kochar and Schmidlin, 1990). However, there have been relatively few studies detailing the effects of rural land use change on local climate. Those which have dealt with rural land use have done so for specific points in time rather than dealing with conversion from one land use to another. The impacts of rural land use changes need to be explored further because most of the earth's land area is rural.

Purpose

The climatic element to be studied in this thesis is mean monthly surface temperature. According to Mather (1974), there have been significant differences recorded in terms of surface temperatures, based on land cover. He noted sunny day temperatures of 31°C for short grassed areas with no shade and 26°C for soil in the shade of oak trees. Oliver (1973) reported that low-altitude, mid-latitude forested areas were as much as 2.8°C cooler than non-forested areas. However, Oliver also suggested that determination of climatic modification by forests was difficult due to the wide varieties of forest structures. Both of these studies related forested land to lower temperatures, when compared with non-forested land. There have been a number of elements suggested as contributors to climatic change at various scales. Such elements included fluctuations in precipitation (Thompson, 1989) and carbon dioxide concentrations (Henderson-Sellers and Gornitz, 1984).

The hypothesis to be tested in this thesis is that changes in rural land cover have had a measurable effect on local mean monthly temperature. It is suggested that the linear trend in local mean monthly temperature is an increase of approximately 3.0 °C over the past 40 years. This hypothesized magnitude of the global climatic trend is determined from the geographical literature (Mather, 1974 and Oliver, 1973). Therefore, the purpose of this thesis is to quantify and evaluate the interrelationship between rural land uses and local climate. Enough evidence is not available, however, to expect a direct cause-and-effect relationship between land use and surface temperature. It is further hypothesized that the surface-climate relationship will be most significant at the subregional (county) level. This is based upon the notion that a greater number of environmental factors must be considered at the regional, state and even hemispheric levels; thus, the significance of any single factor (i.e. land use) is not as clear at such scales.

Study Area

The area used for this research was a 6-county area within the Oklahoma Cross Timbers. The Cross Timbers is an ecotone---a zone of biological transition---between the eastern hardwood forests and the prairie grasslands of the west (Drass, 1984). It is characterized by dense stands of post-oak and blackjack oak with interspersed areas of grassland. The Cross Timbers has been recognized as a distinct vegetation region since the mid-1800s, when a number of expeditions traversed the region. In fact, it is the largest natural vegetative region in Oklahoma (Morris, et al., 1976).

The Cross Timbers extends from central Texas, through central Oklahoma and into southeastern Kansas. According to Wyckoff (1984), the Cross Timbers is only a portion of an even larger ecotone---the Osage Savanna biotic district. The Cross Timbers varies from five to thirty miles in width and comprises the southern portion of this ecotone (Figure 1; Wyckoff, 1984). Wyckoff used the title "Osage Savanna biotic district" because the name "Cross Timbers" implied that the ecotone was a zone of vegetative transition alone. In fact, the region is also distinct in terms of fauna. There was no evidence of wildlife as an agent of change on the landscape; therefore, it was excluded from the analysis. This thesis uses the term "Cross Timbers" to refer to this ecotone, because the vegetation is the primary focus in terms of climatic implications.

The selection of the Cross Timbers as a study area was based on

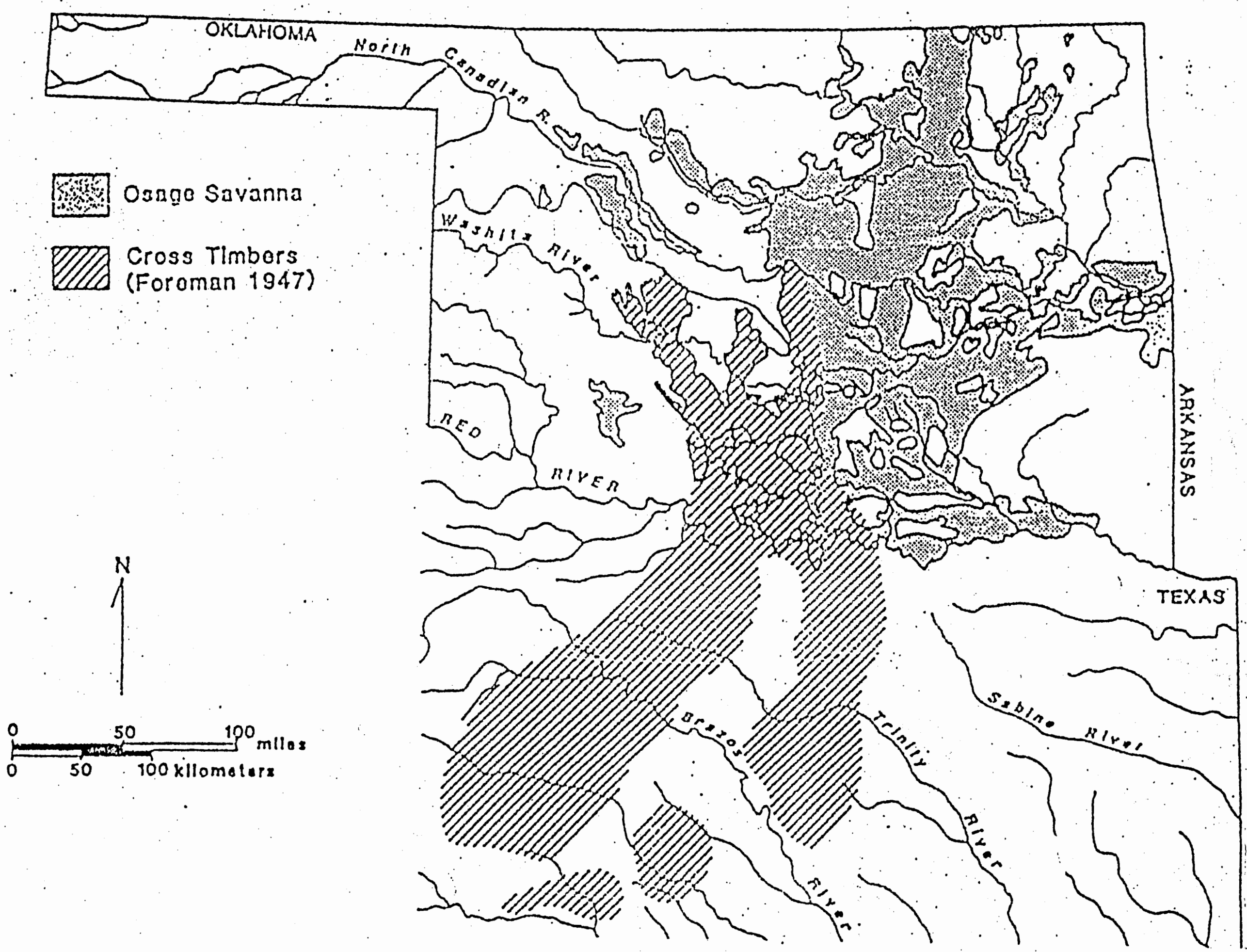

Figure 1. Location of the Cross Timbers in Northern Texas and Southern Oklahoma. Source: Wyckoff, D.G. (1984).

historical records. This area underwent dramatic changes, in terms of land cover, during the past 100 years. The rural landscape was greatly altered, as will be discussed in Chapter IV. Therefore, this seemed a proper setting to analyze the surface - climate relationship for rural areas.

The counties of Creek, Hughes, Lincoln, Okfuskee, Payne and Seminole were used for this study (Figure 2). The selection of these counties was dependent upon two key factors---geographic literature and data availability. With regards to the former, several sources defined the areal extent of the Cross Timbers within Oklahoma. All were similar to that given by McPherson (1990; Figure 3). A combination of maps from such literature, as well as written descriptions of the Cross Timbers, led to the determination of an 8-county study region. This region represented the "core" of the present-day Cross Timbers in Oklahoma. However, due to a lack of climatic data from Pottawatomie and Pawnee counties, only the six counties could be included in this research.

Geographic Relevance

There have been a number of studies dealing with human impact on the natural environment. However, the literature is relatively void of research linking rural land use changes to local climatic fluctuations at a subregional level. When considering the geographic literature regarding anthropogenic climate change, the majority deals with changes in atmospheric composition, more specifically, increases in atmospheric carbon dioxide concentrations and depletion of ozone.

Land use patterns demand more attention, especially in terms of

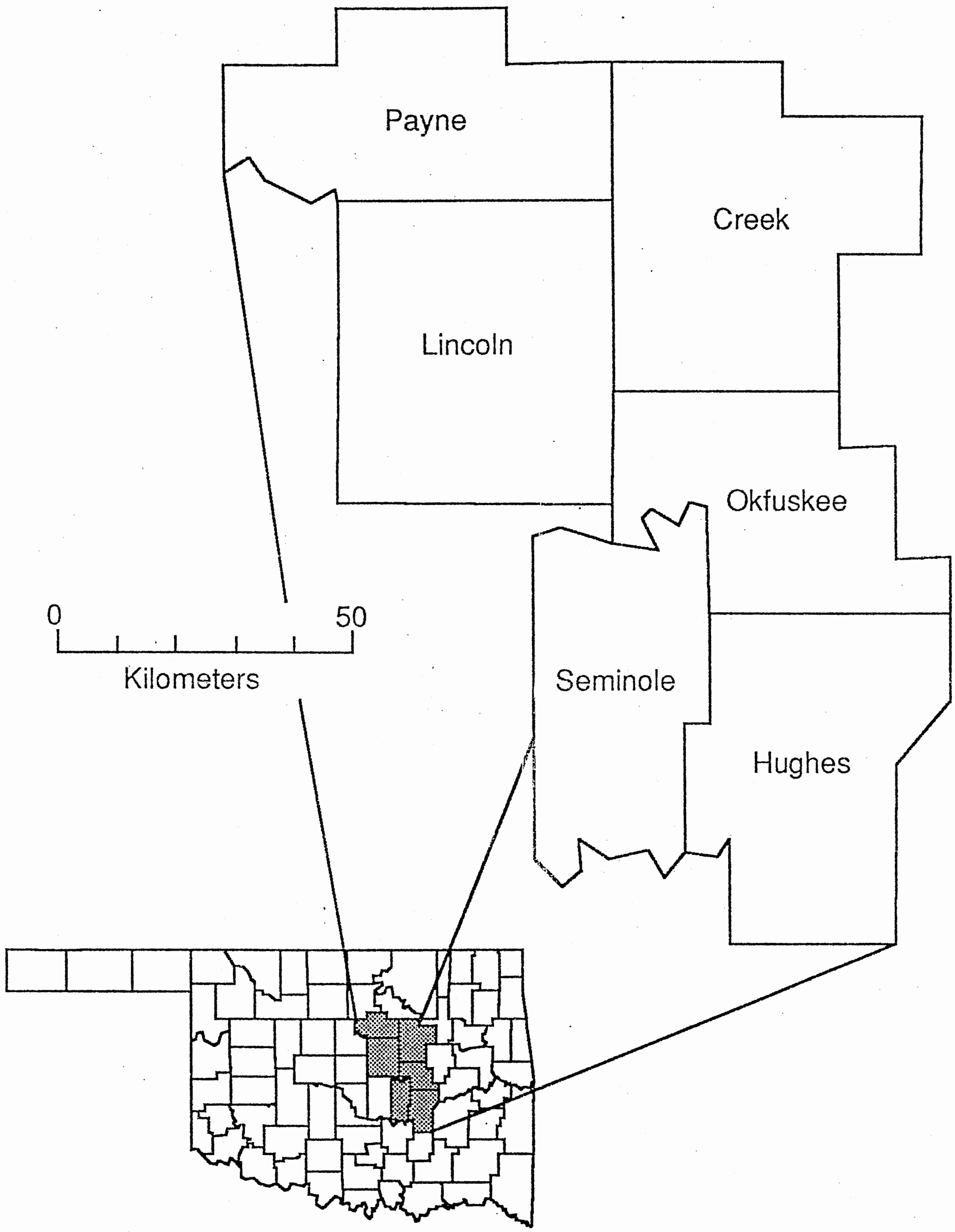

Figure 2. 6-County Study Area

Figure 3. Study Area in Relation to the Cross Timbers in Oklahoma.
Source: McPherson, J.K., 1990 (in press)

the rural environment. Humans have clearly altered local climate as a result of land surface modification (Kellogg, 1987). As world population continues to increase, more and more rural land falls victim to human abuse. The climatic ramifications of such actions are not fully understood as yet. A detailed discussion of geographic literature concerning the relationship between land surface and climate will be given in Chapter II.

The global climatic models which currently are being used need more input from local areas. Current models are not yet reliable to predict climatic change at the subregional level (Kellogg, 1987). The present study is geographically relevant, for it will attempt to answer some of the questions of climatic change and will help set the stage for future research.

CHAPTER II

LAND SURFACE CLIMATE

A variety of literature has addressed the surface-climate interrelationship. Most of it has focused on the effects of climate on the vegetation of a given area. Comparatively, there have been few studies on the effects of vegetation on the local climate; however, recent developments in mesoscale atmospheric research have suggested the existence of vegetative feedbacks to the atmosphere. The purpose of this chapter is to review some of the recent literature dealing with the land surface climate.

Climatological Studies of Vegetation

Vegetation studies, such as that of Henderson-Sellers and Gornitz (1984), have shown that forest canopies are noticeably cooler than farmland. Tropical rainforests have comparatively lower albedos than do farmland areas. Compared to farmland, rainforests have more of the incident radiation taken into the canopy---either being absorbed and used for photosynthesis by the vegetation or reflected within the canopy. This surplus of energy results in turbulence within the forest stand itself, thus, leading to the accelerated exchange of sensible heat. Furthermore, evapotranspiration rates are greater in areas of dense vegetation. Evapotranspiration has an apparent cooling effect on local climate, as shown by Gornitz (1985). It has been shown by Sagan, et al. (1979) that land cover changes from temperate forest to cropland can alter the microclimate. As mentioned in Chapter I, it has also been noted that areas containing short, grassy vegetation have warmer temperatures than forested areas (Mather, 1974). Such alteration could lead to changes over larger areas of land. However, much more research is necessary before final conclusions can be drawn as to the influence of surface cover on the regional climate (Lockwood, 1983).

The Influence of Soil Moisture and Evapotranspiration

It has been suggested that soil moisture plays a prominent role in determining local surface temperature. The sensible heat/latent heat (Bowen) ratio is modified by soil moisture; thus, soil moisture is suggested as an influence on surface air temperature (Walsh, et at., 1985). Nicholson (1988) stated that soil moisture is the primary determinant of temperature patterns for non-vegetated surfaces because of the high specific heat and thermal conductivity of water, and the expenditure of sensible energy for evaporation. One study of soils showed wetter than normal conditions persisting for several months. The corresponding climate record, in that particular study, showed a decline in regional temperature of 2-6 °C over a period of 1-2 months (Walsh, et al., 1985).

Evapotranspiration has also been related to local air temperature. Generally, local decreases in rates of evapotranspiration have been linked with local increases in temperature. Gornitz (1985) suggested that temperature rise resulting from reduced evapotranspiration may offset the decreased temperature caused by an increase in surface albedo. When comparing two areas of different vegetal cover, temperature variations have been observed. Such temperature variation was attributed to differing evapotranspiration characteristics due to different canopies (Anthes, 1984).

Anthropogenic Climatic Changes

Studies in anthropogenic alteration of climate can be separated into two categories----those dealing with alteration of the surface and those dealing with alteration of the composition of the atmosphere. The former refers primarily to changes in the albedo and Bowen ratio response to surface modification and is directly related to this thesis.

Beginnings of Anthropogenic Surface Modification

Human impact on the climate really began 5,000 to 9,000 years ago, when the advent of agriculture brought about changes in the surface characteristics (Lamb, 1977). A better understanding of past anthropogenic changes may aid in understanding the impact of present-day surface modifications (Sagan, et al., 1979). As Abbe (1977) illustrated, there are differing relationships between climate and surface characteristics depending on, for instance,the type of crop covering the land. Other studies, such as that done by Norton, Mosher, and Hinton (1979), have shown that there are variations in the albedo of a given area according to soil moisture content. Seasonal variations in albedo between wet and dry seasons have been measured as high as 80% in Sahelian Africa. Such dramatic variations were experienced on land which had been denuded of much of the vegetation due to excessive drought. Obviously, then, there have been several characteristics of the land surface linked to climatic changes.

Urban Heat Islands

When discussing land surface changes, urban heat islands must be mentioned. They represent the most dramatic form of surface alteration as a result of human activity. When an urban landscape is developed, a natural surface cover is transformed into an artificial surface. Urban heat islands are understood quite well in terms of their climatic implications. This has been confirmed in both temperate and low-latitude cities (Adebayo, 1987). For example, studies have shown that heating due to the presence of concrete surfaces occurs downwind from the source area (Goldreich, 1985).

Urban climatology has been covered thoroughly in the geographic literature. Relatively, the rural environment has been, until recently, neglected. The study at hand deals with such rural surfaces. Since none of the six counties within the study area contain significant urban areas (Appendix B), the influence of urban heat islands was discounted as a major element in the local climate of the Cross Timbers.

Irrigation

Another way in which human activity has altered the earth's surface has been through irrigation. This has been most significant in semi-arid to arid regions. Irrigation has been shown to affect precipitation patterns due to changes in the local humidity. It has been suggested that local precipitation increases in response to increased irrigation (Yeh, et al., 1984). Evaporation rates increase because of irrigation, and this leads to greater availability of atmospheric moisture. However, Barnston and Schickedanz (1984) suggested that irrigation resulted in increased precipitation only if the atmospheric conditions provided low-level convergence and enough uplift to get the excess moisture up to cloud base. Temperature alteration has also been linked to irrigation. Local surface temperature depends, in part, on evapotranspiration. Irrigation changes the vegetation canopy; therefore, it would lead that irrigation has an effect on local surface temperature (Anthes, 1984).

Several studies have detailed the relationship between irrigation and surface temperature. Nearly all agree that irrigation decreases the local surface temperature (Barnston and Schickedanz, 1984; Yeh, et al., 1984; and Pant and Hingane, 1988). According to Barnston and Schickedanz (1984), local surface temperature was lowered 1-2 ^{o}C as a result of irrigation in parts of the southern Great Plains. A study in northwestern India used an area weighted mean temperature anomaly series to quantify the effect of increased irrigation on surface temperature. According to that study, the magnitude of the linear temperature trend was -.52 ^{o}C/100 years (Pant and Hingane, 1988). It is, therefore, obvious that surface changes lead to local climatic changes. Although irrigation practices have not been widespread within the study area, it remains a significant portion of the geographic literature regarding human impact on climate.

Surface Albedo Studies

By far, studies in surface albedo have been most numerous in the geographic literature. Potter, et al. (1981) found that an increase in albedo resulted in a decreased surface temperature. Gornitz (1985), however, made mention of the fact that contradictory results have been given as to the relationship between albedo and temperature. He suggested that a temperature rise, resulting from decreased evapotranspiration, may offset the reduced temperature caused by increased surface albedo (Rabin, et. al, 1990). The climatic implications of albedo change have been debated.

Albedo can be measured with remote sensing techniques. As a result, updated models have been developed which allow temperature estimation through remote sensing (Rao, et. al, 1990). Remote sensing methods have enabled scientists to make detailed analyses of vegetation canopy reflectances and make some hypotheses about environmental implications (Colwell, 1974). Much of the current studies of this type have been based on Landsat multispectral scanner data, but as Courel, et al. (1984) pointed out, only a small fraction of the Landsat data have been used and uncertainties of climatic effects are large. Landsat data are not useful for the study at hand because they only date back as far as 1972. It was evident that a decrease in the study area's woodland began much before 1972. Therefore, the Landsat data were not applicable to this particular study.

Desertification and Deforestation

Geographic studies of anthropogenic albedo change have increased in number. Most of the attention has been drawn to the repercussions of desertification and deforestation. A broad definition of desertification was given by Verstraete (1981). According to that definition, desertification refers to a number of ecological depletion processes which eventually lead to desertic conditions as being a general lack of moisture accompanied by a depletion of vegetation. The process of desertification has been seen as somewhat of a "self-perpetuating" mechanism. Sagan, et al. (1979) discussed how the depletion of vegetation, due to desertification, has enhanced the encroachment of desert into the Sahel. The depletion of vegetation increased the surface albedo, changing the larger-scaled circulation patterns, which caused less precipitation and led to further denudation of vegetation. The desertification of parts of the Sahel in Africa has been linked directly to rapid growths in human and wildlife populations (Sagan, et al., 1979). This desertification has been a result of overgrazing in semi-arid to arid areas (Gornitz, 1985). Such denuded, or overgrazed, surfaces have been suggested, by some, to be cooler than vegetated land (Otterman, 1974). Others, however, have illustrated exactly the opposite. Jackson and Idso (1975) stated that denuded land was actually warmer than vegetated land. They attributed the warmer denuded land to a lack of latent heat release; more specifically, an alteration of the Bowen ratio. It is not believed that desertification is in progress within the Cross Timbers. The vegetation has not truly been denuded; rather, there have been changes in the types of vegetal cover. The decrease in woodland during the past 40 years is believed to have led to an increase in local surface temperature due to greater moisture availability and cloud development. Therefore, the results of vegetation denudation as presented by Jackson and Idso (1975) were accepted for the purpose of this thesis.

Another issue of global concern is that of deforestation. Deforestation is simply the denudation of the forest canopy in a given area. This may eventually lead to desertic conditions if the deforestation is extensive and if the area is semi-arid in terms of climate. In many parts of the world, vast areas of forested land have been and continue to be cleared for various reasons. In West Africa, deforestation has occurred to accommodate agriculture, grazing and logging (Gornitz, 1985). Such activity has led to an increase in surface albedo (Gornitz, 1985; Potter, et al., 1981; Potter, et al., 1980; and Sagan, et al., 1979). Other results of deforestation include changes in the ratio of sensible heat to latent heat transport and modification of surface winds (Lockwood, 1983). Deforestation has also been linked to decreases in precipitation and evaporation (Henderson-Sellers and Gornitz, 1984; and Gornitz, 1985). The process of deforestation applies to the Cross Timbers study area. The past 40 years have seen a decrease in woodland with a corresponding increase in pastureland (Figure 10, Chapter IV). This decrease in woodland, in fact, is the primary concern of this thesis in terms of land use trends.

Quantification of Surface Changes

There have been efforts to quantify changes in surface cover, as well as the climatic responses. Studies in the Sinai have shown surface temperature to be 5 °C cooler over grazed land than over ungrazed land (Nicholson, 1988). This has been related to an increase in albedo over heavily grazed areas. Lockwood (1983) suggested that if global albedo increases by 1%, a surface temperature change of -2 °C will result. Climate models have shown that a global albedo increases by 1% will result in a surface temperature change of approximately -2 °K (Sagan, et al., 1979). More research is needed to adequately predict climatic responses to surface changes. Quantitative studies of climate change resulting from anthropogenic albedo alteration have been few in number.

Climatic Trend Studies

The study of climatic trends is a major part of climatic literature. Differentiation of climatic "trends" from climatic "fluctuations" has been a major obstacle to many scientists. Karl (1988) made mention of this problem when he said that climatic records show fluctuations on a variety of time scales. Climatic fluctuations have also exhibited correlations with natural events such as volcanic eruptions (Understand Climate Change, 1975). Mistaking such fluctuations for climatic trends has been a problem in some of the research. This is why it has been difficult to determine the stability of secular climate. The 40-year study period used for this research was believed to be suitable for relating rural land use changes to local climate. Although a longer time period would have provided indications of the climatic "trend" of the Cross Timbers, there were only 40 years of climatic data for the region as a whole. The problems with the data, both land use as well as climatic, will be discussed in detail in Chapter V.

Global Trends

When looking at the global temperature trend, several episodes become apparent. Between the 1890s and the 1940s, there was an obvious warming. Around 1950, a cooling trend began and lasted until the mid-1960s (Thompson, 1989). Most scientists have been in agreement with the period of warming between 1890 and 1940. After 1940, however, there has been some debate as to the global temperature trend (Jones, et al., 1982). Lockwood (1983) argued that the global mean temperature has declined since the 1940s. It seems, however, that most agree that a gradual warming trend has been evident since 1940 (Thompson, 1989; and Brinkmann, 1985).

Trend Representativeness

There have been problems with the representativeness of temperature trends. Global and hemispheric trends have been difficult to rely on because of the lack of reporting stations over the oceans (Jones, et al., 1982; and Brinkmann, 1985). Since the majority of the earth's surface is water, this problem is significant. Another problem dealing with large-scale temperature trends is that of small-scale representativeness. Brinkmann (1985) suggested that the northern hemisphere mean temperature has increased since the 1940s (Figure 4). It has been assumed by some that the hemispheric temperature trend is representative of small-scale trends. As Brinkmann (1985) pointed out, this is not necessarily true. One reason is that climatic systems change

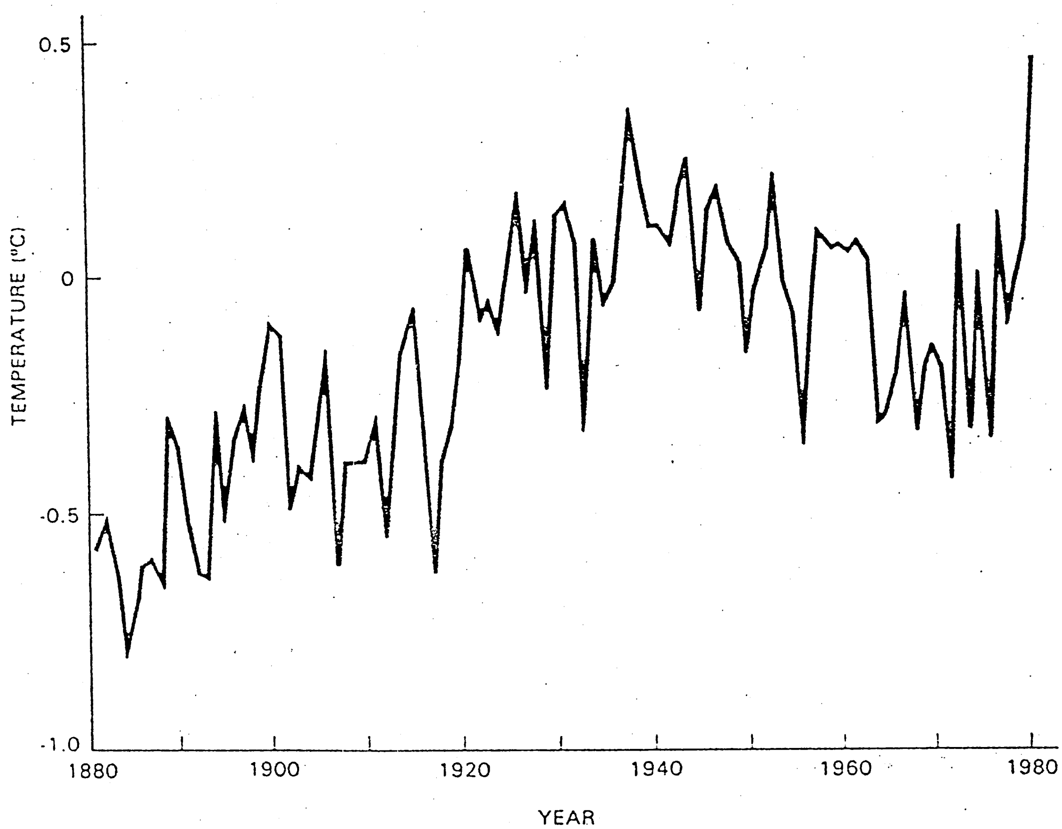

Figure 4. The Northern Hemisphere Temperature Curve
Source: Brinkmann (1985)

over time. Also, climate has been suggested as having a "multi-stable" nature. By this, it is meant that climate fluctuates until it reaches a more or less stable state. It will remain at that general state for a time, and then, the climatic regime will change again. This has resulted in a series of "plateaus" in the climate record (Brinkmann, 1985). Therefore, it is problematical to use the Northern Hemispheric Temperature Curve to determine relationships for relatively small areas.

It was appropriate to analyze the climatic trends at different scales to achieve the results of this thesis. Based on the literature, it was difficult to assess the representativeness of the Northern Hemisphere Temperature Curve; however, it was thought that this curve would represent the state and regional trends. This assumption was based on the climatic data from the 1980s (Oklahoma Climatological Survey, 1980-1988). Several of the warmest summers occurred during the 1980s; therefore, it is expected that a warming trend for the Cross Timbers will be evident for the study period of this thesis.

The present research differs from what has already been done, in that, it attempts to describe and explain change in a local area over a reasonably long period of time. Thus far, studies have only been concerned with showing surface/climate relationships over relatively large areas at a particular point in time. There has been no work dealing with the complexities of local spatial variation. This thesis attempts to provide a better understanding of the effects of scale on climatic research. Subregional (county) analysis was expected to enhance the interrelationship between local climate and specific rural land uses.

CHAPTER III

PHYSICAL SETTING OF THE OKLAHOMA CROSS TIMBERS

The Cross Timbers is a region which has undergone significant land use change, and has played an important role in the development of Oklahoma. However, there have been few studies of the region which have sought explanations to patterns and processes. The purpose of this chapter is to describe and explain the physical characteristics of the Cross Timbers. There is, however, little documentation of the portion of the Cross Timbers used as the study area in this research, specifically. Therefore, a somewhat broad discussion will be given for the Oklahoma Cross Timbers as a whole.

Vegetation

The region consists of dense stands of forest with interspersed grassland prairies. Within this ecotone, there are several distinct vegetation communities. These communities, however, have changed during the past 20,000 years, in terms of geographic distribution.

Although there is virtually no paleo-environmental data from within the Cross Timbers region, there is enough data from surrounding areas to suggest some distinct vegetation sequences. These changes in the Cross Timbers vegetation have been attributed to climatic fluctuations (Drass, 1979). Prior to 10,000 years before present, central Oklahoma was dominated by deciduous forest, much as eastern Oklahoma is at present. Sometime after that, dryer conditions became the norm, and grassland vegetation dominated. These conditions remained until 3,000-4,000 years before present. At that time, it was suggested, the vegetation communities changed to those observed by the first white explorers in the 1500s.

The natural vegetation of the Cross Timbers is divided into three communities----upland forest, grassland and floodplain forest. The upland forest is dominated by post-oak, blackjack oak and hickory. These species are the most areally extensive vegetation types within the Cross Timbers. The grassland areas are found in the lowlands and are generally representative of the tall prairie grasses. The floodplain forest consists of pecan, cottonwood and sycamore (Drass, 1979). Figure 5 shows, in a more general sense, the dominant vegetation regimes which are found throughout the study area. Although Figure 5 does not categorize the Cross Timbers vegetation in terms of upland forest, floodplain forest and grassland, the general distributions of forest and grassland are virtually the same.

Climate

There are a number of physical influences on the Cross Timbers which work in combination to determine the geographic location of the region. Climate is one such physical influence on the Cross Timbers. The climate of central Oklahoma is basically warm to temperate and subhumid. There are gradual seasonal changes; however, abrupt daily

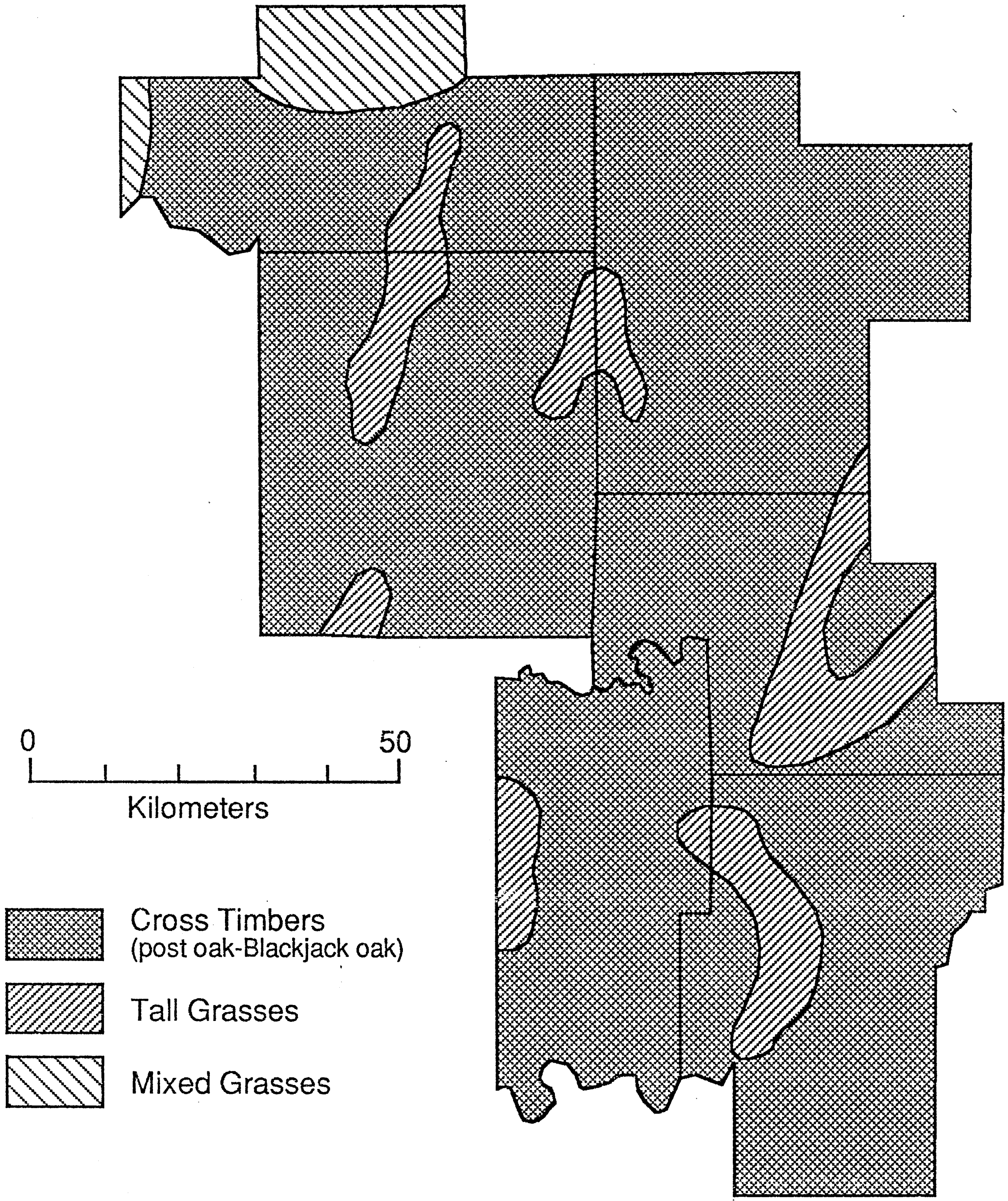

Figure 5. Vegetation of the Cross Timbers Study Area.
Adapted from Morris, et al. (1976)

variations are not uncommon. The mean annual temperature for this part of the state is 16 °C , with long, hot summers and short, mild winters being the rule. Annual precipitation equals or slightly exceeds evapotranspiration. Soil moisture availability is instrumental in the distribution of forests and grasslands in the Cross Timbers. Evaporation usually exceeds precipitation during most of the year. As a result, the soil moisture regimes are diverse. The forests have developed on shaded slopes which have relatively high moisture retentions. Where soils are fine-textured clays, water retention is relatively low and grassy vegetation dominates (Drass, 1979). Mean monthly June temperatures for each county in the study area are shown in figures 19 through 24 in Chapter VI (Oklahoma Climatological Survey, 1948-1988).

The climatic causes of the Cross Timbers ecotone are poorly understood, at present. According to Corcoran (1982), the pre-settlement ecotone has been attributed to spatial variation of such elements as fire, drought, potential evapotranspiration, precipitation and air mass dominance. Corcoran suggested a relationship between the forest/grassland ecotone of the Cross Timbers and the development of an upper level pressure ridge over the Rockies. During summer, a pressure ridge over the Rockies is accompanied by a pressure trough in the eastern United States. The area under the pressure ridge experiences dry conditions due to increased subsidence; whereas, the eastern United States has increased uplift which results in moist conditions (Figure 6). The forest/grassland ecotone represents the division between these two climatic regimes (Corcoran, 1982).

Apparently, drought has had an effect on the Cross Timbers.

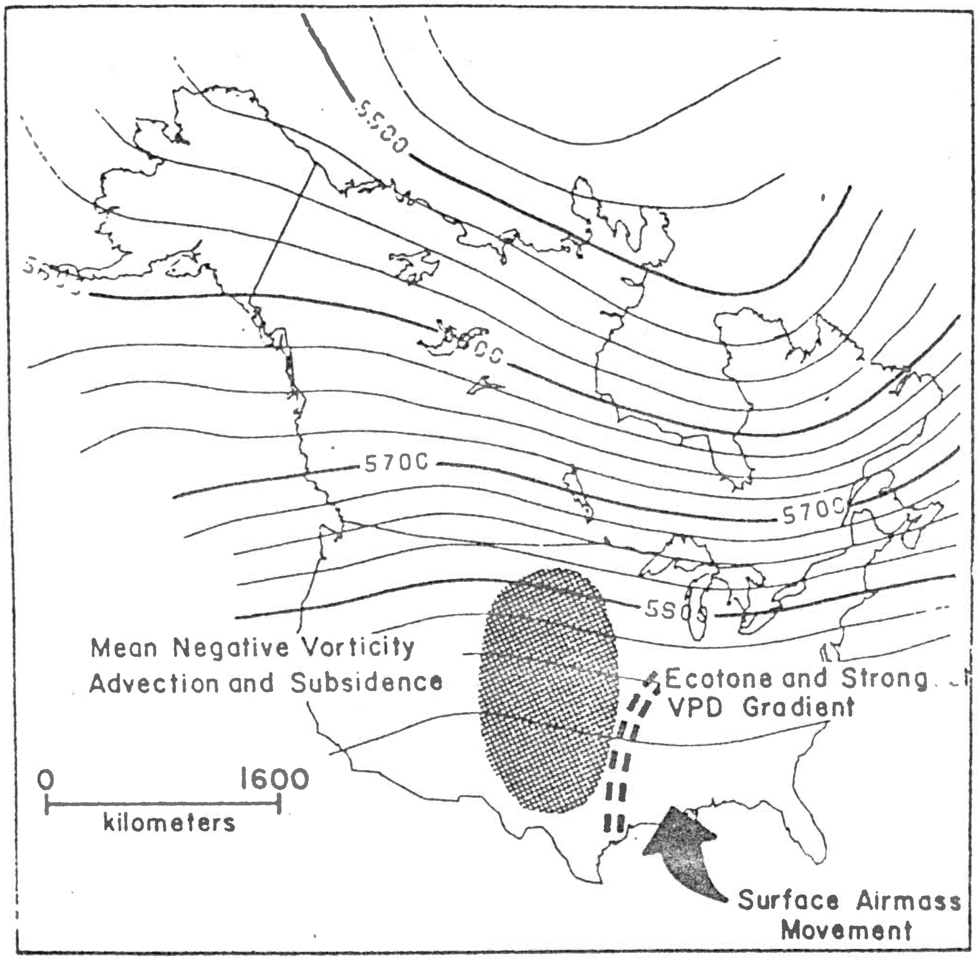

Figure 6. Forest/Grassland Ecotone with Respect to
Surface Airmass Movement.
Corcoran, W.T. (1982)

Periodic, excessive drought has reduced the number of trees which, in turn, may have aided the expansion of the grassland, the development of more open forests or of oak savannas (Wyckoff, 1984). Furthermore, substantial loss of vegetation has allowed occasional heavy thunderstorms to enhance the gully-forming processes (Goodman, 1977). As will be discussed in Chapter IV, the general trend over the past 40 years has been a decrease in cropland. One reason for this decline in cropland is extensive soil erosion brought on by deforestation. The effects of a loss in tree cover are enhanced by the topographic characteristics of the Cross Timbers.

Topography and Soils

The topography of the Cross Timbers is rugged, with steep slopes and occasional floodplain areas. As the tree cover was stripped away, in an attempt to create more cropland, the steep slopes enhanced the erosional processes in the region. Figure 7, from Lincoln County, shows that the Cross Timbers has a rugged terrain (Oklahoma City Quadrangle, 1978). Similar topography is found throughout the study area.

The influence of topography was enhanced by the soil characteristics of the region. The soils of the Cross Timbers are the results of a sequence of events which began approximately 300 million years before present. At that time, eastern Oklahoma was experiencing an episode of uplifting, causing streams to flow westward into a shallow inland sea. Along the margins of the inland sea, sands were deposited in the same fashion as in present-day coastal environments. The sandy soil of the Cross Timbers marks the eastern margin of the ancient inland sea

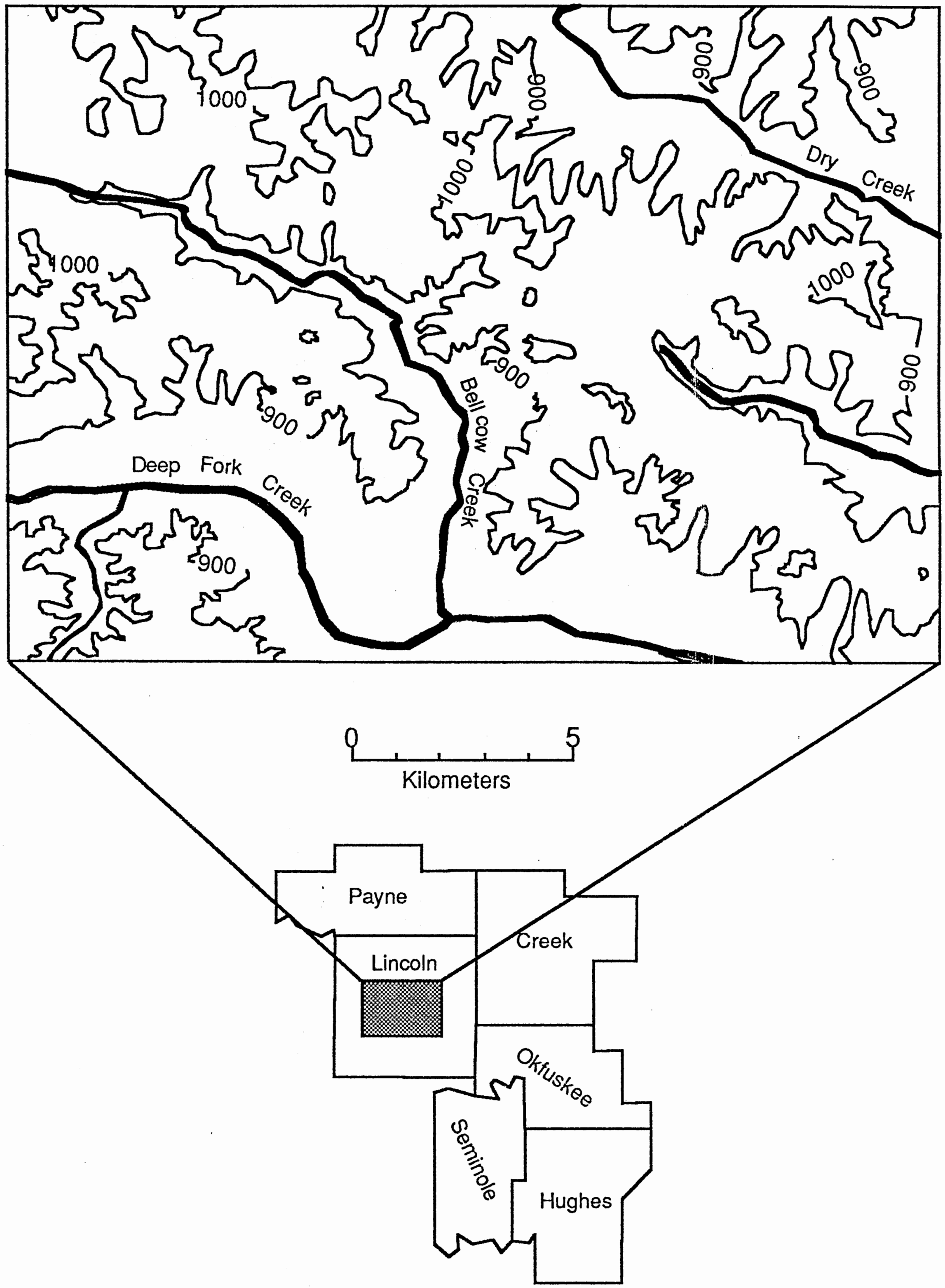

Figure 7. Cross Timbers Topography. Adapted from Oklahoma City Quadrangle, 1961

(Cross Timbers: Oklahoma Landmark, 1989).

The dominant soils in the Cross Timbers are the Darnell-Stephenville and the Dougherty-Teller-Yahola series (Figure 8). There are light-colored, sandy soils with reddish subsoils on variousandy materials. The soils are developed partially as a result of the overlying oak-hickory forests of the region (Gray and Galloway, 1959).

Likewise, the distribution of the vegetation that inhabits the region is affected by the underlying material. The upland forests are located on sandy soils; whereas, the grasslands are located in the lowland areas and are established on fine-textured soils formed on shale and limestone bedrock (Cross Timbers: Oklahoma Landmark, 1989 and Wyckoff, 1984). The forests of the floodplains have developed on layers of fine alluvium. The floodplain forests have been greatly altered by human activity and will be discussed in greater detail in Chapter IV.

Geomorphology

The relationship between geomorphology and the Cross Timbers has been debated. According to Morris (1954), the Cross Timbers extends from the Sandstone Hills to the eastern Red Beds Plains region. Similarly, Gray and Galloway (1954) showed the Cross Timbers as coinciding with the Eastern Sandstone Plains and Hills and the Western Prairie Plains (Figure 9). Another study, by Wyckoff (1984), contends that the Cross Timbers coincides with the Central Redbed Plains and Dissected Coastal Plain. The geomorphic province names are different, but the geographic location of the Cross Timbers ecotone through central Oklahoma is fairly consistent in the literature. Wyckoff (1984), however,

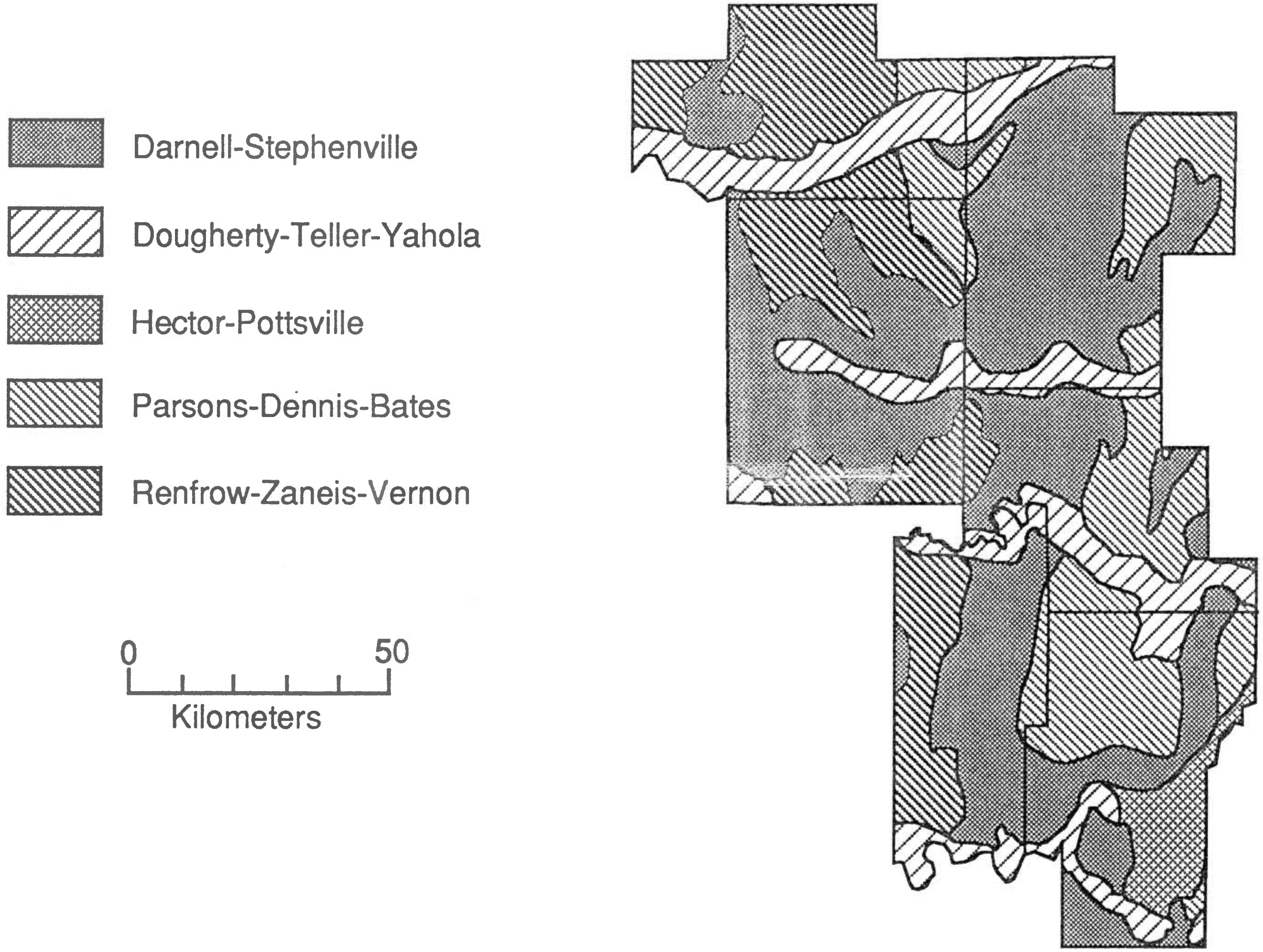

Figure 8. Soils of the Cross Timbers. Adapted from Gray and Galloway, 1959

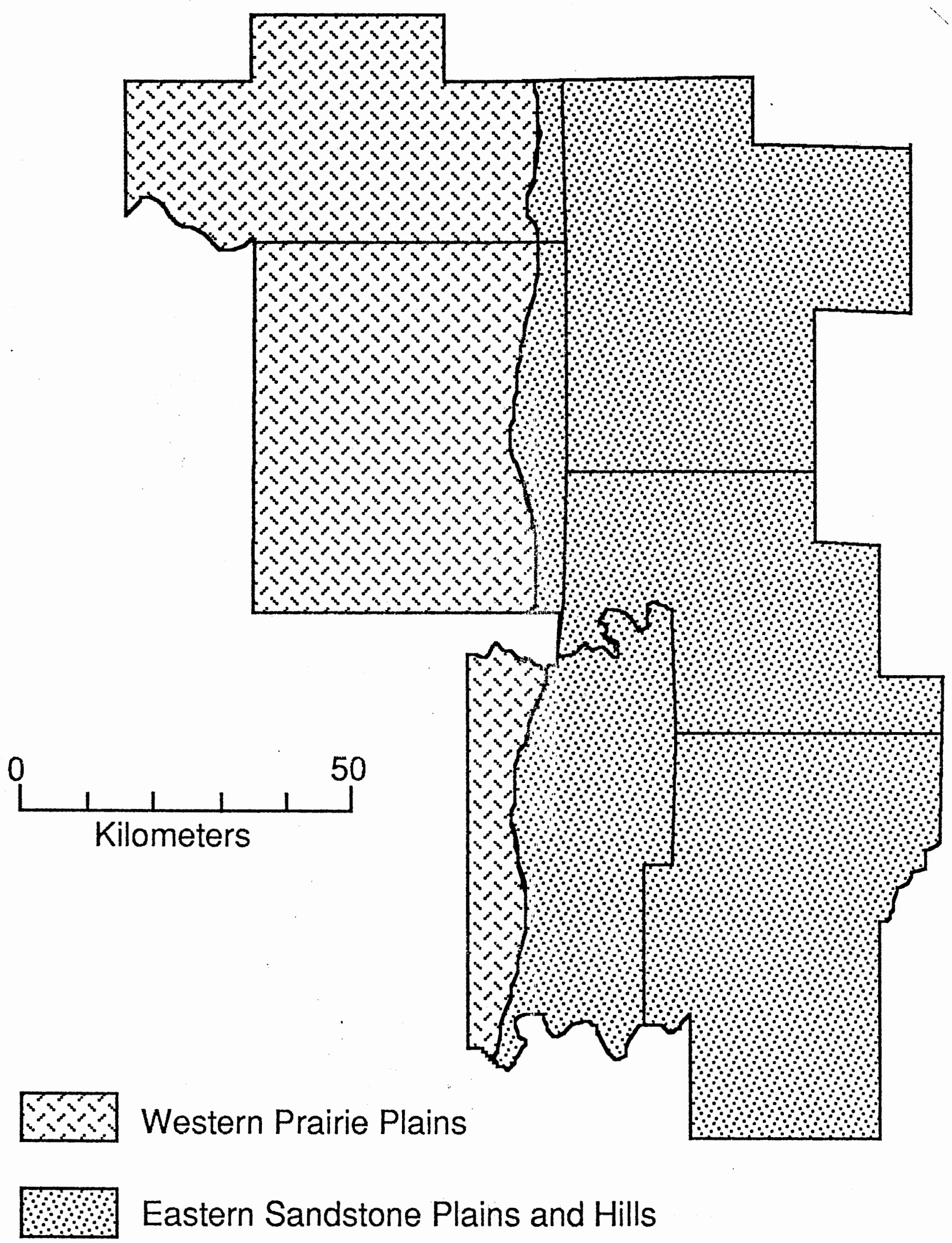

Figure 9. Landforms of the Cross Timbers

identified the Cross Timbers as being located primarily in southern Oklahoma. Despite this, it is evident in the literature that the Cross Timbers is located on the transition between the rugged sandstone hills in eastern Oklahoma and the gently-rolling prairies of western Oklahoma. This suggests a connection between landforms and the Cross Timbers ecotone.

Influence of Fire

Another factor in the location of the Cross Timbers has been the presence of fire. The premise of fire used by the Native Indians to clear sections of forest previous to white settlement will be discussed in Chapter IV. Fires kill the undergrowth and leave patches of the larger trees interspersed within the prairie grasses. The larger trees have thick bark which protects them from the fast-moving prairie fires. This process has been another factor in the development of open areas in parts of the Cross Timbers (Cross Timbers: Oklahoma Landmark, 1989; and Rice and Penfound, 1959). Such prairie fires, be they natural or human-related, have been considered a major factor in keeping the forest from invading the grassland areas, which have become established within the Cross Timbers (Bruner, 1931).

Summary

The natural processes involved in the distribution of the Cross Timbers as a geographic region are complex and not very well documented. Evidence presented in this chapter has illustrated the

CHAPTER IV

HISTORICAL GEOGRAPHY OF THE OKLAHOMA CROSS TIMBERS

The historical geography of the Cross Timbers is not well-documented. In terms of literature, there are archaeological records and historical accounts which discuss human activity within the region. This chapter will detail the historical geography of the Cross Timbers as explained through archaeological records and written accounts.

Archaeological Records

Human occupancy in the Cross Timbers can be traced back approximately 20,000 years, through archaeological data. In general, the cultural history of the region has been poorly-documented. During the Paleo-Indian Period (18,000-7,000 B.C.), bands of hunters and gatherers traveled throughout the Cross Timbers. The paleo-Indians hunted large mammals such as bison and elk, which were native to the region. Evidence has been found in the form of "kill sites" to support this idea. Evidence of burning has also been found which indicates early signs of land surface alteration. It has been suggested that the Native Indians used fire to maintain open, grassy areas. It is, however, difficult to ascertain, from the archaeological record, the source of such fires. As natural setting of the Cross Timbers. The history of the region has been marked with change. It is believed that human activity has been the dominant agent of change in the region, and this is the subject of Chapter IV.

mentioned in Chapter III, natural fires also occurred and had an impact on the distribution of vegetation in the Cross Timbers. Furthermore, the magnitude of the impact the fires had on the landscape is difficult to determine without written records. Literature suggests that the impacts were negligible at that time (Drass, 1979).

The Archaic Period (7,000 B.C. - A.D. 1) represented a time of more intensive exploitation of the region by hunters and gatherers. Evidence in the form of "kill sites" was, again, the reasoning behind this determination. Gathering was probably more important during the Archaic Period. Again, some evidence of human-caused fire has been found similar to that of the Paleo-Indian Period (Drass, 1979).

The Plains Woodland Period (A.D. 1 - A.D. 800) was a transitional period from nomadic hunting and gathering to semi-sedentary horticulture. It was similar to the Archaic Period with the exception of cultivated plants, which supplemented collected plants. This was the beginning of agriculture. However, it is not believed that this "agriculture" was extensive enough to alter significant areas of land within the Cross Timbers (Drass, 1979).

The Late Prehistoric Period lasted from A.D. 800 to A.D. 1450. Semi-sedentary horticulture was the dominant activity with hunting being supplementary. The Indians which inhabited the area were nomadic during part of the year. However, the rest of the year was spent in one area raising plants for food. Permanent dwellings began to appear during this period, as well (Drass, 1979).

Finally, the Historic Period (1450 - present) has been the most poorly represented, in terms of the archaeological record. Few and described the hardships of crossing the region. Josiah Gregg gave the following description of the Cross Timbers:

> ... a continuous brushy strip composed of various of undergrowth; such as blackjack, post-oaks and in some places hickory, elm, etc. intermixed with a very diminutive dwarf oak, called by the hunters 'shin-oak' ... as to form almost impenetrable 'roughs', which serve as hiding places for wild beasts, as well as wild Indians (West, 1976).

Another account of the Cross Timbers was given by A.W. Whipple. He led a party of engineers and cartographers through the region with the objective of finding a suitable rail route through the Cross Timbers (Foreman, 1947; and Wyckoff, 1984). Whipple, like most of the early explorers, provided accounts describing the Cross Timbers as a boundary between Indian tribes and also as a hindrance to east-west travel. In fact, these explorers have been credited with the term "cross timber", which they used to refer to the densely-wooded strip of land they had to cross when traveling east or west. The outer margin of the Cross Timbers was used as a rendezvous point for traders and explorers (Foreman, 1947).

It has been suggested that significant human impact was negligible before white settlement began (Drass, 1979). Many of the early Indians were hunters and gatherers. Such activities had no significant impact on the landscape. It was not until agriculture became well-established within the region that human impact began to alter the natural environment of the Cross Timbers archaeological dig sites have been established. It was believed that the Washita River People, who were the primary inhabitants of the Cross Timbers, migrated to the north and east between 1400 and 1500. This period was, however, represented rather well in the form of historical documentation (Drass, 1979).

The changes in lifestyles from one period to the next has not been explained. Such changes from hunting and gathering to agriculture may reflect a change in climate. Such a change could cause a shift in the distributions of both flora and fauna of the region, requiring the Indians to alter their lifestyles in order to survive. There was no documentation to support this hypothesis, however, and that reflects the lack of data available when studying the historical geography of the Oklahoma Cross Timbers.

Despite 20,000 years of occupancy, one must look at the past 125 years, approximately, to study the greatest impact of human activity in the region. This is due to the fact that the Native Indian populations were low within the Cross Timbers prior to white settlement, which began approximately a century ago. It was during this time that humans really began to alter the landscape of the Cross Timbers.

Historical Record

The earliest documentation of the Cross Timbers came from the journals of 19th century explorers such as Washington Irving and Josiah Gregg. In Tour on the Prairies (1955), Irving told of:

> " ...areas having sandy soil and covered with a growth of blackjack oak and post-oak..."

Settlement History

Agricultural practices resembling present-day agriculture were introduced to central Oklahoma approximately 400 years before present by the "Gardening Tribes". They established small village settlements and hunting was supplemental to their agricultural activities. Alteration of the landscape was not widespread, as the total Indian population was very small.

Agriculture among the Indians did not really begin to develop until the early- to mid-1800s. At that time, the Five Civilized Tribes were forced into the central regions of Oklahoma (Harlow, 1961). These tribes were being forced from their homelands in the eastern United States and relocated in Oklahoma. The future Oklahoma was regarded as a dumping ground for the Indians from neighboring areas (Foreman, 1942). Despite this migration into central Oklahoma, the natural land cover of the Oklahoma Cross Timbers appeared not to have been significantly changed until the 19th century when large-scale white settlement began.

The period between 1830 and 1860 saw the Cross Timbers becoming established as a buffer zone between the civilized tribes of the east and the plains Indians of the west. The U.S. government wanted to preserve the region as a divisive feature; therefore, military garrisons were established at Fort Washita, to the east of the Cross Timbers, and at Fort Arbuckle, to the west. The primary purpose of the garrisons was to keep the plains Indians and the "civilized" tribes separated, so as to avoid any Indian disputes (Wyckoff, 1984).

During the mid-19th century, tracts of land were assigned to the

Chickasaw, Creek and Seminole tribes. The land in central Oklahoma which was not part of those assigned tracts was known as the "Unassigned Lands". Those lands marked the western margin of the Cross Timbers. In 1889, the Unassigned Lands were settled in the Oklahoma Land Run (Cross Timbers: Oklahoma Landmark 1989; Drass, 1979). At that time, the settlers were comprised primarily of entrepreneurs and freed blacks (Cross Timbers: Oklahoma Landmark, 1989). This push of settlement led to the development of rail transportation in and around the Cross Timbers.

The original rail networks paralleled the densely-forested Cross Timbers. In 1890, the Chicago, Rock Island and Pacific railroads built a north-south route on the grasslands just west of the Cross Timbers. It was some time before east-west rail routes were developed through the region. The proximity of the railroad to the Cross Timbers region, combined with the Land Run, led to the extensive alteration of the Cross Timbers landscape. The majority of the landscape alteration was a result of natural resource exploitation and agriculture.

In terms of natural resources, the Cross Timbers became one of Oklahoma's leading oil-producing regions. Petroleum was the chief attraction to early white settlement (Goodman, 1977). Natural gas was also important to the region, and the extraction of petroleum and natural gas remains significant today (Wyckoff, 1984). Agriculture, however, has been the most prominent form of human impact on the landscape of the Cross Timbers.

Within the last 40 years, human activity in the Cross Timbers has resulted in dramatic decreases in both cropland and woodland and an accompanying increase in pastureland (Figure 10). Actually, such alteration began much earlier in the 20th century, and this was documented in historical literature (Lincoln County Conservation District, 1989; Okfuskee County Conservation District, 1989; Payne County Conservation District, 1989; Seminole County Conservation District, 1989; and Creek County Conservation District, 1985). However, there were no periodic statistics on land use which dated back more than 40 years before present. During the early 1900s, large tracts of woodland were cleared for agricultural purposes, as a result of white settlement. Such land-clearing practices have continued throughout the 20th century. For example, in Creek County, woodland decreased in areal extent by 75% between 1954 and 1987 (Figure 11). Unfortunately, a combination of environmental factors, including topography, soil type and climate, resulted in excessive soil erosion. Therefore, much of the agricultural land has either been converted to pastureland and rangeland or has been abandoned altogether. This pattern was also evident in the land use record of Lincoln County. The amount of pastureland increased by nearly 50% between 1949 and 1964 (Figure 12; U.S. Census of Agriculture, 1945-1987).

Some of the most dramatic changes in surface cover occurred in the floodplains of the Cross Timbers. The floodplain forests have been greatly altered by human activity, and this was directly related to the clearing of the natural vegetation. An example of this is Deep Fork Creek in Lincoln and Creek counties. Between the years 1912 and 1923, sections of Deep Fork Creek were straightened in Lincoln County. This increased the velocity of the stream, which increased the erosion along

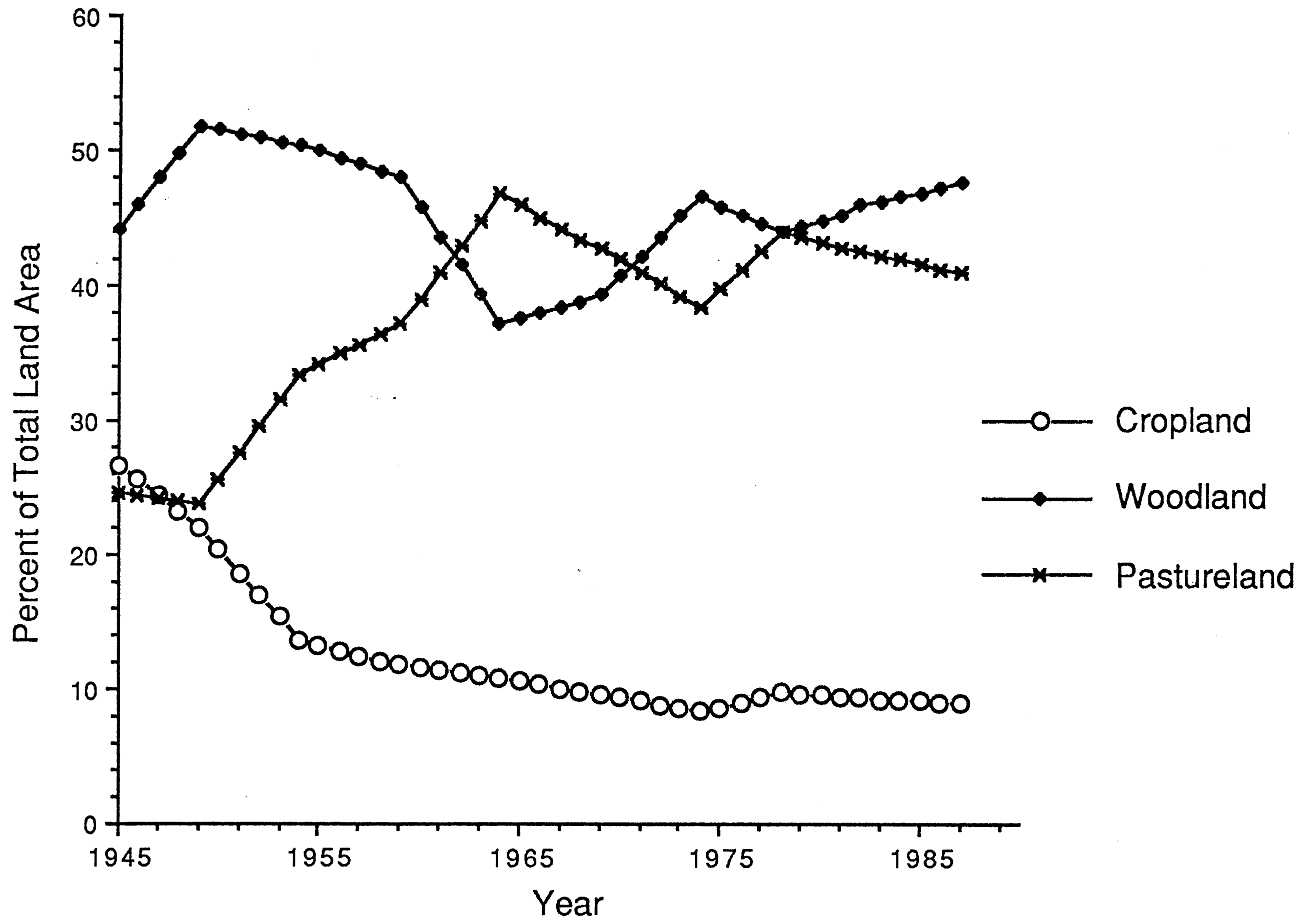

Figure 10. Rural Land Use for the Cross Timbers. Compiled by author from the U.S. Census of Agriculture, 1945-1987

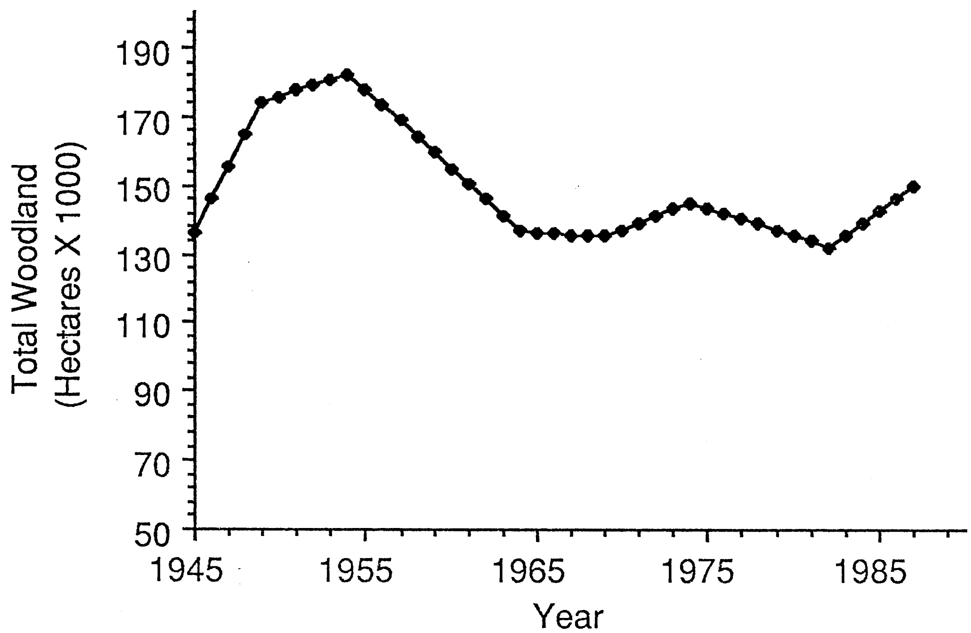

Figure 11. Creek County Woodland. Compiled by author from the U.S. Census of Agriculture, 1945-1987

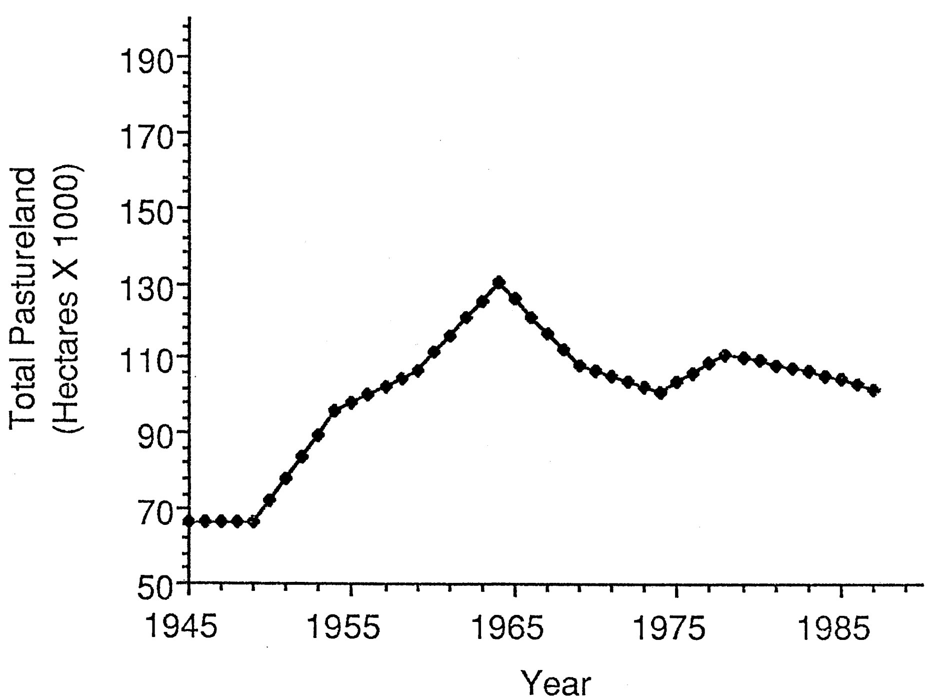

Figure 12. Lincoln County Pastureland. Compiled by author from the U.S. Census of Agriculture, 1945-1987

the stream channel. When the stream passed into Creek County, where a natural, meandering stream channel remained, the velocity decreased and resulted in increased deposition rates. The rate of deposition in the floodplain was so great that the oak-hickory forest could not survive being buried in alluvium. In some cases, the original forest was buried in ten feet of sediment. As a result, the oak-hickory forest was replaced by varieties of ash, cottonwood and willow because these species could keep up with the aggradation of the floodplain (Featherly, 1940). Similar scenarios, although not as dramatic, were created throughout the Cross Timbers as a result of human activities. Since that time, government policies have been aimed at improving the rural land use practices in the region.

As early as 1928, Congress passed an appropriation to establish ten experiment stations in the Cross Timbers to monitor erosion rates and establish some principles of erosion control (Debo, 1949). Even with government aid, however, erosion took its toll on the land. Furthermore, the intensive production of cotton was particularly detrimental to the land in terms of soil erosion and depletion.

Cotton farming began in the Cross Timbers as a result of two factors. The land was seemingly suitable for the production of cotton, and many of the early white settlers were from the southern areas of the U.S. where cotton was the dominant crop. Unfortunately, due to a lack of care for the soil, depletion of nutrients ensued. Furthermore, cultivated slopes were not properly contoured, thus, leading to soil erosion (Lincoln County Conservation District, 1989 and Okfuskee County Conservation District, 1989). Much of the land was subsequently abandoned; thus, reverting back to pastureland vegetation.

Summary

The Cross Timbers is a distinct vegetative region of Oklahoma. A combination of physical and human factors have formed the landscape into its present-day configuration. The introduction of agriculture has led to surface alteration, dramatic in some cases. It has already been shown that such changes have environmental implications in the form of increased erosion rates. Therefore, this region is one with which geographers should be concerned. Further research of the Cross Timbers will help predict future environmental trends in other parts of the world.

CHAPTER V

DATA AND METHODOLOGY

Statistical analysis is one method of illustrating relationships on the surface of the earth. Climatic modeling and testing for such aspects as normality and correlation are examples of such quantitative methods. Numerical data are compiled and manipulated in such a way as to reveal subtle relationships and clarify those already observed. This chapter deals with the data compilation and methodology used in the determination and explanation of the climatic trends found in the Oklahoma Cross Timbers during the past 40 years.

Data Compilation

Land Use Data

The rural land in the Cross Timbers study area is presently dominated by agricultural practices. It was evident, from historical records, that this was true during the early- to mid-20th century (Lincoln County Conservation District, 1989; Okfuskee County Conservation District, 1989; Payne County Conservation District, 1989; Seminole County Conservation District, 1989; and Creek County Conservation District, 1985). This made the U.S. Census of Agriculture the best source for land use data. This was published at 4- and 5-year intervals, beginning in 1945 and continuing through 1987. There was no other source for the land use data at the county level which spanned the entire study period and contained sufficient detail of the rural land use practices. It was believed that sufficient rural land use data could be obtained from the U.S. Census of Agriculture.

The data were divided into total woodland, total cropland and total pastureland. These data were compiled from each census between 1940 and 1987. The determination of these land use classifications was based on the need to categorize the major forms of rural land cover with respect to possible climatic impacts. It was believed that each canopy would have a distinct microclimate associated with it; thus, a distinct climatic change was expected depending upon the type of land use change. It was essential to understand exactly how the canopies had changed during the study period. In another sense, it was more important to understand for what activities the rural land had previously been used rather than simply determining what the current land uses were. A good example of this is the increase of pastureland noted in the Cross Timbers (Figure 10; Chapter IV). One can not hypothesize as to the climatic implications of an increase in pastureland without knowing what the previous land use had been. An increase in pasture could have a cooling effect on local climate if the land had previously been cropland; however, the opposite would be expected if the pastureland was a result of deforestation. This is due to differences in evapotranspiration rates (Jackson and Idso, 1975). The greater the amount of vegetation on an area of land, the greater the rate of evapotranspiration. Relatively higher rates of evapotranspiration have been linked with comparatively lower air temperatures (Chapter II).

The clarification of these land use categories was somewhat difficult. Total woodland was not taken directly from the U.S. Census of Agriculture. The definition of total woodland, according to that source, included all land which had at least 25% of the surface in trees. Tree size was irrelevant to the Census' definition of total woodland. Thus, this statistic was inappropriate for the research at hand because it only included the woodland used for agricultural purposes. It was believed that much of the Cross Timbers woodland was not included in the survey employed for the U.S. Census of Agriculture. In fact, in the 1940 issue of this publication it was stated that large tracts of woodland were excluded if such lands were not being used for agricultural purposes. Total woodland was, therefore, calculated by adding "total woodland" to the difference between the total land area and the total land in farms, for each county. The vast majority of the land not in farms was, obviously, in large tracts of woodland. This was based on personal observations within the study area.

Total cropland, for this thesis, was defined as land from which row crops were harvested. A combination of the following land use classifications was used to calculate the total amount of cropland in each county: "cropland harvested", "cropland failed" and "cropland idle or fallow". Total cropland, as given in the U.S. Census of Agriculture, could not be used because it included significant acreages of pastureland which could have been cultivated with crops without additional clearing or improvements. For the purposes of this thesis, cropland was separated from pastureland because of the different canopy structures. This has been suggested in the literature as being a significant consideration in local climatic studies (Nicholson, 1988). Total cropland, therefore, was calculated from several classifications which excluded land with a pasture canopy.

Total pastureland was also derived from several classifications of rural land use. The statistic labeled "total pastureland" given in the U.S. Census of Agriculture included woodland which was used for pasture. Again, canopy was the primary concern; therefore, the land with a tree canopy had to be deleted. The definition of total pastureland used for this study included all land which was classified as pastureland or rangeland and was less than 25% covered with trees. A distinction was made between pastureland and rangeland. Land covered with introduced species of grasses was considered pastureland; whereas, land covered with native species of grasses was identified as rangeland. There was no need to separate these, since the canopies were very similar.

The three land use classifications, as derived for this thesis, were used to calculate percentages of the respective county areas. The raw statistics of areal coverage for each variable were not seen as truly representative of the relationships between county land use trends. One county may have had much more area devoted to woodland, for example, than did another county simply as a function of the overall county size. The proportions of woodland, however, may have been nearly equal between the two counties; thus, land use trends based on the raw acreages would have been misleading. Using percentages of the total area gave a better indication of how similar the counties were in terms of specific land use trends.

The calculation of percentages required the determination of the total area of each county. A decision had to be made whether to use the total land area of each county or the total surface area. "Total land area" was given in the U.S. Census of Agriculture, and the definition changed during the study period. This classification excluded surfaces covered with water. An increase in the number of impoundments during the past 40 years---usually small farm ponds---resulted in a decrease in land area for each county. For this thesis, the total surface area was calculated by digitizing the boundaries of each county from a map, and it included the total area, water or land, within the political boundaries of each county. As Figures 13-15 illustrate, the land use trends for the Cross Timbers were essentially the same using either land area or surface area. These figures show the linear trend lines, and it is evident that both linear trends have very similar magnitudes of change. It was not necessary to use both surface area and land area statistics. Therefore, the "land area" classification from the Census was used for this research.

The final step of the compilation of the land use data was the calculation of regional (Cross Timbers) classifications. The purpose was to determine if scale had an impact on the clarity of the results. This would also test the representativeness of the state and regional trends with respect to the subregional (county) trends. Beginning with the subregional data already discussed, land use classifications were created for the Cross Timbers study area. The total amounts of cropland, woodland and pastureland by county were combined to determine the total cropland, woodland and pastureland for the Cross Timbers. Also, the total land areas of the counties were combined to establish the total land area

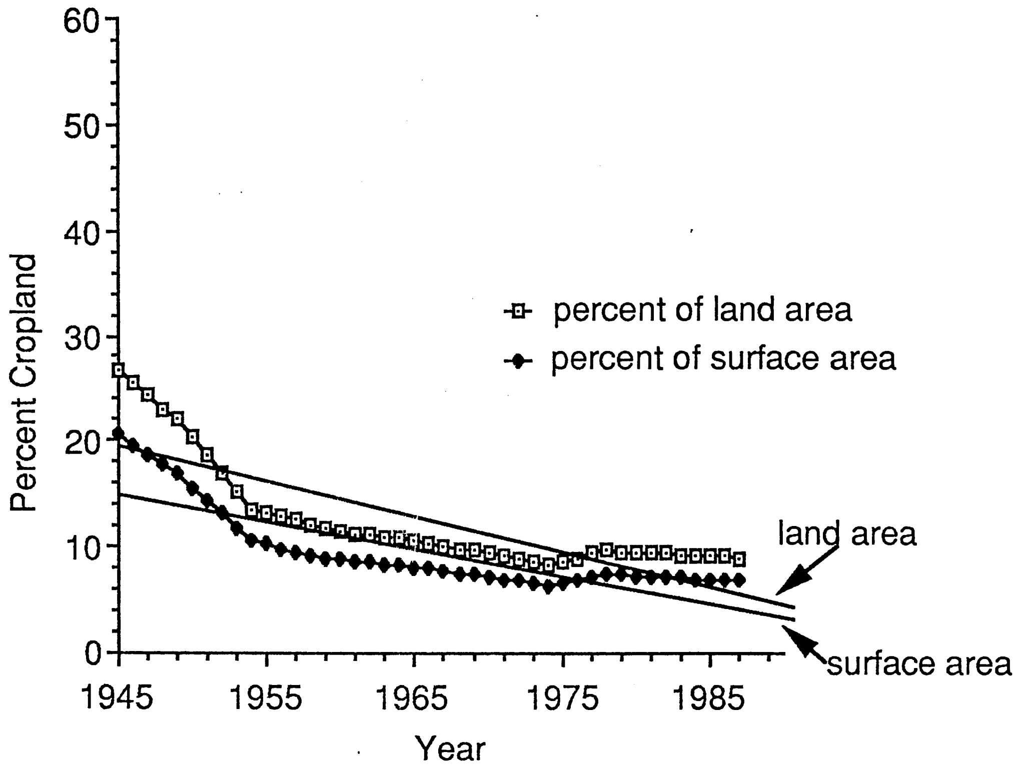

Figure 13. Cross Timbers Cropland Linear Trend: Percent of Land Area vs. Percent of Surface Area

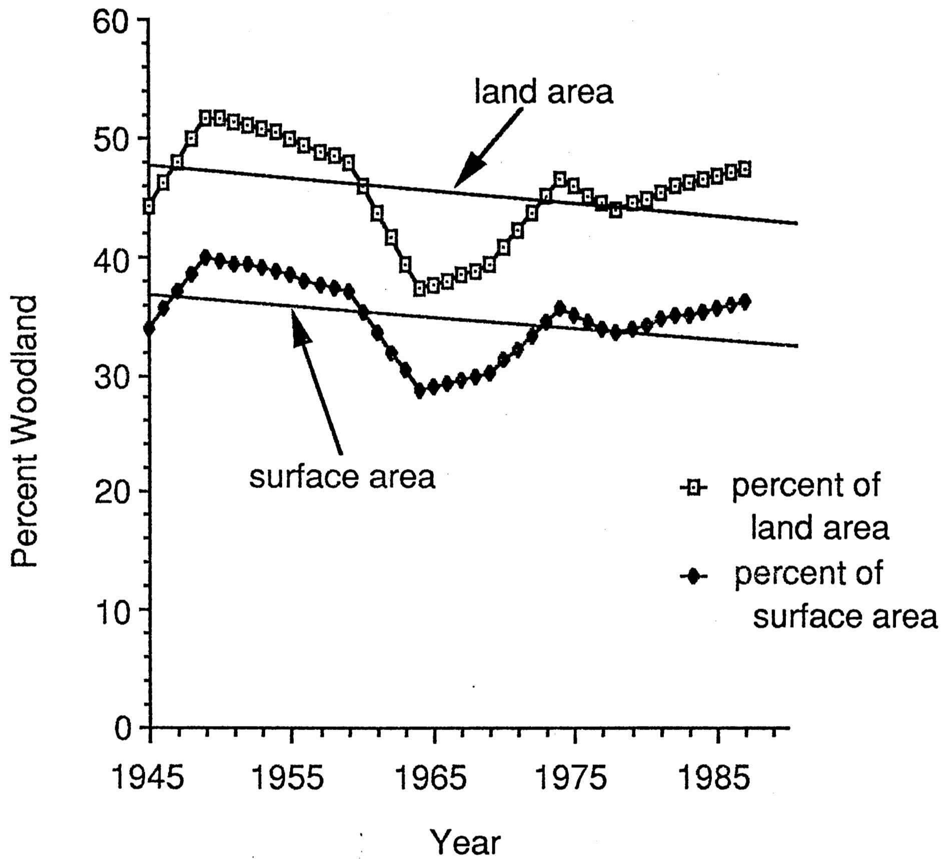

Figure 14. Cross Timbers Woodland Linear Trend: Percent of Land Area vs. Percent of Surface Area

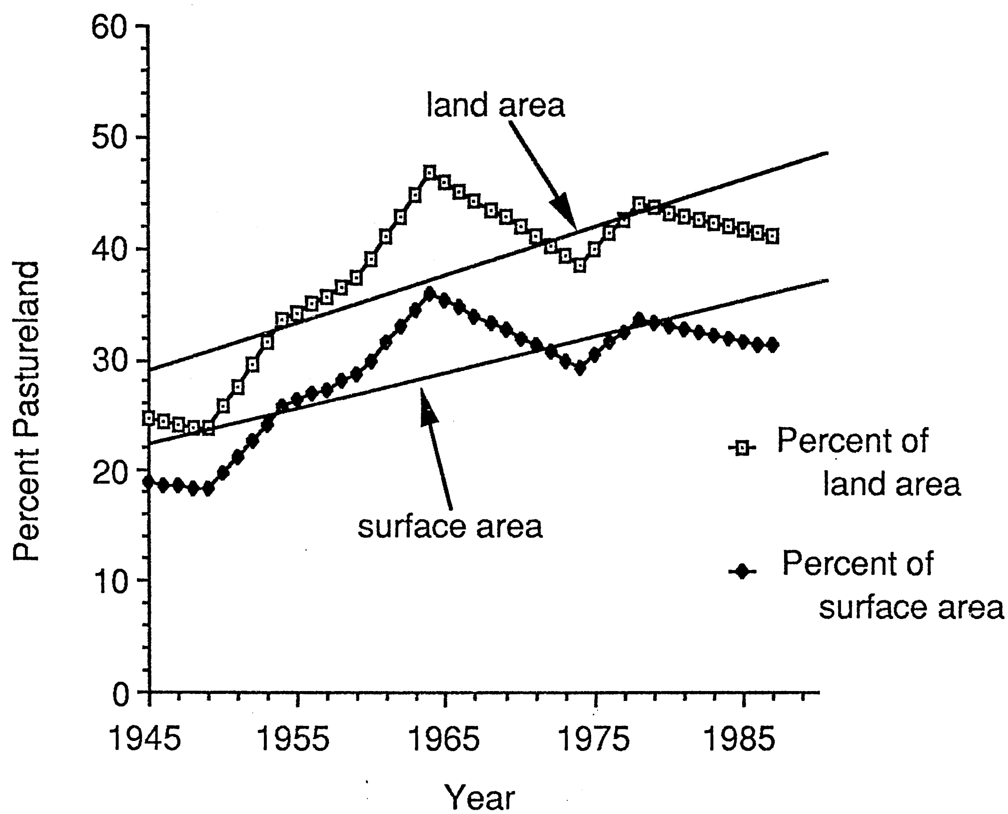

Figure 15. Cross Timbers Pastureland Linear Trends:
Percent of Land Area vs. Percent of
Surface Area

of the Cross Timbers. Finally, the totals for cropland, woodland and pastureland were divided by the total land area to convert the land use data in hectares to percentages. These were the land use classifications used to represent the Cross Timbers.

Climatic Data

The climatic data consisted of mean monthly temperatures for January and June. It was believed that January and June were the months with the greatest contrast in vegetation canopies. In June, woodland, pastureland and cropland all have full canopies. In January, vegetal cover is greatly reduced, or, in the case of cropland, absent altogether. Using differences in vegetal cover, it was hoped that variations in the magnitude of the surface-climate relationship with seasonality would be revealed. These data were gathered from cooperative reporting stations with records beginning in 1948 and ending in 1988. The data were published by the Oklahoma Climatological Survey. Mean monthly temperature was used to show the relationship between local climate and rural land use changes. Daily minimum and maximum temperature data were compiled to calculate the monthly minimum and monthly maximum temperatures. These data were then averaged to determine the mean monthly temperature.

The climatic data were used to create running averages for temperature. These were calculated to help discern the long-term climatic trends from the year-to-year fluctuations. As mentioned in Chapter II, separating "fluctuations" from "trends" has been an important consideration in climatological time-series analyses. There are typically significant yearly changes in climate; however, these are not necessarily representative of the long-term changes. A 5-year running mean was calculated for temperature to create a smoothed climatic trend. The 5-year interval is common in current geographic literature (e.g. Brinkmann, 1985).

The running mean temperatures were calculated at different scales for the same reasons as given for the land use variables. The running mean temperatures for each county were averaged on a yearly basis to establish the climatic trends for the Cross Timbers. The county climatic data were provided by reporting stations within the area. All of the reporting stations within the study region which provided yearly data throughout the entire 40-year period were used for this thesis. This amounted to eight stations, the locations of which are shown in Figure 16. Climatic data were also compiled for the entire state of Oklahoma. The purpose was to determine if there was a significant difference between the state and regional trends. It was hoped that such a difference in trends could be attributed to local changes in rural land use.

The state trends were developed differently from the regional trends. One climatic reporting station was chosen from each of the nine climatic divisions defined by the Oklahoma Climatological Survey (Figure 17). The selection of each station was based on its geographic location. An attempt was made to select the most centrally-located station with respect to its climatic division. This was not always possible, due to incomplete climate records at some stations. In such cases, the nearest station providing the required length of climatic record was chosen to represent the given division. The 5-year running

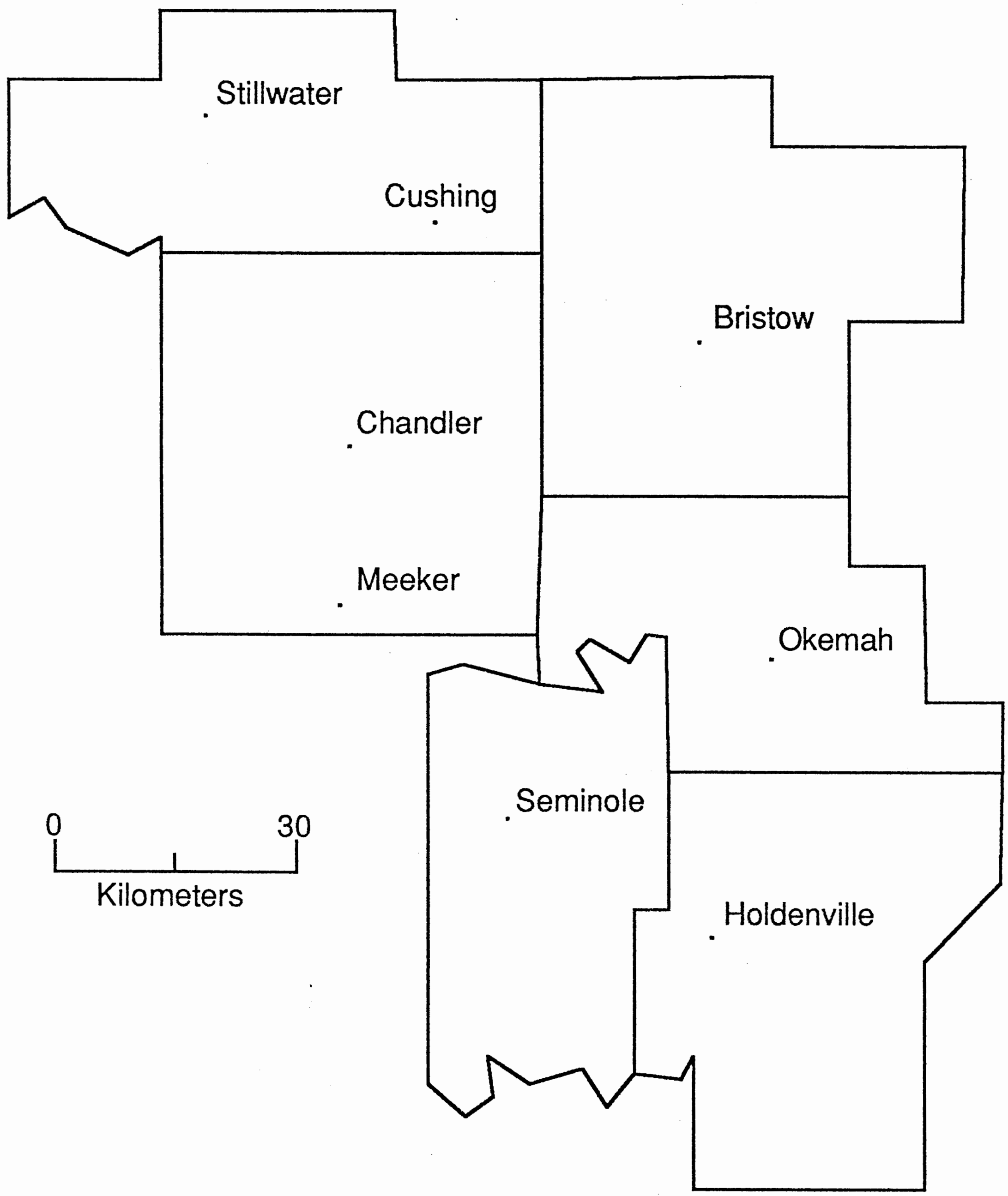

Figure 16. Locations of Climatic Reporting Stations
Within the 6-County Study Area

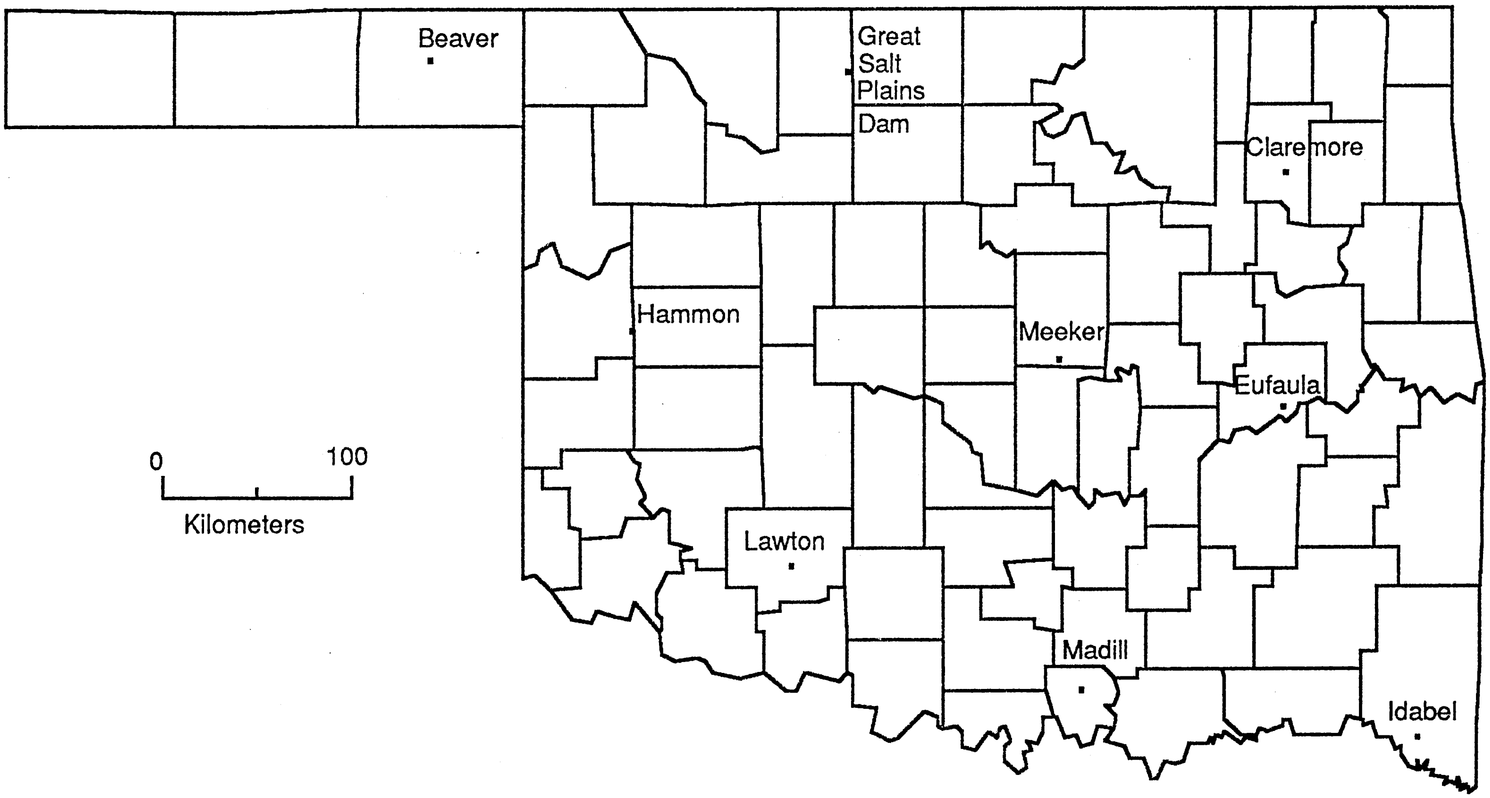

Figure 17. Locations of Divisional Reporting Stations throughout Oklahoma

mean temperatures for January and June were calculated for each of the stations, and these were averaged together to create state-level climatic data. The resulting data were used to establish the state climatic trends.

The geographic and topographic locations were considered as possible influences on the climatic data. The station location relative to settlements as well as physiographic features could have affected the data. The results of the spatial analysis of the climatic reporting stations are summarized in Appendix A. It was obvious that there was considerable similarity, in terms of geographic location, among the reporting stations located within the Cross Timbers study area. The stations were located on the outskirts of towns. Few of the towns were substantial urban areas; therefore, the effects of urban heat islands should not interfere with the possible "signal" from changes in the rural landscape (Appendix B). In terms of topography, some of the stations were located on hillsides and some were located within floodplains. Site was not a significant factor, as this was a time-series study. Although different environments were sampled, sites were not so different as to significantly alter the long-terms temperature trends. Absolute temperatures between stations were not as important as the temperature changes which occurred during the study period. Therefore, location of the stations was dismissed as irrelevant to this research.

Problems

There were some problems encountered during the data compilation phase of this study. These were unavoidable, but should be considered before the results of the analysis are discussed in Chapter VI. The first problem concerned the land use data, specifically, the accuracy of the data. The data from the U.S. Census of Agriculture were compiled from mailed surveys. The results were dependent upon the respondents who completed and returned the surveys. Follow-up contacts were made, or attempted, by telephone with nonrespondents. There was a standard error statistic calculated to account for nonrespondents remaining after all attempts of contact failed. Approximately 95% accuracy was assumed by the U.S. Department of Commerce as a final result of responses and error calculations in the U.S. Census of Agriculture. This was a problem which could not be avoided, for there was no other source which provided enough land use data for this research. The compilation methodology devised by the U.S. Department of Commerce remained the same throughout the study period; therefore, the trends which were evident should have been accurate.

Second, the land use data were available at 4- and 5- year intervals; whereas, the climatic data were recorded yearly. This was not a problem for determining the general trends in land use and climate, but for statistical analysis, this was a problem. The number of observations were not the same between the two types of data; therefore, the original data could not be paired for analysis. A formula was created which assumed a linear gradient between consecutive years of the U.S. Census of Agriculture. This method provided yearly land use data. Although this procedure was not as satisfactory as using land use data for individual years, it was viewed as acceptable for this study. There was no evidence suggesting drastic changes in the land use between census years which might have altered the long-term trends.

Another problem existed in the climate record. The data were recorded mainly by volunteers. There were occasions when the data were not recorded. Therefore, some missing records were estimated based on surrounding stations. The missing records were relatively few (approximately 2%), so the estimation of the missing data did not affect the long-term climate trends significantly.

There was also a problem with the comparison of county-level land use data to the climatic data which were point data. This raised a question as to the representativeness of the climatic reporting stations with respect to the given county. The temperature recorded at a specific station is often the result of the conditions surrounding that station. Therefore, the trends were believed to be intact, as were the interrelationships between rural land use changes and local climate. The comparison of point data to areal data was consistent throughout the study period.

Another important consideration of this study was the length of the land use record. The land use record only dated back to 1940, and it was believed that significant alteration of the rural landscape began earlier in the 20th century. In fact, the beginning of this study period actually marked the end of the period of the most dramatic landscape modification of the early settlement days. This idea was supported in the literature, which indicated that extensive deforestation occurred in the early 20th century to create more land for agriculture. The land use data which were available were too late to fully illustrate the changes which occurred in the Cross Timbers. As previously mentioned, there were no other sources which offered detailed land use statistics from that time period. Furthermore, the land use record matched, temporally, the climatic record, so the relationship between the two were believed to be evident.

Finally, there was some difficulty in the categorization of the land use data. This was the most significant problem with the data compilation procedures. The U.S. Census of Agriculture was arranged for agricultural and economic purposes. The definitions of total woodland, total cropland and total pastureland were not mutually exclusive and could not be used for this thesis. Categories had to be established from an "atmospheric" point of view. In other words, attention was given to the differentiation of rural land use canopies rather than detailed land use categorization. For example, all woodland was combined to represent the total woodland for each county, whether it was woodland used as pasture, managed forest or simply wilderness. The reasoning was that the various forms of woodland all had similar canopies; thus, similar climatic implications could be expected. The U.S. Department of Commerce only enumerated land used for agricultural purposes, as previously discussed; therefore, significant areas of land were excluded (Appendix C). This made it difficult to group the rural lands into woodland, cropland and pastureland. Unfortunately, this problem was unavoidable, as the U.S. Census of Agriculture was the only source for the land use data. It was believed that the rural land use trends would still be intact, as the compilation methodologies remained consistent throughout the study period.

The problems discussed in this section were generally of minor significance for time-series analysis. Absolute temperature at any one point in time was not the concern, rather, the type and magnitude of temperature change and land use change were the key interests. The data collection methodology remained consistent throughout the study period; therefore, the temperature trends remained intact. The problems with the land use data were unavoidable due to a lack of a reliable source other than the U.S. Census of Agriculture.

Methodology

The analytical methodology used in this thesis was rather simple. It was centered around extensive comparison of various graphs. The graphs included plots of linear and polynomial trend lines. Also, Spearman's rank correlation analysis was used to help determine the significance of the surface-climate relationship at different scales.

Graphic Analysis

Line graphs were constructed for individual counties as well as the Cross Timbers as a whole. Trend lines were plotted and comparisons were made between land use (Figures 13-15) and climatic trends (Figure 18; Chapter VI) as well as comparisons between counties (Figures 19-24; Chapter VI). This was done to determine if a particular county seemed to have the most obvious surface-climate interaction.

The first set of graphs were simple plots of the three land use categories of woodland, cropland and pastureland. Line graphs of individual counties and the Cross Timbers study area were created to show how representative each county was of the entire study area. Percentages of rural land use, with respect to total land area, were plotted by year. The results of these linear trend plots are summarized in Table I (Chapter VI). Linear trend lines were generated by computer and overlaid onto the graphs. The purpose was to make the long-term land use trends more apparent within the year-to-year variability.

The next set of graphs were line graphs of the climatic data which showed temperature variations on a year-to-year basis. The running averages were used for this set of graphs, which were created for each county, the Cross Timbers and the state (Figures 18-24). In this case, linear trend lines were generated using a statistical program for the Macintosh computer. The purpose was to determine how representative each county was of the climatic trends for the entire study region and the state.

There were additional graphs constructed which were variations on those previously discussed. New graphs using the same land use and climatic data as before were created; however, polynomial curves were fitted to compare trends in land use with temperature trends. The polynomial trends were used to determine if the relationship between land use and temperature was more apparent than with the linear trend plots. Polynomial curves usually provide more accurate "fits" to the graphed data. The higher the order of the polynomial, the more accurately the curve fits the original data. Due to the nature of the data in this thesis, however, the highest orders possible were 2nd-order, for the climatic data, and 3rd-order, for the land use data. Attempts to use higher orders resulted in multicollinearity problems. As a result, no significant advantages were anticipated using the polynomial trend lines rather than the linear trends.

As previously mentioned, all of these graphs were used for the purpose of visually comparing the trends for rural land use and local climate. These trends were analyzed at both regional and subregional levels. The graphs were also used to determine rates of change in land use and temperature. These rates were determined from the linear trends and are summarized in Table I in Chapter VI. The purpose of this was to determine if greater rates of land use change were accompanied by greater rates of change in local temperature.

The graphs constructed for this thesis comprised the basis for analysis. However, additional testing was deemed necessary. According to the literature, correlation analysis has been one of the most favorable statistical tests for determining associations between two variables (Hammond and McCullagh, 1980). Correlation analysis was used to supplement the graphic analysis in this study.

Correlation Analysis

The Spearman's Rank Correlation test was used due to the nature of the data. This test is a "nonparametric" test, and such tests are sometimes more valid than "parametric" tests. The latter make assumptions about the background populations from which the sample data are extracted. The most frequent assumption is that the population is normally distributed. "Nonparametric" tests are also known as "distribution-free" tests because the background populations are not assumed to be normally distributed (Hammond and McCullagh, 1980). The Spearman's Rank Correlation test was determined to be the most favorable to determine the surface-climate relationship for the Cross

Timbers.

The data used for correlation were generated by using the polynomial trend line information. Values were given for each year along the actual trend line. Therefore, the correlation testing was between polynomial trend lines rather than the original or running mean data. The reasoning behind this was that the yearly fluctuations represented in the original data may have diminished the magnitude of the surface-climate interrelationship. It was believed that such evidence would be much more apparent by using polynomial trend data, as the smoothed curve virtually deleted the yearly fluctuations.

Summary

The compilation of data for this thesis revealed several problems which were unavoidable. Fortunately, due to the nature of the study, the difficulties encountered seemed to be of minor consequence. The most significant problem was the classification of the rural land. There was, undoubtedly, some error involved; however, it was believed that adequate trend information was obtained due to the fact that the original data were compiled in the same manner throughout the study period. In terms of methodology, although very basic, analysis of trend lines was the best method to use with the data available. The supplemental use of correlation analysis was relevant to help clarify some of the preliminary results. Therefore, the combination of the data and the methodology was expected to yield results which would help determine the connection between local climate and rural land use changes.

CHAPTER VI

ANALYSIS OF RESULTS

In order to determine how significant land use changes were to local climate, it first had to be determined how the Cross Timbers related to the state in terms of climatic trends. A notable difference in climatic trends between the Cross Timbers and the state were essential; otherwise, there would be nothing to substantiate the hypothesis that land use changes have influenced local climate. Figure 18 illustrates that, indeed, there was a noticeable difference in state and Cross Timbers climate trends. The state experienced a decrease in mean June temperature by 1.2 °C during the study period. The Cross Timbers experienced a lesser decrease of 0.7 °C in mean June temperature. Both the Cross Timbers and the state as a whole experienced cooling trends; however, the Cross Timbers was apparently influenced locally such that the cooling was not as pronounced. The goal, at this point, was to determine if rural land use change could reasonably be suggested as a local influence on climate. It also had to be determined at what level of spatial data was this relationship most apparent (state, regional or subregional). Figures 19-24, showing linear trends in mean monthly temperature, were used to indicate the magnitude of the subregional climatic trends.

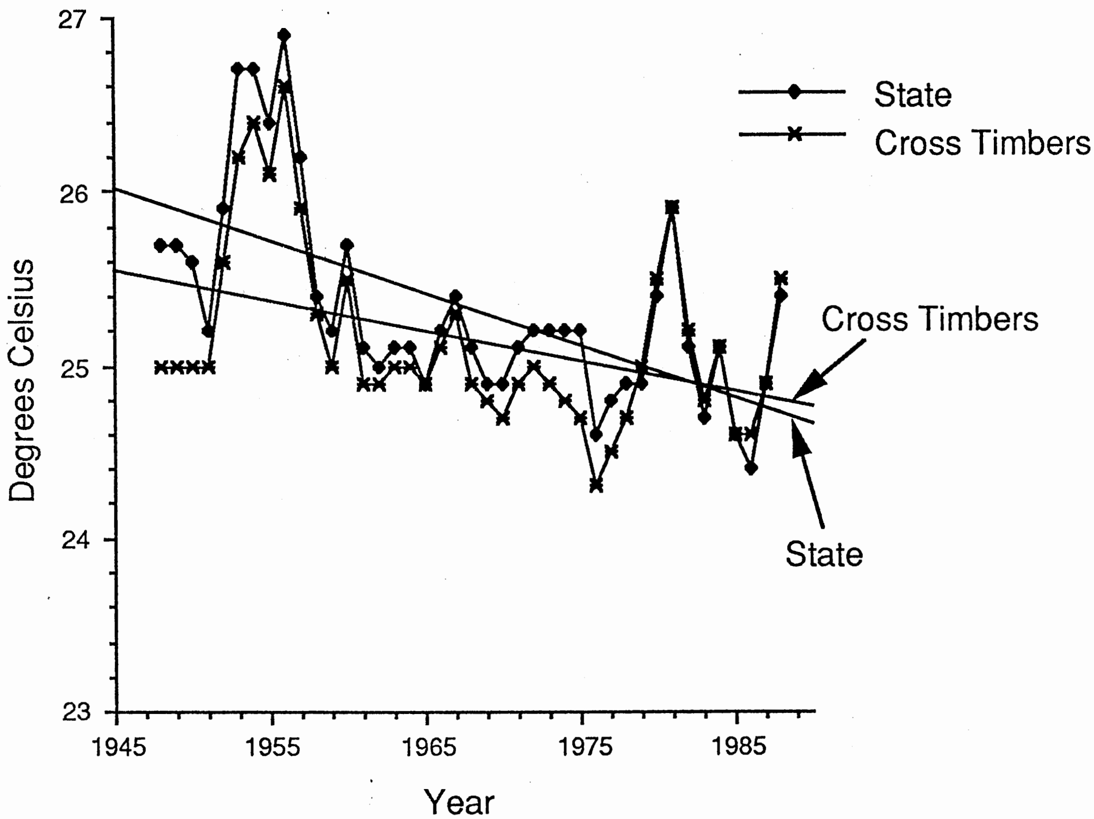

Figure 18. Mean June Temperature Trends: Cross Timbers Study Area vs. the State as a Whole

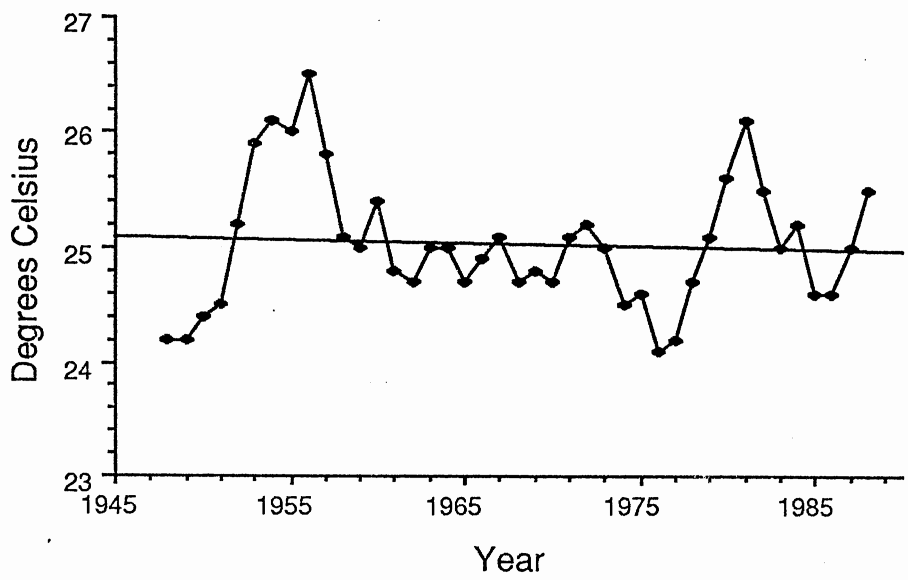

Figure 19. Mean Monthly June Temperature
Trend for Creek County

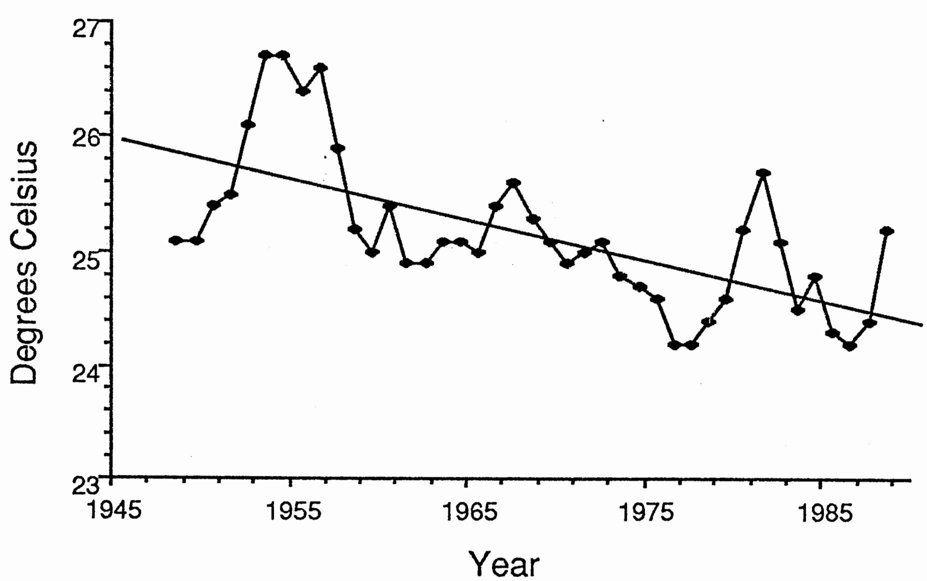

Figure 20. Mean Monthly June Temperature
Trend for Hughes County.

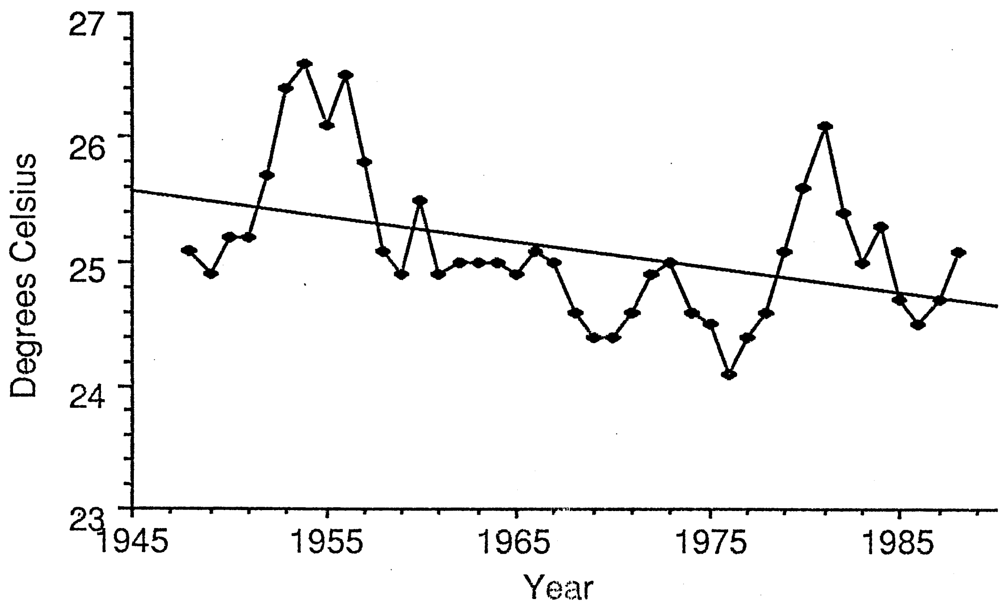

Figure 21. Mean Monthly June Temperature
Trend for Lincoln County.

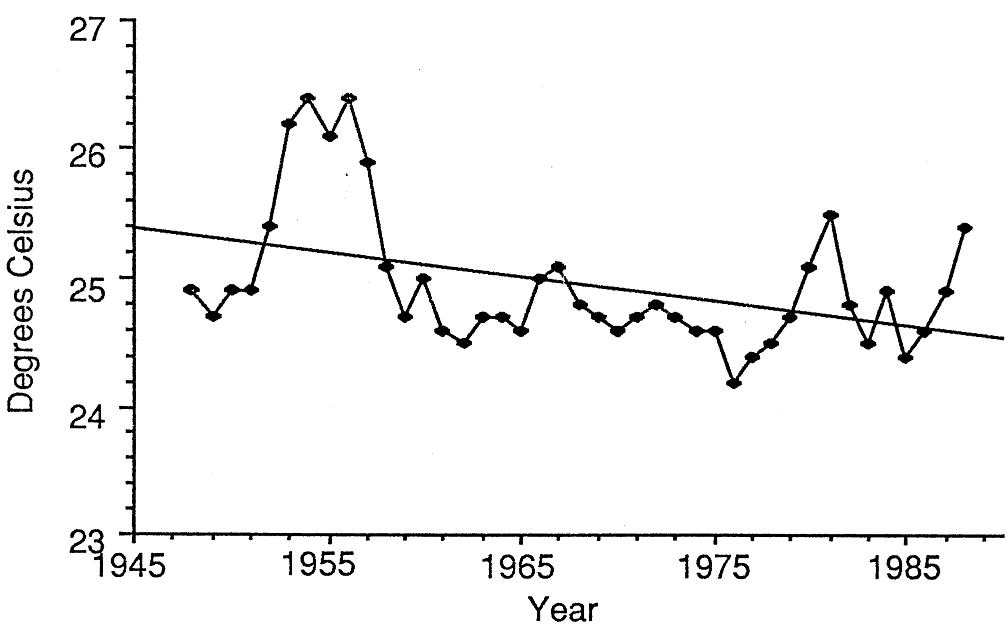

Figure 22. Mean Monthly June Temperature
Trend for Okfuskee County.

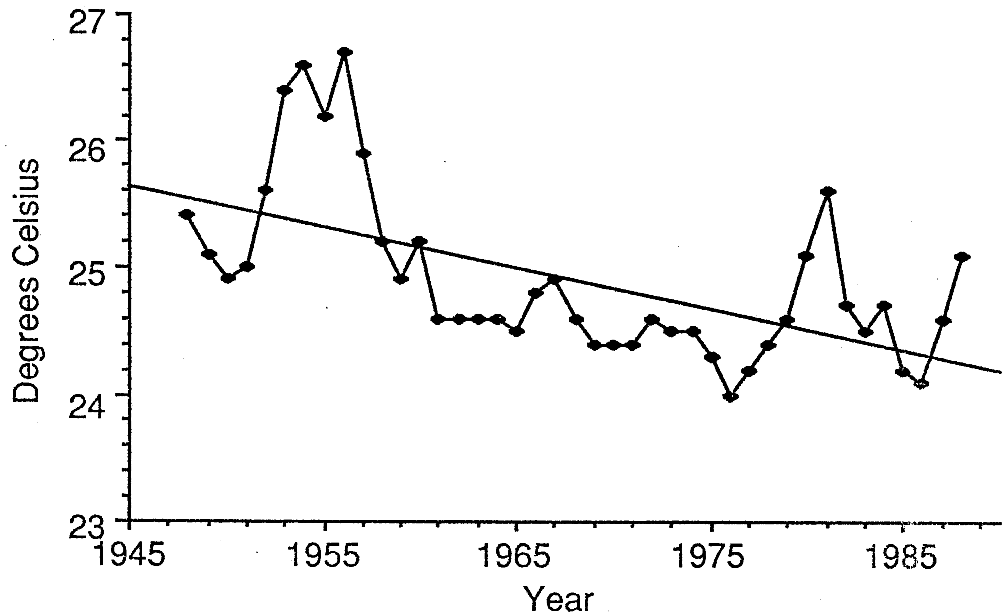

Figure 23. Mean Monthly June Temperature
Trend for Payne County.

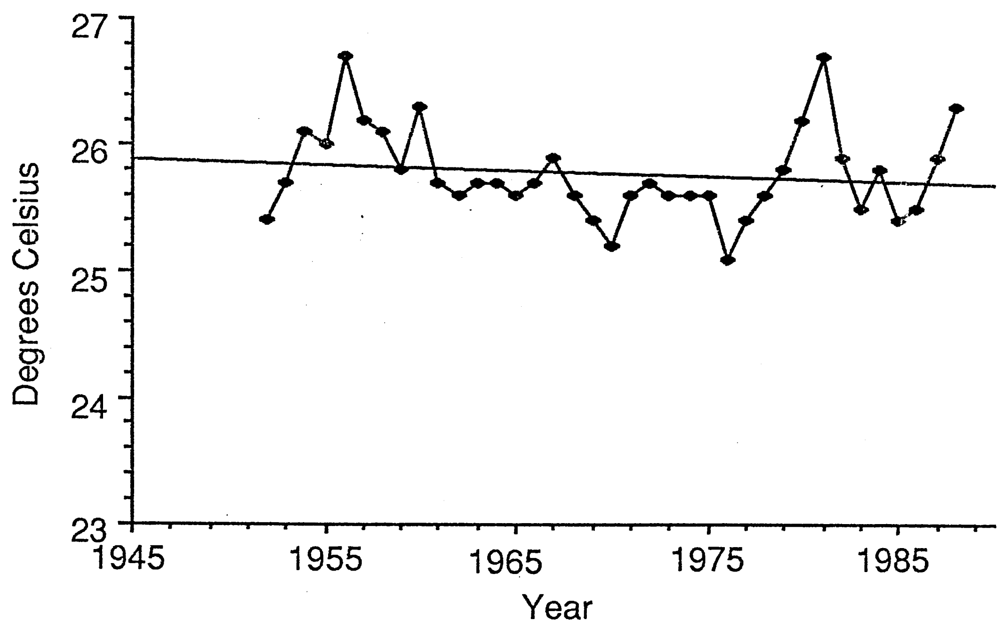

Figure 24. Mean Monthly June Temperature
Trend for Seminole County.

Results of Graphic Analysis

Linear Trend Analysis

The results of the linear trend analysis are summarized in Table I. It should be noted that the magnitudes given were the results of statistical analysis and were not merely estimated from the graphed trend lines. Values along the trend lines were generated with a statistical program on the Macintosh to determine the magnitudes at the beginning and ending of the study period.

A brief inspection of the regional data for the Cross Timbers revealed an ambiguous relationship with the land use trends. The reduced rate of temperature decrease within the Cross Timbers, relative to the state trend, was not easily explained from the land use record. The individual land use trends were superimposed on the overall regional trend. There it was not surprising that the relationship between land use and local climate was not as apparent at the regional level. The land use trend for the Cross Timbers was basically cropland reverting to pastureland. The amount of decrease in cropland was equivalent to 13.9% of the total study area. Pastureland increased by an equivalent of 17.9% of the Cross Timbers land area (Table I). This alone would suggest a "cooling" effect on local climate (Oliver, 1973). However, the trend in woodland must also be considered before making such an assumption. Although the magnitude of change in woodland was not as great as those of cropland and pastureland, a decrease of 4.4% of the total Cross Timbers land area was viewed as significant (Table I). As Oliver (1973) stated, forest has the greatest influence on local climate, in terms of

TABLE I

RESULTS OF LINEAR TREND ANALYSIS

	Mean Monthly Temperature (°C)		Land Use (% of total county area)		
	January	June	Cropland [a]	Pastureland [a]	Woodland [a]
Creek	-1.6	-0.1	-10.8	+22.1	-10.7
Hughes	-2.5	-1.4	-15.5	+19.8	-9.6
Lincoln	-2.2	-0.7	-14.2	+13.6	+1.0
Okfuskee	-2.4	-0.8	-19.9	+24.9	-3.7
Payne	-3.0	-1.3	-15.4	+6.9	+9.3
Seminole	-2.2	-0.2	-9.1	+20.6	-10.7
Cross Timbers	-2.1	-0.6	-13.9	+17.9	-4.4
State	-1.9	-1.2			

a: "+" signifies an increasing trend and "-" signifies a decreasing trend.

vegetation types. This suggested that less acreage of woodland was required to have a marked influence on local climate. Despite this, further analysis was necessary to determine the significance of the surface-climate relationship. Therefore, trend line analysis was conducted at the county (subregional) level.

The high correlations between January and June data seemed to indicate that little would be gained by using data for both months (Table II). Therefore, it became apparent that both January and June temperature data were not necessary for further analysis. Due to the fullness of the canopy, June was used for further analytical purposes.

The counties which experienced the greatest amounts of change in woodland were Payne, Creek and Seminole. In the case of Payne County, an increase in woodland acreage was noted for the study period. The magnitude of change was equivalent to 9.3% of the total land area of Payne County. The corresponding change in temperature was a decrease of 1.3 °C for the mean June temperature. This was the second highest rate of change in June temperature, behind Hughes County, and was substantially higher than the magnitude of change for the Cross Timbers study area (-0.6 °C). Another significant fact was that the amount of increase in pastureland was markedly less than all of the other counties (6.9%). Cropland decreased in Payne County by an equivalent of 15.4% of the total land area (Table I). Therefore, the dominant change in the landscape was from cropland to woodland. An increase in canopy should have led to a cooler local climate, according to the original hypothesis. In this case, however, the cooler climate was reflected in the increased rate of temperature decrease relative to the state and regional temperature trends.

Opposite situations of Payne County were experienced by Creek and Seminole counties, which exhibited the greatest rates of decrease in woodland (10.7% for both counties). In terms of pastureland and cropland, both experienced similar rates of decrease in cropland and rates of increase in pastureland. The two counties also had similar trends in mean June temperature. Creek County exhibited a 0.1°C decrease (the lowest rate among all six counties) while Seminole County had a 0.2 °C decrease. Both counties experienced dominant land use changes from woodland to pastureland. It should be noted that the magnitudes of woodland and cropland changes were similar. However, as previously mentioned, the effect of woodland on local climate is greater than any other vegetal cover (Oliver, 1973). Thus, with the dominant land use change in both Creek and Seminole counties being an overall decrease in canopy, a corresponding increase in temperature would be expected. As with Payne County, the most significant aspect of the climate trend was the magnitude. The rate of temperature change was substantially less than the rate of change for the Cross Timbers or the state as a whole. Although the trends were still decreases in mean June temperatures, the decreases were not of as great a magnitude as those of the state or the Cross Timbers (Table I). Therefore, Creek and Seminole counties had situations which were as hypothesized.

The counties which showed only slight changes in woodland acreage were Lincoln and Okfuskee. Lincoln County showed an increase of 1.0%, while Okfuskee County had a decrease equivalent to 3.7% of the county land area. In terms of pastureland, Lincoln County had a 13.6% increase while Okfuskee County had an increase of 24.9% (the highest rate of all six counties). The two counties were very similar in climatic trends. Lincoln County had a 0.8 °C decrease in mean June temperature, while Okfuskee County experienced a decrease of 0.7 °C (Table I). Although the two counties were similar in climatic trends, it was difficult to relate these changes to rural land use from the linear trend analysis alone. It is suggested that the trend of woodland in each county is largely responsible for the unclear relationship between land use and local climate. In both cases, the woodland acreages were relatively stable throughout the study period. A threshold is believed to exist in terms of the amount of woodland required to bring about measurable climatic change. Possibly, there was not enough change in woodland acreage to bring about significant change in mean monthly temperature. From the other counties of this study, it is suggested that the magnitude of change in woodland must be approximately 8% of the land area at the subregional level to show meaningful change in mean monthly temperature. The data available, however, was not sufficient to formally test this.

The final situation was anomalous to the rest of the counties in the study area. Hughes County, in terms of climatic trends, had a 1.4 °C decrease in mean June temperature (similar to Payne County); however, the dominant land use aspect was a decrease by 9.5% in woodland acreage (similar to Seminole and Creek counties; Table I). The situation presented by Hughes County was contrary to the hypothesis---a decrease in woodland with a corresponding increase in the rate of temperature relative to the regional and state trends. Hughes County was found to be similar to the other five counties in the study region in terms of physical characteristics such as topography, geology and climatology. Furthermore, there was no evidence of any anomalous human activity within the county (i.e. urbanization, number/locations of climatic reporting stations, agricultural practices, etc.). Therefore, it is suggested that Hughes County was influenced by large-scale climatic characteristics more than regional or subregional factors. Possibly, precipitation trends over the study period were different in Hughes County from the rest of the Cross Timbers. It is suggested that an increase in precipitation has had a moderating effect on mean monthly temperatures in Hughes County. Possibly, a regional effect on convective cloud development similar to that detailed by Rabin, et. al (1990) led to an increase in precipitation in Hughes County. Such data was not analyzed in this study.

Three situations became apparent from the graphic analysis of the individual county land use trends. All three concerned the relationships between woodland and changes in June climate. The counties which experienced the greatest changes in woodland (increasing or decreasing by approximately 10% of the total county land area) generally experienced the greatest rates of temperature change. The counties which had relatively modest changes in woodland had relatively insignificant correlations with June temperature trends. Finally, Hughes County exhibited trends which were anomalous within the study area.

Polynomial Trend Line Analysis

The analysis of the polynomial trends presented results which were expected, based on the linear trend analysis. As previously mentioned, these were graphed to determine if there was a significant difference from the linear trends. Figures 25-29 illustrate the Cross Timbers study region in terms of polynomial trends. Although the trend lines "fit" the original data better than did the linear trend lines, the nature of the polynomial trend lines would not allow precise analysis in terms of trend magnitudes. The counties which showed only marginal surface-climate relationships with the linear trend plots (Lincoln and Okfuskee counties) did not change any of the interpretations of the data.

Results of Correlation Analysis

The results of the Spearman correlation analysis were supplemental to the graphic analysis. The correlation coefficients substantiated the relationships previously noted, and the results are summarized in Table II.

The correlations noted at the regional level (Cross Timbers) were relatively clear, in terms of land use. The relationships between land usages reinforced the idea that cropland and woodland had been converted to pastureland. There were strong negative correlations to indicate this. The Spearman rank correlation coefficients were -.83 for the cropland/pastureland trends and -.90 for the woodland/pastureland trend. These were statistically significant at a level of .001. This significance level was deemed important to show the relationships desired in this study. Similar clear-cut results were not available for the correlation analyses between land uses and climatic trends. There were some strong relationships, for instance, between cropland and mean monthly temperature. A strong positive correlation (.82) existed for June.

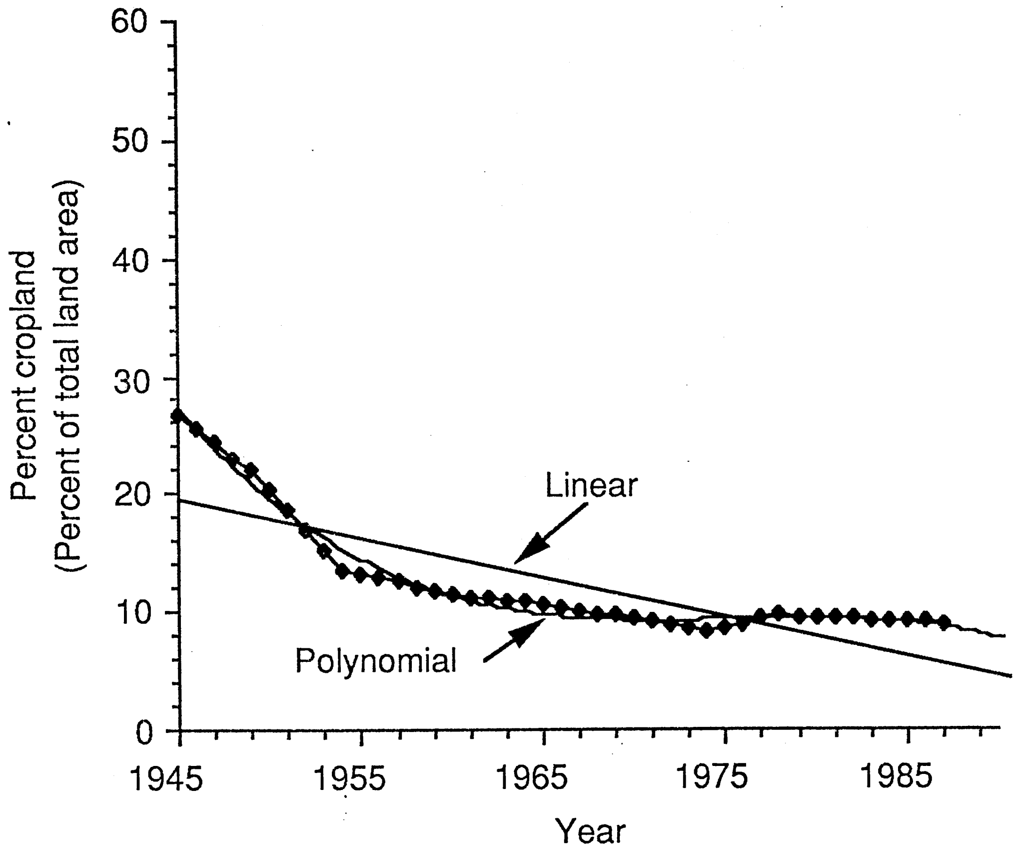

Figure 25. Cross Timbers Cropland Trends:
Linear vs. Polynomial

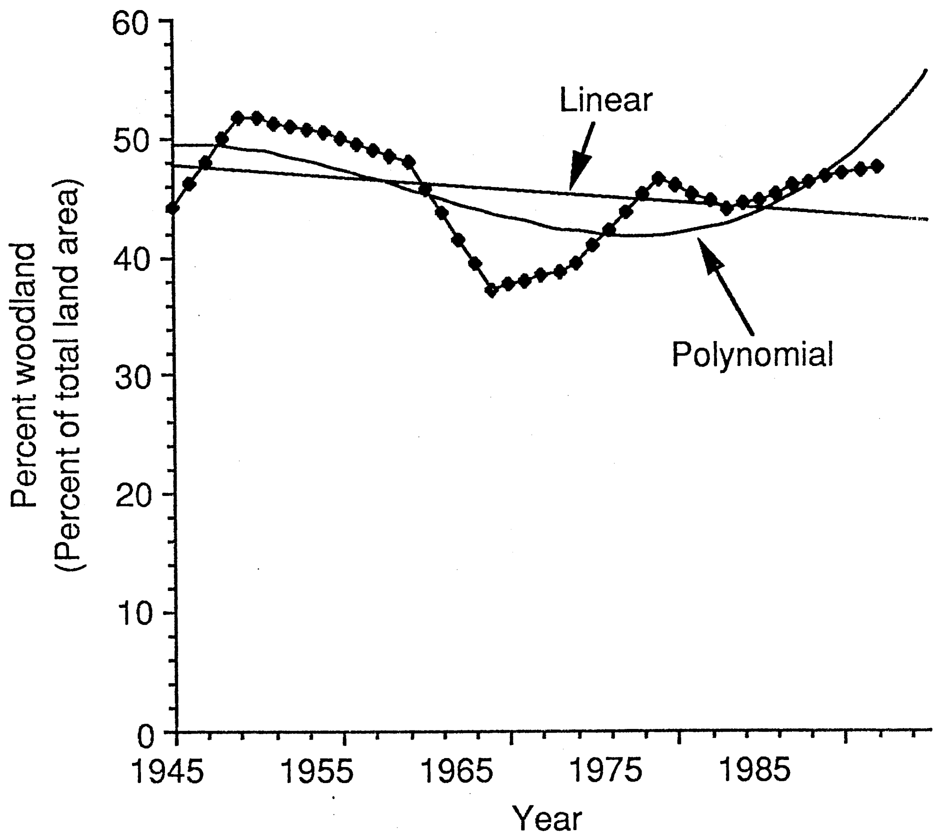

Figure 26. Cross Timbers Woodland Trends:
Linear vs. Polynomial

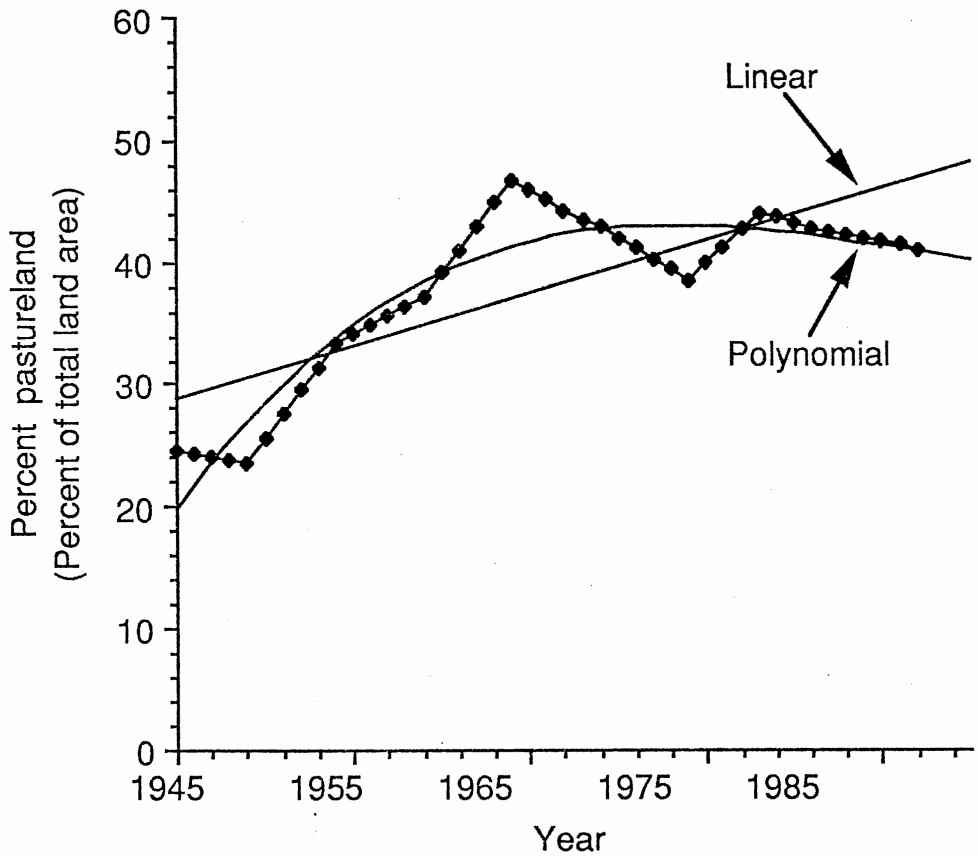

Figure 27. Cross Timbers Pastureland Trends:
Linear vs. Polynomial

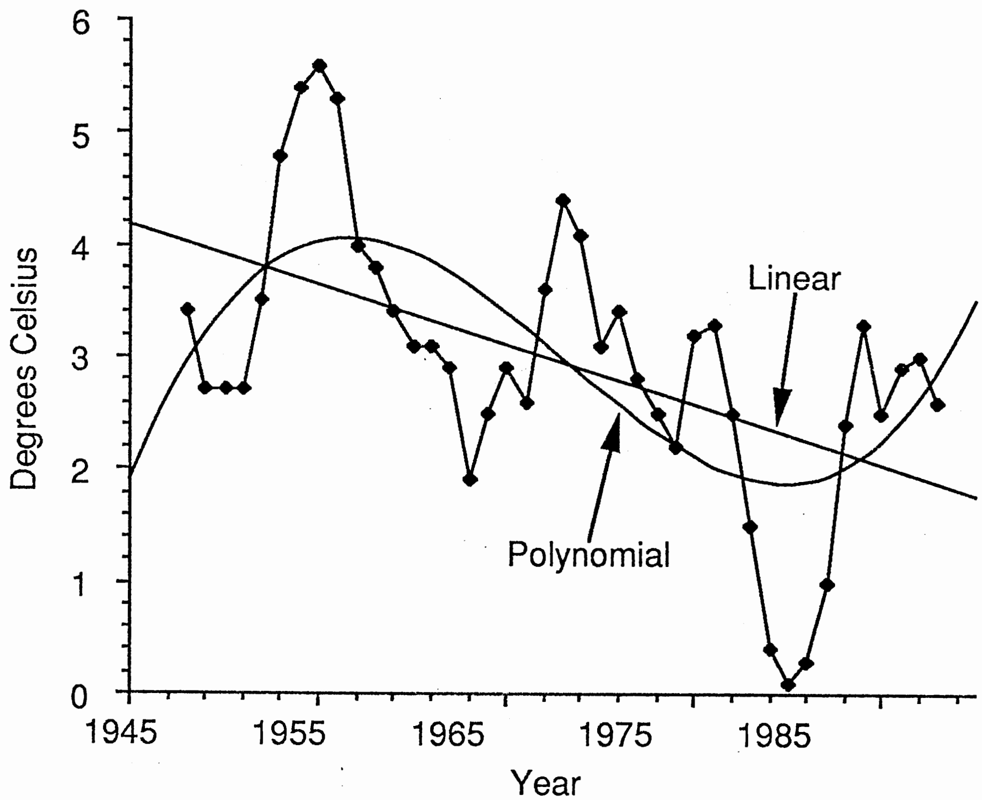

Figure 28. Cross Timbers January Mean Temperature Trends: Linear vs. Polynomial

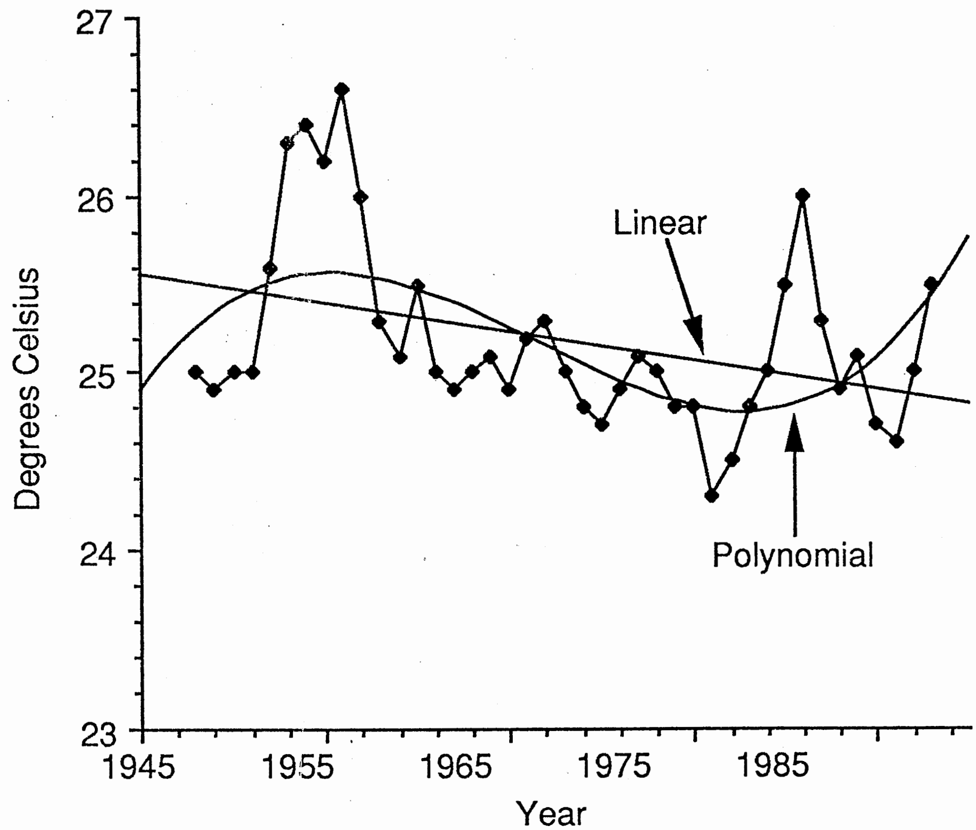

Figure 29. Cross Timbers June Mean Temperature Trends: Linear vs. Polynomial

TABLE II

RESULTS OF SPEARMAN CORRELATION ANALYSIS

	Cropland/ Woodland	Cropland/ Pasture	Cropland/ Jan. Temp.	Cropland/ June Temp.	Woodland/ Pasture	Woodland/ Jan. Temp.	Woodland/ June Temp.	Pasture/ Jan. Temp.	Pasture/ June Temp.	Jan. Temp./ June Temp.
Creek	.62[a] (.0002)[b]	-.71 (.0001)	.69 (.0001)	.60 (.0001)	-.90 (.0001)	.74 (.0001)	.91 (.0001)	-.85 (.0001)	-.98 (.0001)	.89 (.0001)
Hughes	.65 (.0001)	-.77 (.0001)	.98 (.0001)	.98 (.0001)	-.98 (.0001)	.52 (.0012)	.52 (.0012)	-.68 (.0001)	-.68 (.0001)	1.00 (0.0)
Lincoln	-.03 (.0001)	-.42 (.0062)	.99 (.0001)	.77 (.8686)	-.87 (.0001)	-.23 (.1559)	.22 (.1808)	-.27 (.0881)	-.59 (.0002)	.73 (.0001)
Okfuskee	.17 (.0001)	-.73 (.0001)	.79 (.0001)	.61 (.2646)	-.50 (.0013)	.66 (.0001)	.84 (.0001)	-.95 (.0001)	-.97 (.0001)	.86 (.0001)
Payne	-.57 (.0001)	.05 (.7608)	.94 (.0001)	.99 (.0002)	-.64 (.0001)	-.80 (.0001)	-.71 (.0001)	.12 (.4451)	.17 (.2826)	.89 (.0001)
Seminole	.54 (.0013)	-.45 (.0039)	.02 (.9079)	.54 (.0004)	-.79 (.0001)	.67 (.0001)	.89 (.0001)	-.98 (.0001)	-.41 (.0148)	.34 (.0419)
Cross Timbers	.57 (.0002)	-.83 (.0001)	.89 (.0001)	.82 (.0002)	-.91 (.0001)	.35 (.0306)	.44 (.0055)	-.71 (.0001)	-.76 (.0001)	. 96 (.0001)

[a] correlation coefficient

[b] prob > R

Likewise, a significant negative correlation was noted between pastureland trend and mean monthly temperature (-.76 for June). However, in the case of woodland, the results were insignificant and inconclusive. The correlation coefficients were .35 for January and .44 for June; neither of which were significant at the .001 level (Table II). Thus, it appeared from these results that the conversion of cropland to pastureland was more closely related to the climatic trends than was the denudation of woodland areas. The differences between January and June coefficients may be attributable to the fact that the polynomial trends did not match on a yearly basis. Although the linear trends for the two months were very similar in direction and magnitude, the yearly variations would have been apparent in the correlation coefficients.

The situations discussed in the "graphic analysis" section of this chapter were further substantiated by the correlation analyses. In the case of Payne County, there were significant correlations between cropland and woodland (-.57) as well and woodland and pastureland (-.64; Table II). It should be noted that the correlation coefficient, in the case of woodland/pastureland, was not truly representative of the actual long-term trends. According to the given coefficient, it appeared that woodland and pastureland experienced opposite trends in coverage. On the contrary, both land use types experienced an increase in coverage during the study period (Figures 30-31). The short-term (yearly) changes were opposite from one another, which were reflected in the negative correlation coefficient.

Other significant correlations in Payne County included cropland compared to woodland (-.57), woodland compared with the temperature

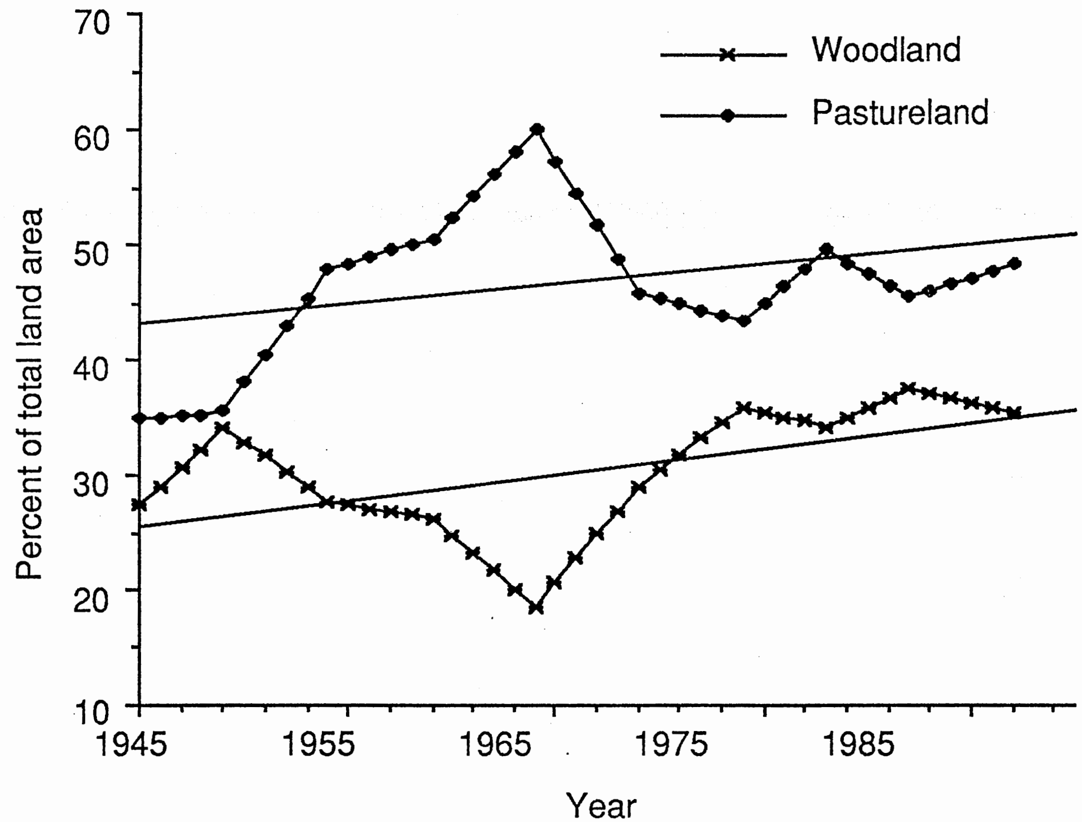

Figure 30. Payne County Linear Trends
for Woodland and Pastureland

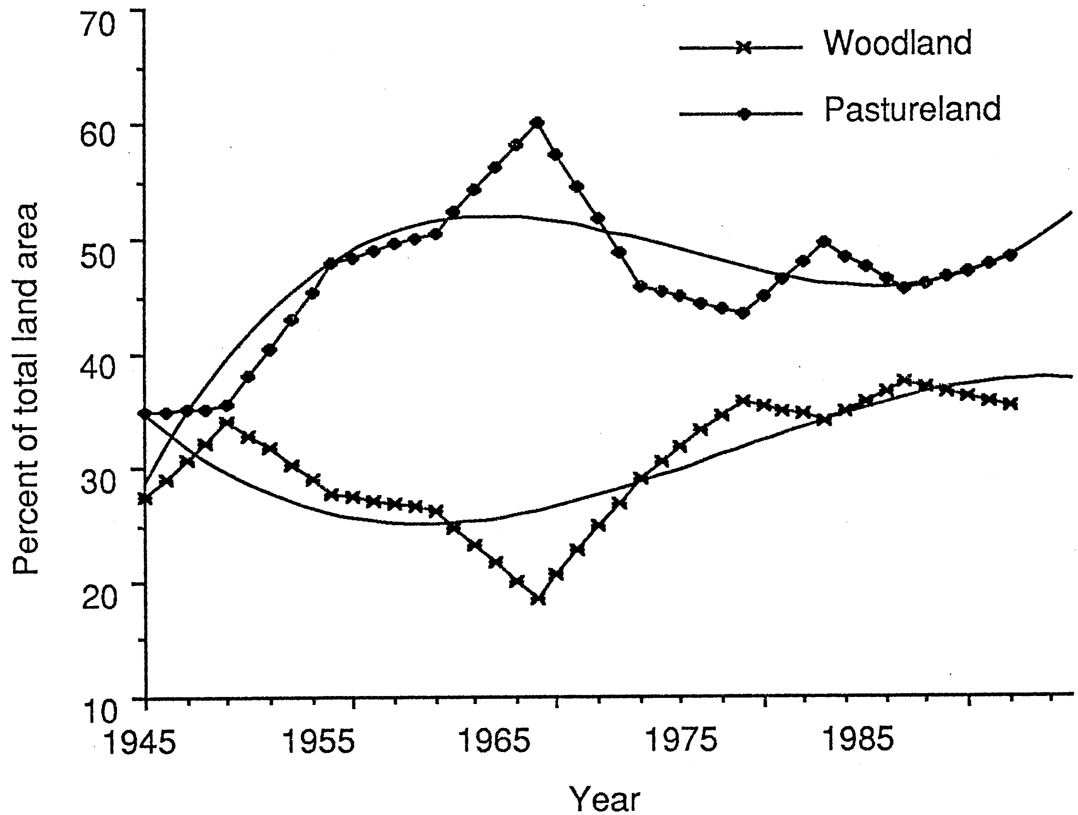

Figure 31. Payne County Polynomial Trends
for Woodland and Pastureland

trend for June (-.71), and cropland compared to mean monthly temperature (.99 for June; Table II). The cropland/woodland coefficient appeared to be reflective of the land use trend from cropland to woodland over time. It has already been discussed that woodland and pastureland actually exhibited similar long-term trends. As far as cropland and pastureland are concerned, there was no significant relationship between those land uses. The conversion of cropland to woodland; therefore, is suggested as having a significant impact on local temperature in Payne County.

Two counties with similar situations were Creek and Seminole. Both experienced strong negative correlations between woodland and pastureland (-.90 for Creek County and -.79 for Seminole County; Table II). These coefficients represented the highest correlations between land use types. This suggested that the dominant land use trend was from woodland to pastureland. The most significant relationship between land use and mean monthly temperature was indicated by high correlation coefficients between woodland and local mean temperature, as well as between pastureland and local mean temperature. The coefficients for woodland and June mean temperature were .91 for Creek County and .89 for Seminole County. Creek County exhibited the most significant correlation between pastureland and local climate (-.98 for June temperature). The relationship between pastureland and June mean temperature was not so obvious for Seminole County. In fact, there was not a significant correlation at a level of .001. Seminole County was the only county which exhibited no significant positive correlation between January and June mean temperatures. Several retests of the data were performed, all resulting in a coefficient of .34 with a probability of .0419 (Table II). The trends possibly indicate an increasingly extreme climate. In other words, the winters have become colder, while the summers have become warmer. The result has been diverging temperature trends between June and January. It should be noted that the divergent trends of January and June did not occur consistently the same. If the January and June temperature trends remained the same throughout the study period, a negative trend would occur. The climatic trends can be closely tied to the corresponding changes in land use, in particular, woodland and pastureland.

The relative stability of the woodland acreage of Lincoln and Okfuskee counties was reflected in the correlation coefficients which were generated. Significant negative correlation coefficients were noted between woodland and pastureland (-.87 for Lincoln and -.50 for Okfuskee). The only other significant correlation between land use variables was noted in Okfuskee County between pastureland and cropland (-.73). In terms of surface-climate relationships, both counties showed strong positive correlations between cropland and mean monthly temperature. The June coefficients were .61 for Okfuskee and .77 for Lincoln. Also for Okfuskee County, a significant relationship was evident between woodland and mean monthly temperature (.84 for June; Table II). There was no significant correlation noted in the case of Lincoln County, and it is suggested that this was attributable largely to the woodland trends. There was a greater amount of change in woodland coverage for Okfuskee County, which was illustrated by significant correlation between woodland and mean monthly temperature. However, for Lincoln

County, the amount of woodland changed only slightly during the study period. Therefore, there were no apparent relationships with mean monthly temperature in Lincoln County. Overall, the correlations between land uses and mean monthly temperatures were less significant than with the previous counties.

Finally, the anomalous situation discovered for Hughes County during the graphic analysis was reflected in the correlation testing. Among the coefficients generated, the strongest correlation between land use types was between woodland and pastureland (-.98). This suggested that woodland generally was converted into pastureland. Somewhat less significant correlations were indicated between cropland and pastureland (-.77) as well as cropland and woodland (.65). It was evident from these coefficients that the dominant land use change in Hughes County was an increase in pastureland. In terms of climate, the strongest correlation was exhibited between cropland and mean monthly temperature (.98 for June). This coefficient was significantly higher than the coefficients for cropland/woodland (.65) and for cropland/pastureland (-.77; Table II).

The results of the correlation analysis between the deviations from the state trend and the regional and subregional data were similar to those previously discussed. Yearly deviations in mean monthly temperature from the state trend were calculated and statistically analyzed using the Spearman rank correlation test. It was determined that no significant relationship existed. In each case, there were no significant correlation coefficients which were not already evident.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Geographic analysis of human impact on the natural environment has become a topic of growing concern in recent years. The purpose of this thesis was to call attention to the effect which humans have on local rural climates, in terms of temperature. It was determined that such a study should be enacted for rural areas, as a void was noted in terms of similar studies in the geographic literature.

Results

The original hypothesis was that a decrease in the amount of woodland in the Cross Timbers has led to an increase in mean monthly temperature. This correlation, it was hypothesized, would be detectable at the sub-regional (county) level of data compilation. In fact, the correlation between woodland and mean monthly temperature was most pronounced at the sub-regional level, as expected.

It was discovered that there was a measurable difference between the mean monthly temperature trends for the state and the Cross Timbers over the last 40 years. Both experienced decreases in mean monthly temperature; however, the Cross Timbers had a lower rate of decrease than did the state as a whole. Through graphic analysis of linear and polynomial trend lines and statistical analysis of correlation coefficients it was determined that a statistical relationship existed between rural land use changes and local climate. At the regional level, this relationship appeared to be a change to pastureland, which corresponded to a lesser rate of mean monthly temperature change relative to the state trend. While pastureland increased, woodland and cropland both declined in areal extent. It has been widely accepted that woodland has a moderating effect on climate; in fact, woodland has the most marked influence of vegetation upon climate (Oliver, 1973). According to Mather (1974), grassed areas are noticeably warmer than forested areas; therefore, one would expect a change from woodland to pastureland to yield a regional temperature trend of lesser temperature decrease than the state climatic trend. This appears to be the case for the Cross Timbers; however, to better understand the surface-climate relationship, subregional analysis was utilized.

The results of the county analysis helped to substantiate the correlation between rural land use and local climate, especially in terms of woodland. All six counties experienced decreases in mean monthly temperatures during the study period. The magnitudes of the trends, however, could be linked to the changes in woodland acreage. There was only one of the six counties which did not fit the hypothesis. Increases in woodland could be linked to increased rates of temperature decrease; likewise, decreases in woodland were correlated to decreased rates of temperature increase. The counties which exhibited little change in woodland acreage had temperature trends which were similar to the state and regional trends, in terms of magnitudes. Therefore, it is reasonable to suggest that rural land use does have a measurable effect on local climate. Based on the results of this study, it is suggested that a decrease in woodland by 5% of the total land area may result in a temperature increase of 0.5°C. It is further suggested that woodland has a greater impact than any other rural land use type.

The trends exhibited in the Cross Timbers were opposite to the Northern Hemisphere Temperature Curve. The northern hemisphere has been experiencing an increase in temperature, while the Cross Timbers has shown a decreasing trend in mean monthly temperature. This illustrates the problem of representation which was discussed in Chapter II. The Northern Hemisphere Temperature Curve does not represent the climatic trend of the Cross Timbers. This is not unusual, based on the arguments presented in the literature (Brinkmann, 1985). The year-to-year variability at the regional and subregional levels are often different from the hemispheric variability, which is simply the average conditions over a very large area.

Future Research

This thesis was, by no means, an ending to a research problem; on the contrary, it has left several questions for further research. One such question involves that of the previously mentioned "thresholds" of land use change. It is suggested here that a 5% decrease in woodland is required to raise the monthly mean surface temperature 0.5°C at the subregional level. Obviously, there would be many considerations in such a study. The size of the surface area would be one of the most significant. Also, a detailed understanding of the physical environment---including topography, climatic characteristics and vegetal cover---would be required. Such a study would help quantify human impact on local climate in rural environments.

Another possible research problem might involve a more detailed classification scheme of rural land use. Rather than simply determining between pastureland, cropland and woodland, further subdivision within each of these land use classes may yield another aspect of climatic implications of land use change. For example, this study has shown that woodland has a greater influence on local climate than cropland or pastureland. What have not been determined, in terms of trends, are the differences between types of woodland canopy with respect to local climate change. This would give a better understanding of specific climatic implications associated with changes in specific types of woodland. Although the literature deals with this topic in terms of a specific point in time, conversion of canopy has received little, if any, attention.

Conclusion

Humans interact with the natural environment, and it involves both human influence on the environment as well as environmental limitations to human expansion. Recently, agricultural practices have had implications in rural areas. This thesis has shown that changes in rural land use have had measurable effects in such environments in terms of local climate. Mean monthly temperatures have been altered by changing vegetal canopies and the full scale of impact is not fully understood, as yet. The demands placed on the rural environment will continue as long as the human population continues to grow. As rural land accounts for the majority of the earth's land area, it is essential to understand the impacts resulting from human activities in such environments.

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APPENDIXES

APPENDIX A

CLIMATIC REPORTING STATIONS

FOR THE CROSS TIMBERS

Station Name	Longitude (degree, min.)	Latitude (degree,min.)	Elevation (in feet)	Station Location	
				Geographic Description	Topographic Description
Bristow	96 24'W	35 50'N	823	west part of town	upslope, margin of floodplain
Chandler	96 53'W	35 42'N	953	southwest of town	floodplain environment
Cushing	96 46'W	35 59'N	950	west part of town	upslope environment
Holdenville	96 23'W	35 05'N	860	northwest part of town	upslope, margin of floodplain
Meeker	96 54'W	35 30'N	925	west part of town	hillside
Okemah	96 18'W	35 26'N	935	west part of town	hillside
Seminole	96 40'W	35 14'N	865	east part of town	floodplain
Stillwater	97 05'W	36 07'N	895	west part of town	margin of floodplain

Sources: Bristow Quadrangle, 1978; Chandler Quadrangle, 1978; Cushing Quadrangle, 1978; Holdenville Quadrangle, 1978; Meeker Quadrangle, 1978; Okemah Quadrangle, 1978; Seminole Quadrangle, 1978; and Stillwater Quadrangle, 1978

APPENDIX B

POPULATIONS NEAR REPORTING STATIONS

County	City/Town	Population
Creek		59,210
	Bristow	4,702
Hughes		14,338
	Holdenville	5,469
Lincoln		26,601
	Chandler	2,926
	Meeker	1,032
Okfuskee		11,125
	Okemah	3,381
Payne		62,435
	Cushing	7,720
	Stillwater	38,268
Seminole		14,338
	Seminole	8,590

Source: Rand McNally Road Atlas 1986

APPENDIX C

LAND IN FARMS PROPORTION OF

TOTAL LAND AREA

Year	Creek	Hughes	Lincoln	Okfuskee	Payne	Seminole
1945	74.6%	68.5%	85.0%	91.5%	86.9%	70.8%
1949	64.2%	69.4%	80.7%	77.3%	79.9%	70.3%
1954	62.2%	68.0%	77.9%	75.2%	80.8%	69.0%
1959	59.6%	72.9%	78.9%	65.7%	84.1%	65.1%
1964	70.2%	79.4%	79.7%	73.4%	90.3%	74.6%
1969	63.3%	84.7%	75.8%	73.8%	78.0%	69.0%
1974	53.8%	65.3%	67.3%	68.3%	69.6%	60.2%
1978	53.4%	68.3%	65.9%	69.6%	71.5%	64.6%
1982	54.8%	65.6%	65.5%	66.8%	69.0%	62.7%
1987	47.0%	63.7%	62.7%	68.5%	71.1%	62.7%

Source: U.S. Census of Agriculture, 1945-1987

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