CHANGING STRUCTURE OF RURAL LAND USE IN NORTHWESTERN KANSAS

by

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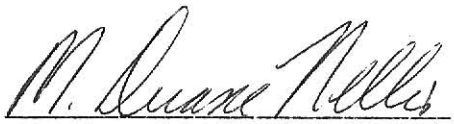

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CHAPTER 1

INTRODUCTION

From prairie to wheat field, the historical transformation of the state of Kansas has been dramatic in that today about 95 percent of the land in Kansas is devoted to agricultural uses (Water and Power Resources Project, 1981). The contributions to this transformation have been based on many factors, e.g., new grain varieties, irrigation, and other resource converting techniques.

In Northwestern Kansas, (Figure 1.1) as in most of Kansas, the structure of land use and its intensification has been strongly influenced by irrigation, especially since 1950. The estimated total area available for irrigation in Northwestern Kansas, for example, has increased from 147,980 acres in 1964 (Center for Public Affairs, 1970) to 678,279 acres in 1982 (Cooperative Extension Service, 1982).

Land Use Change

Irrigation (primarily by diversion from streams) has been practiced in Northwestern Kansas for a long time. Since World War II, however, the primary source of the water for an expanding irrigated area has been the Ogallala aquifer. Associated with the increase in irrigation is the decrease of available groundwater. This is due to the noncompatibility of rates of withdrawal and recharge within the Ogallala aquifer. For example, in Groundwater Management District No. 4 (centered on Sherman and Thomas Counties) in 1975, the total irrigated area of 434,000 acres

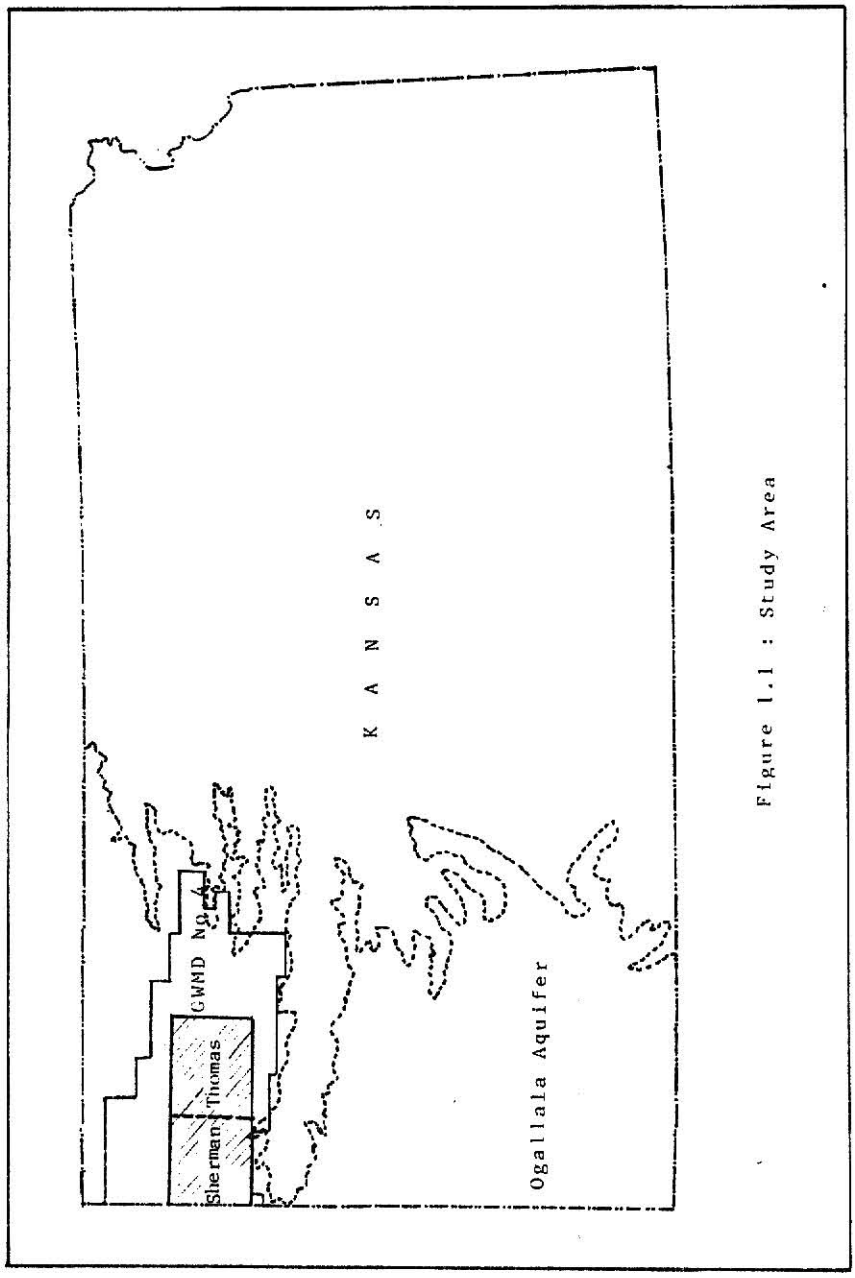


Figure 1.1 : Study Area

used 763,000 acre-feet of groundwater while the amount of water recharge was 111,000 acre-feet (Kansas Agricultural Experiment Station, 1980).

In response to the water depletion problem and associated agricultural land use trends in Northwestern Kansas (as well as other areas of the state), the legislature adopted the Groundwater Management District Act (1972). The Act made possible the formation of regionally controlled groundwater management units with the authority to develop comprehensive management plans. The policies implemented by the districts were to provide for the orderly development of the Ogallala water reserves in order to extend the life of available water supplies. Each district was to be formed at the initiation of water users and land owners in an area that would prepare management plans tailored to fit area needs. Among the management tools available to the districts were control on the spacing of well, tailwater control, well construction criteria, metering of water use, monitoring of water quality, promotion of water conservation, and modification of weather.

During this same period, energy prices and trends, crop prices, and other factors associated with irrigation development also contributed to changes in land use. Cost of energy used to pump water, for example, has contributed significantly to land use decisions. Irrigation is an energy intensive agricultural process. It is estimated that two to three times the energy is required to grow a crop in irrigated land as opposed to dryland (Schmidt, 1977). With the increasing energy costs, farmers are faced with the need for serious assessment of the economics of irrigation agriculture.

Due to the human-environmental occurrances and trends (groundwater depletion, state regulations, and the increase of energy prices, as well

as other factors such as crop prices), land use for cropland as well as the pattern of dryland and irrigated farming are changing.

Problem Statement

The last 10 years (1972-1982) has been the period of the most dramatic increases in irrigated land in Western Kansas (U.S. Department of Commerce, 1981, Crop and Livestock Reporting Service, 1977-80). But, it is believed by this researcher that in the last two to three years, with problems associated with groundwater depletion, state regulations, increasing costs of energy and equipment, and crop prices, that the trends in land use (in Northwestern Kansas), including land reversion to dryland cropping, are beginning to change. Therefore, it was the purpose of this study to examine changes in land use that have occurred in Sherman and Thomas Counties over the past 10 year period (1972-1982). In addition, the study will attempt to draw some conclusions about possible reasons for the changing land use structure e.g., energy costs, crop price changes, groundwater depletion, GWMD (Groundwater Management District) policy changes and all other factors that can be isolated.

Study Area

The study area is Sherman and Thomas Counties in Groundwater Management District No. 4 (GWMD No. 4) in Northwestern Kansas (Figure 1.1). GWMD No. 4 covers all or parts of 9 counties which overlie the Ogallala aquifer. The total area is about 5,795,264 acres. Sherman and Thomas Counties are the most intensively developed irrigated counties within the district. Land use in Sherman and Thomas Counties has historically been agricultural. In 1979, there were 650,946 acres and

681,886 acres of land in farms in Sherman and Thomas Counties respectively (U.S. Department of Commerce, 1981). A detailed look at the study area is included in Chapter 2.

Justification

This study fits within the Man-Land Tradition (Pattison, 1963). In recent years, geographers such as Furuseth, Lee, and Evans and Cant have provided examples of the growing research effort in land use change analysis (Furuseth, 1979, Lee, 1979, Evans and Cant, 1981). This study will build on these past studies by examining changing land use structure (from pasture land to croplands and from irrigated land to non-irrigated land and vice versa). In addition, insights into possible factors that may have influenced the changes in use will be provided. The study will provide the policy maker with a base of needed information to determine the effectiveness of current land use policies in the area. The study will also support land use managers with information on land use change in an area of increasing water resource stress.

Literature Review

Studying various aspects of the human-land system and the related land use change characteristics has been a focus for a number of researchers in recent years. Three central themes related to this study are presented in the literature: factors affecting rural land use decisions, dryland versus irrigated rural land use systems, and the role of remote sensing in studying rural land use changes. Geographers have played a significant role in each of these themes.

Studies by Grigg (1983), Cromley (1982), De Garis De Lisle (1982), and McKnight (1983) illustrate the first of these themes: factors affecting rural land use decisions. Grigg's article emphasizes that both physical and social-economic factors influence agricultural development. His examples of physical factors which influence rural land use are climate and location. He also discusses how the availability of food processing industries, commercial businesses, and other socio-economic factors influence rural land use.

Cromley (1982) indicates that the pattern of agricultural land use varies according to the goals and corresponding behavior modes of farmers. Cromley suggests that management decision theory can assist farmers in attaining their goals by providing a calculus for improving decisions made in an unpredictable environment.

In Canada, De Garis De Lisle (1982) reveals that distance is one of several factors that affect the cropping pattern internal to the farm. De Garis De Lisle suggests that social and technological factors have encouraged farmers to grow intensively cultivated grains on the outfields.

A study by McKnight (1983) examines the use of center pivot irrigation in California and assesses reasons for center pivot failure. McKnight concludes that center pivot is not well suited to the environmental contiditons of the Central Valley.

The second theme, dryland versus irrigated rural land use systems, is presented in a study by Evans and Cant (1981). The study reveals the success of dryland farming as compared to irrigated farming in New Zealand. In this instance, more monetary success was derived from dryland as compared with irrigated farming. Irrigation required more capital outlay and technology for irrigating while dryland needed less capital, and the farming system was already well known.

Wiese and Unger (1983) illustrate another example of this second theme. This research presents new insights where methods of combining limited irrigation, dryland farming, and limited tillage led to a profitable conservation farming system. The practices contribute greatly to the economic stability of dryland crop production, consistent yield (minimizing the number of crop failures), and the profitability (efficiency) of production. In addition, this method greatly reduces the threat of soil erosion by wind and water.

The last theme contributing to a background for this study and illustrated here is the role of remote sensing in studying rural land use changes. Studies by Campbell (1983), Estes et. al. (1982), Furuseth (1979), and Lee (1979) provide examples of this theme.

Campbell (1983) explains how land use change maps are prepared and how they are used in studying land use changes. Campbell emphasizes the importance of low level aerial photography which provides the capability to reconstruct previous land use patterns.

Estes et. al. (1982) stress that the ability to accurately detect changes in land use/land cover patterns is central to the use of remotely sensed data for planning and resource management purposes. Estes points out, however, that there is no technique using Landsat data and digital processing techniques that can be used consistently to detect total land use/land cover change in a given area with a high degree of accuracy (greater than 85 percent) for all standard classification categories.

Furuseth (1979) studied the characteristics and type of agricultural land undergoing transformation to urban uses in Washington County, Oregon. He used aerial photographs in examining the study area for evidence of agricultural land conversion. Lee (1979) used data from satellite imagery to inventory new cropland development in the Great Plains and Southeastern U.S. between 1972 and 1976. Lee examined the conversion of rangeland to irrigated and non-irrigated cropland, and cropland to irrigated cropland for the Great Plains. For the Southeastern region Lee examined the amount of forestland cleared.

Although these studies contribute significantly to background for this research, this study attempts to tie all of these themes together. Thus, the results of this research effect will not only examine factors affecting rural land use decisions, but also contribute to the understanding of advantages of dryland versus irrigated cropland, and remote sensing approaches to land use change analysis.

Data Acquisition and Analysis

In collecting data and information for this study, various procedures were used in order to meet the purpose of the research. The land use data and information were obtained from a search of published

materials, low and high altitude aerial photography, field observation, and questionnaires.

Published Materials

Reports obtained through library research and from correspondence with specific state agencies provided an important part of the data base for this study. Key agencies and departments that cooperated in providing detailed information about land use in Northwestern Kansas include: The Kansas Crop and Livestock Reporting Service, The Kansas State Board of Agriculture, Groundwater Management District No.4, Colby, The Water Resource Research Institute, KSU (Kansas State University), The Division of Water Resources, Kansas State Board of Agriculture, The Cooperative Extension Service, KSU, The Department of Agricultural Engineering, KSU, and The High Plains Underground Water Conservation District No. 1, Lubbock, Texas.

Kansas Crop and Livestock Reporting Service provided informative data from 1972 to 1982 on number of farms, land in farms, farm values, and wheat, corn and sorghum statistics by cropping practices. Details of the major crops included acres planted, acres harvested, yield per acre, and production (both for irrigated and non-irrigated land). Concerning the irrigated area, this agency also provided total acres of wheat, corn, and sorghum. Energy prices of diesel, gasoline, and L.P. gas were also received from this agency.

Groundwater Management District No. 4 provided information on their Management Programs (from the inception to the present program), along with the information on energy prices, and the rate of recharge of the Ogallala aquifer in GWMD No.4.

The Water Resource Research Institute, KSU, was the source of information about Ogallala Aquifer Studies which related to this study, and also included some information of Water Law in Kansas.

The Division of Water Resource - Kansas State Board of Agriculture, also provided information on GWMD No. 4's Management Programs, amount of water use in 1981 and 1982, and publications on water-level changes in Northwestern Kansas, 1950-1976.

Data and information recieved from KSU Cooperative Extension Service included pamphlets on water resources and supplies, irrigation wells, irrigation tailwater management systems, sprinkler irrigation, water measurement, and irrigated crops.

The Department of Agricultural Engineering provided information from the 1978 to 1982 Kansas Irrigation Survey, which included irrigation systems data, number of wells, units of energy used, and number of farmers irrigating.

The High Plains Underground Water Conservation District No. 1, Lubbock, Texas, provided the map of the Ogallala aquifer and comparative information on the Ogallala aquifer in Texas.

Questionnaire Design and Administration

Two questionnaires were used to evaluate the awareness and the ideas of farmers and officials on the change of crop acreage and associated land use structure change in relation to water depletion, crop prices, energy costs, and the enforcement of water laws. Fifteen questions were prepared for farmers in Sherman and Thomas Counties (see Appendix A). Part of the questionnaire responses provided information on: type of farming unit, total area in farms, type of irrigation system,

and the perception of respondents toward Kansas water laws at the state and local level. In addition, responses provided information on awareness and ideas on the change of crop acreage in relation to water depletion, crop price, energy costs, etc. The questionnaire designed for the officials was basically the same as for the farmers but excluded farm characteristic information. The questionnaires were sent randomly to 60 farmers in Sherman and Thomas Counties and four officials specifically involved in making decisions that influence land use.

Remote Sensing Techniques

Remote sensing techniques used in this study included aerial photographs and high altitude film positives. Black and white aerial photos were only available in the study area for 1976 and 1980 of Sherman County and for 1976 of Thomas County through the U.S. Aerial Photography Field Office in Salt Lake City. All photographs were taken in September. Photos were contact prints with a 10''x10'' format and scale of 1:60,000. Color film positives covering the study area were taken from a high altitude on May 13, 1974, and were provided by the EROS Data Center in Sioux Falls, South Dakota. The film positive characteristics included 9''x9'' format, 0% cloud cover, and excellent quality. The scale of the high altitude imagery was 1:122,000 and 1:123,000 for Sherman and Thomas Counties respectively.

In interpreting both the black and white photos and color film positives the basic characteristics considered included: shape, size, pattern, tone, texture, site or location, and shadow (Lillesand and Kiefer, 1979). The information derived from the aerial photos for this study related to cropland and pasture land. The most important

characteristics used in this interpretation were texture and tone. The texture distinguished cropland from pasture land because cropland has a fine, even texture while pasture land has a rough and usually mottled appearance. Tone or hue were extremely important criteria for interpreting land use in the rural area although the gray tones reproduced on black and white photographs did not always correspond to the researcher's perceptions of the objects in nature. In this study, cropland tone ranged from black to light gray, and pasture land had medium photo tone.

The problem with the aerial photos used in this study was the late date. They were taken in September, not during the mid-growing season. While this created some difficulties in distinguishing cropland from pasture land, it most significantly limited the researcher from gathering specific crop data from the photography. Film positives were easier to interpret than black and white photos because it was easier to judge the differences between color tones than between shades of gray.

Land use maps for 1974, 1976, and 1980 of Sherman County and land use maps for 1974 and 1976 of Thomas County were made after the interpretation. Preparation of a land use map from aerial imagery is essentially a process of segmenting the image into a mosaic of parcels, with each parcel assigned to a land use class. The classification system must be simultaneously compatible with the needs of the map users and consistent with image detail and map scale. Maps created from the aerial images can be considered as original information in the sense that they are generated by first hand examination of direct evidence of the land use patterns, rather than by compilation from a secondary source (Campbell, 1983).

Land use change maps were prepared by comparing the land use maps developed using remote sensing. This process required comparison of two separate land use maps on two dates. In this study, two land use change maps of Sherman County (land use change from 1974 to 1976 and land use change from 1976 to 1980) and one of Thomas County (land use change from 1974 to 1976) were made. Areas where changes occurred were recorded on a third map. Land use change maps show only the changed area. Changes in acreage were computed by using an acreage computer grid system. The formula used to determine the area per grid cell on the acreage computer grid is:

$$\text{area} = \frac{16 \times \text{No. of dots}}{(\text{scale in inches per mile})^2}$$

After interpretation of land use and change, ground truthing was performed in the study area. This procedure was necessary in order to aid in the interpretation process. Ground truthing was somewhat limited because of probable changes in the land use pattern between the ground truth and recording of the photos. It was found, however, that there were still enough field patterns similar to the 1983 ground truth data to develop interpretation signatures on the aerial photography.

A two-day trip for ground truthing was made in the study area. The major purpose of ground truthing was to observe the physical and cultural conditions of the area, to check the pattern of land use, and to collect data on land use, crop types, farming patterns, and irrigation systems. A frontal traverse land use sampling technique was used to compile this information. The traverse method allowed for estimated 1983 data on cropland and pasture land, as well as crop types, farming patterns and irrigation systems.

Analytical Procedure

The acreage change in land use derived from census reports and the acreage change in the case study area (derived from aerial photography) were portrayed in tabular and map form for analysis. Pre-conversion and post-conversion land use and the continuity of converted parcels were determined by the land use change map. The impacts of changed were examined in relationship to physical characteristics and the dynamics of other variables, e.g., crop prices, energy costs, and laws and regulations.

REFERENCES

1. Anderson, James R. et al. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, Geological Survey Professional Paper 964. U.S. Government Printing Office, Washington D.C.

2. Bossert, Wayne A., 1983. Information on groundwater withdrawal, recharge rate, number of wells, irrigation and energy (Written Communication).

3. Campbell, James B., 1983. Mapping the Land: Aerial Imagery for Land Use Information, Resource Publication in Geography, Commerical Printing Inc. State College, Pennsylvania.

4. Center for Public Affairs, the University of Kansas, 1970-1981. Kansas Statistical Abstract. Lawrence, Kansas.

5. Cooperative Extension Service, 1983. ''1982 Kansas Irrigation Survey''. Engineering Newsletter, KSU, Manhattan, Kansas.

6. Cromley, Robert C., 1982. ''The Von Thünen model and environmental uncertainty''. Annals of the Association of American Geographer, Vol 72, 3: pp. 404-10.

7. Estes, John E., et al., 1982. ''Monitoring land use and land cover changes''. In Remote Sensing for Resource Management, ed. J. Johannsen and James L. Sanders, pp. 100-10. Soil Conservation Society of America.

8. Evans, Marry and Cant, Gart, Oct. 1981. ''The effect of irrigation on farm production and rural settlement in mid-Canterbury: a comparison of the irrigated and dryland farming zones in the Lyndhurst-Pendarues area, 1945-1976. New Zealand Geographer, Vol 37, 2:58-65.

9. Furuseth, Owen J., May-June 1979. ''The Structure of agricultural land conversion in Washington County''. Journal of Soil and Water Conservation, Vol. 34, 3: pp 138-141.

10. De Garis De Lisle, D., 1982. ''Effects of distance on croppong patterns internal to the farm''. Annals of the Association of American Geographers, Vol. 72,: pp. 88-98.

11. Grigg, David, 1983. ''Agricultural geography''. Progress in Human Geography, Vol 7, 2: pp. 255-60.

12. Kansas Agricultural Experiment Station, Aug. 1980. The Colby Branch Experiment Station and Agriculture in Northwestern Kansas with Special Mention of Soils, Bul. 636, KSU, Manhattan, Kansas.

13. Lee, Linda K., 1979. ''Interpreting land use change through satellite imagery''. Agricultural Economic Report No. 422, U.S. Department of Agriculture: pp. 1-18.

14. Lillesand, Thomas M. and Kiefer, Ralph W., 1979. Remote Sensing and Image Interpretation, John Wiley and Sons.

15. McKnight, Tom L., Jan. 1983. ''Center pivot irrigation in California''. The Geographical Review, Vol. 73, 1:1-14.

16. Pattison, William D., 1971. ''The Four Traditions of Geography''. Geographical Research and Writing, by Robert W. Dunenberger, Crowell, N.Y.

17. Schmidt, Glen M., 1977. Energy Use in Irrigation in Kansas: a Computer Simulation, KSU, Manhattan, Kansas.

18. U.S. Department of Commerce, 1981. 1978 Census of Agriculture, Vol 1. State and County Data, Part 16, Kansas. AC 78-A-16: pp 657,686.

19. Water and Power Resource Service Project, 1981. Kansas, U.S. Department of Interior: pp.3

20. Wiese, Allen F., and Unger, Paul W., May-June 1983. ''Irrigation + dryland farming + limited tillage: a profitable combination''. Journal of Soil and Water Conservation, Vol 38, No. 3, The Soil Conservation Society of America. pp: 233-236.

CHAPTER 2

BACKGROUND OF THE STUDY AREA

The focus of this study is Sherman and Thomas Counties in Northwestern Kansas (Figure 1.1 in Chapter 1). Topography, climate, soils, and groundwater are four major components of the natural environment which influence land capability and irrigation suitability in Northwestern Kansas. These natural characteristics influence irrigation water management strategies and the resulting institutional setting which also play an important role in the conditions that are either favorable or limiting to crop production.

Topography

Topography can influence whether or not land is irrigated, the location and capability of irrigation pumps, and the potential of surface drainage. However, in Sherman and Thomas Counties topography is not a restriction. The average elevation of Sherman County is 3,700 feet above sea level. In Thomas County elevation ranges from 3,475 feet above sea level in the west-central part to 2,850 feet in the north-western part along Prairie Dog Creek (U.S. Department of Agriculture, 1973, 1980). Change in elevation is 625 feet and slope characteristics are quite gradual.

Climate

Sherman and Thomas Counties have a typical continental climate characterized by low annual precipitation, warm to hot summers, cold

winters, moderate to strong surface winds and wide daily and annual variation in temperature. The average annual temperature and precipitation in Sherman County, according to the survey made at Goodland from 1972 to 1980, were 51.09°Farenheit and 18.96 inches, respectively. Thomas County had an average annual temperature of 50.18°Farenheit and average precipitation of 20.09 inches (U.S. Department of Commerce 1972-1982). The important component restricting agriculture, however, is that daily and annual temperatures vary greatly because of the elevation, the low humidity and the continental location.

Evaporation is high in the study area. For example, from 1966 through 1978, pan evaporation at Colby in Thomas County averaged 64.4 inches each year during the six months from April through September. That amount is more than four times the rainfall generally received within that period (Kansas Agricultural Experiment Station, 1980). Occasionally in Sherman County, heavy and dashing rains from thunderstorms wash out newly seeded crops and cause considerable erosion in cultivated fields. Damaging hail storms are more frequent in Sherman County than in counties farther to the east in Kansas. Hail that falls during severe thunderstorms is also damaging to crops in Thomas County. It frequently falls just prior to harvest, when the wheat crop is most vulnerable. Although these storms are local in extent, they occur frequently enough to be a major risk in the study area.

Snowfall in Sherman County is the heaviest in Kansas. The annual snowfall at Goodland averages 32 inches with most occurring during the period from December through March. The water equivalent to snow is important in the production of winter wheat. In Thomas County the average snowfall is 28 inches.

In Sherman County, winds are moderate to strong in all seasons. The windiest period is March and April, when the average windspeed exceeds 14 miles per hour. The prevailing wind is southerly during the period from April through October and is westerly-southwesterly or northwesterly in other months. The prevailing wind in Thomas County is from the southwest. The average windspeed is highest (15 miles per hour) in March.

Soils

Soil series in the study area mainly consists of Keith, Ulysses, Colby and Goshen soils. Sherman County is dominated by a deep well-drained silt loam on uplands, terraces, flood plains, and in swales. Thomas County is predominately silt loams and silty clay loams on uplands.

In Sherman County, soils can be classified into three associations (Table 2.1 and Figure 2.1). Soils in Thomas County can be classified into two associations (Table 2.2 and Figure 2.2). The suitability of these associations suggest that most of the land in the study area is well suited to either dryland or irrigated cropland use.

Grounndwater

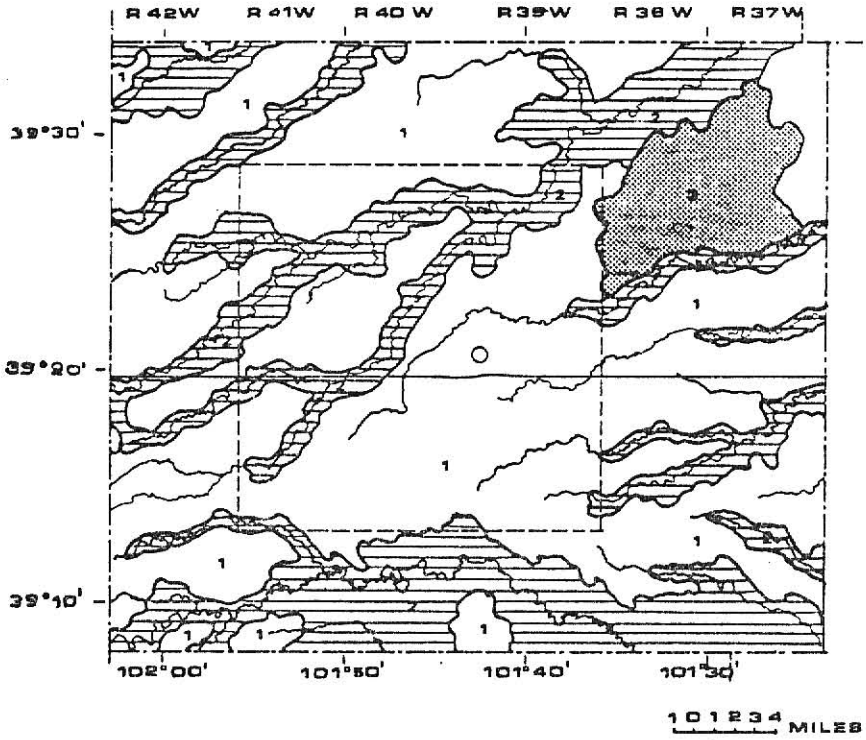
Groundwater has had a significant impact on the characteristics of land use in the area (because of negligible surface water sources). The primary groundwater source in the study area is the Ogallala aquifer, the largest and most heavily developed aquifer in the world (Fund and Clement, 1982). The aquifer underlies about 225 thousand square miles in six states, extending from South Dakota to Nebraska, Colorado, Kansas

Table 2.1: Soil Association in Sherman County

	1. Keith-Ulysses	2. Ulysses-Colby-Goshen	3. Keith-Ulysses-Goshen
Soil Characteristics	Deep, well-drained, nearly level andgently sloping silt loams on uplands	Deep, well-drained, nearly level to strongly sloping silt loams on uplands, terraces, and flood plains.	Deep, well-drained, nearly level to sloping silt loams on uplands and in swaler.
% of soils in the county	62%	32%	6%
% of soils' components	62% Keith soils, 35% Ulysses soils and 3% minor soils(Richfield, Goshen, and Pleasant soils)	50% Ulysses soils, 30% Colby soils, 9% Goshen soils, and 11% minor soils(Bridgeport, Roxbury, and Caruso soils)	37% Keith soils, 35% Ulysses soils, 15% Goshen soils, 13% minor soils(Colby and Pleasant soils)
Layer of Primary soils	The surface layer is grayish brown silt loam about 6 inches thick. The subsoil is about 31 inches thick. It is grayish-brown, firm silty clay loam in the upper part and light brownish-gray, friable silt loam in the lower part.	The surface layer is grayish brown silt loam about 11 inches thick. Below this is light brownish-gray silt loam about 5 inches thick. The underlying material is light-gray silt loam.	The surface layer is grayish brown silt loam about 16 inches thick. The subsoil is about 31 inches thick. It is grayish-brown, firm silty clay loam in the upper part and light-brownish gray, friable silt loam in the lower part. The underlying is very pale brown silt loam.

Table 2.1 (contd)

Layer of secondary soils	The surface layer is grayish-brown silt loam about 11 inches thick. The next layer is light brownish-gray silt loam about 5 inches thick. The underlying material is light-gray silt loam.	The surface layer is dark grayish-brown silt loam about 4 inches thick. The next layer is pale-brown silt loam 8 inches thick. The underlying material is very pale brown silt loam.	The surface layer is grayish brown silt loam about 11 inches thick. Below this is 5 inches of light brownish-gray silt loam. The underlying material is light gray silt loam.
Layer of tertiary soils		The surface layer is about 13 inches thick. It is grayish-brown silt loam in the upper part and dark-gray silt loam in the lower part. The subsoil is about 42 inches thick. It is gray silt loam in the upper part and grayish-brown siltly clay loam to light brownish-gray silt loam in the lower part. The underlying material is very pale brown silt loam	The surface layer is about 13 inches thick. It is grayish-brown silt loam in the upper part and dark-gray silt loam in the lower part. The subsoil is about 42 inches thick. It is gray silt loam in the upper part and grayish-brown siltly clay loam to light brownish-gray silt loam in the lower part. The underlying material is very pale brown silt loam.
Suitability for Land Use	Well suited to all the dryland and irrigated crops.	Most of this association is in native range.	Most of this association is cultivated and is well suited to all dryland and irrigated crops.

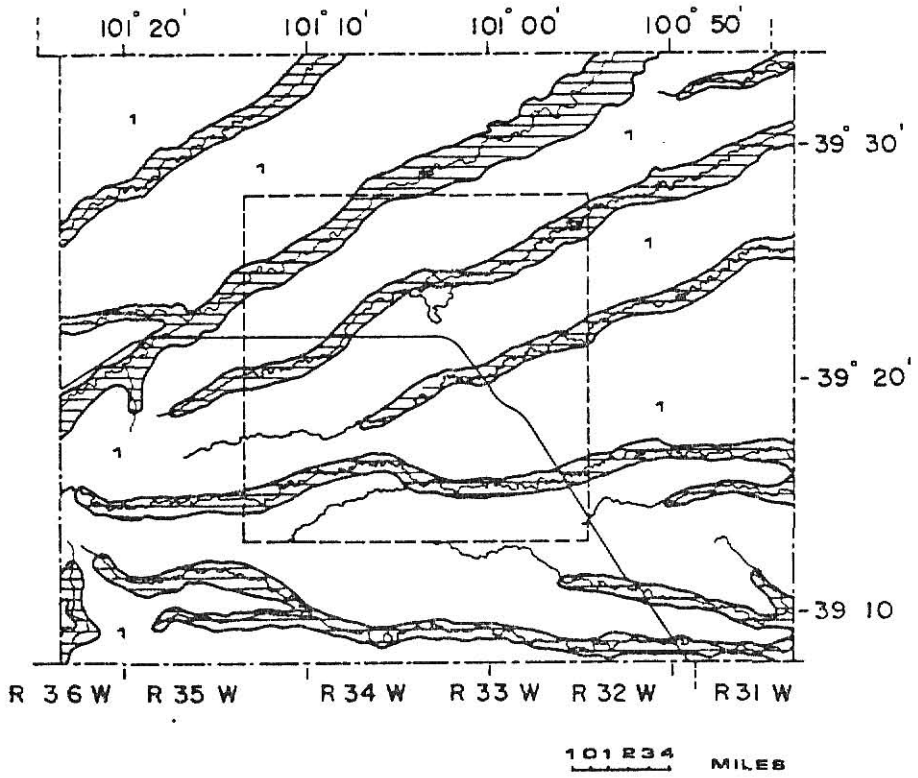


Source : U.S.Department of Agriculture, 1973. Soil Survey of Sherman County.

Figure 2.1 : Soil Associations in Sherman County

Table 2.2: Soil Associations in Thomas County

	1. Keith-Ulysses	2. Ulysses-Colby
Soil Characteristics	Nearly level and gently sloping soils that have a silt loam and silty clay loam subsoil; on upland	Moderately sloping and strongly sloping soils that have a silt loam subsoil; on uplands.
% of soils in the county	82%	18%
% of soils' components	77% Keith soils, 17% Ulysses soils and 6% minor soils (flood coshen soils, Pleasant soils, and Richfield soils)	51% Ulysses soils, 31% Colby soils and 12% minor soils (Bridgeport, Hord, Roxbury and Schambur soils)
Layer of primary soil	The surface layer is dark grayish brown, friable silt loam about 11 inches thick. The subsoil is about 20 inches thick. The upper part is grayish brown, friable silty clay loam, and the lower part is light brownish gray, friable silt loam.	The surface layer is dark grayish brown silt loam about 7 inches thick. The subsoil is grayish brown, friable, calcareous silt loam about 7 inches thick.
Layer of secondary soils	The surface layer is dark grayish brown silt loam about 7 inches thick. The subsoil is friable silt loam about 10 inches thick. The upper part is dark grayish brown, and the lower part is pale brown.	The surface is grayish brown, calcareous silt loam about 4 inches thick. The next 4 inches is pale brown, very friable, calcareous silt loam.
Suitability for land use	The major soils have good potential for cultivated crops, range and windbreak. They have fair to good potential for cropland and rangeland wildlife habitat.	The major soils have good potential for range and windbreaks. They have fair to good potential for cultivated crops and for openland and rangeland wildlife habitat.



Source : U.S.Department of Agriculture, 1980. Soil Survey of Thomas County.

Figure 2.2 : Soil Associations in Thomas County

Oklahoma, Texas, and New Mexico. This groundwater region is a very sizeable remnant of a gigantic alluvial apron formed in late Tertiary time, it formerly extended uninterrupted from the foot of the Rockies to an unknown terminus, probably some hundreds of miles east of its present edge. The alluvium was deposited on the eroded, eastward sloping surface of a thick body of stratified sandstone, shale, and limestone of the Paleozoic, Mesozoic, and Tertiary ages (Walton, 1970).

Unconsolidated sediments containing beds of sand and gravel underlie the region, essentially the area of the High Plains, to considerable depth. Groundwater is also found in consolidated sedimentary rocks, in stream channels or terrace deposits, and in glacial drifts (Walton, 1970, and Fetter, 1980).

The natural recharge of the Ogallala aquifer is restricted, due to low rainfall and thick overburden material (except where there are sand dunes). Thus, groundwater is being depleted and water-table levels are declining in many areas (Bouwer, 1978).

In western Kansas, water enters the Ogallala in three manners: by infiltration from precipitation on the area, by inflow of groundwater from Colorado, and by seepage losses from some of the streams that cross the area. Water is discharged from the Ogallala by some streams that are natural drains of the aquifer, by evapotranspiration, where the aquifer is exposed along streams, and by wells (Pabst, 1976).

The water level in wells is not stationary, but fluctuates in accordance with the rate of discharge and the rate of replenishment of the groundwater reservoir. Under natural conditions over a long period of time, and approximate equilibrium exists. Thus, the water level rises when recharge exceeds discharge and declines when discharge exceeds

recharge. Therefore, water-level changes in wells indicate whether the groundwater reservoir is being replenished or depleted (Brocker, 1977).

The depth of water to the aquifer in Northwestern Kansas is more than 200 feet in parts of Cheyenne and Rawlins Counties, but it ranges from 100 to 200 feet in almost all of the upland areas. The well yield shows larger variation in the western region because of the difference in saturated thickness of the aquifer, the permeability of the water-bearing sand, depth of water in the well while pumping, radius of cone of depression, and radius of the well. Most of the region in Northwestern Kansas has well yields of 500-1,000 gpm(gallons per minute) (Buller, 1982). Sherman County has 70 percent of its area overlying the aquifer, or 396,159 acres has the potential well yield of 500-1,000 gpm. In Thomas County 65 percent of the area overlying the aquifer or 408,303 acres has a well yield of 500-1,000 gpm (Table 2.3)

TABLE 2.3 Percent and Acreage of Land Overlying Aquifer with Potential Well Yield.

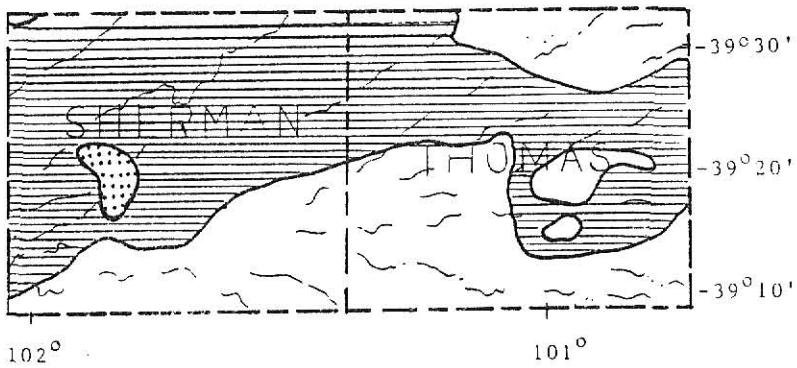
County	Gpm			Total acres	Gpm		
	100-500	500-1000	1000+		100-500	500-1000	1000-more
Sherman Co.	6	70	24	567,681	34,410	396,159	137,112
Thomas Co.	32	65	3	625,718	197,420	408,303	19,995

Source: Kansas Water Resource Board, 1967. Irrigation in Kansas, Topeka

In Northwestern Kansas the average saturated thickness was reduced by 45 feet between 1950 and 1977, which is an annual rate of 1.67 feet per year. In 1977 the saturated thickness was 96 feet and it is

projected to decline to 75 feet in 2020 or 0.5 feet per year (Kansas Water Office, 1982).

In considering the average saturated thickness in Sherman and Thomas Counties, hydrologic data reported by the U.S. Geological Survey were used. From the hydrologic data of 86 observation wells made in Sherman County, it is shown that the average saturated thickness of about 141-180 feet in 1950 decreased to 101-160 feet in 1980 and 1982. In Thomas County, from the hydrologic data of 68 observation wells, it is shown that the average saturated thickness which ranged from 100-160 feet in 1950, decreased to 60-140 in 1980 and 1981 (Figure 2.3).



0 - 100
100 - 200
200 - 400

Saturated Thickness, in feet

Source : "Saturated Thickness of High Plains Aquifer-1980", published in The Cross Section, Vol.27, No.6, June, 1981.

Figure 2.3 : Saturated Thickness of The Ogallala Aquifer in the Study Area

With improved irrigation technology following World War II and the discovery of plentiful supplies of natural gas, groundwater from the Ogallala was pumped to irrigated corn and other heavy water consumption crops not previously grown in the semi-arid climate. As a result, water is being removed more rapidly than the rate of replenishment. The obvious sign beyond the decrease in saturated thickness, is a declining water table or depth to water. In Northwestern Kansas the average annual decline for the 11-year period of 1966-1977 was 0.8 feet (Kansas State Board of Agriculture, 1978) or 0.6 feet for the 16 year period from 1966 to 1981 (U.S. Geological Survey, 1982). In 1980 the water levels declined an average of about 1,5 feet. This represented about a 0.5 foot increase over the 1979 decline, when average water levels dropped about one foot. The continued decline during 1980 probably can be attributed to below normal precipitation and increased irrigation pumpage during the period (Kansas State Board of Agriculture, 1980).

In looking at average depth to water in Sherman and Thomas County, detailed changes can be considered. In Sherman County, the average depth to water in 1950 was 124 feet, and in 1966, 128 feet. It was a 4 foot water level change in the 16 year period or .25 feet change per year. In 1979-1981, the average depth to water was 146 feet, and in 1982 the highest peak of average depth to water was 151 feet. Thomas County had an average depth to water of 116 feet in 1950 and 117 feet in 1966. There was a 1 foot water level change in the 16-year period of 0.6 feet change per year. Since 1976, when the water level was 119 feet, the water level decreased to 128 feet in 1982.

The number of wells and total water use in the study area have been reported in GWMD No.4's Management Programs, the Water Resource Board's

Irrigation in Kansas, the Water Resource Division's record, and Darling's Earning Attributable to the Differential Yields from Irrigated Crops. In Sherman County the number of wells increased from 785 in 1977 to 937 in 1980 and decreased to 928 in 1982 (Table 2.4 and Figure 2.4). The County had an average depth to water of 116 feet in 1950 and 117 feet in 1966.

Table 2.4: No. of Wells and Total Water Use.

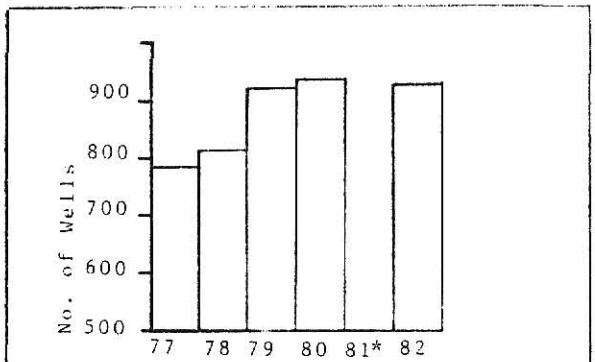
Year	Sherman County		Thomas County	
	No. of Wells	Total Water Use(AF)	No. of Wells	Total Water Use(AF)
1960		20,900		13,300
1966		83,600		30,600
1972		180,529		113,229
1973		196,388		133,066
1974		212,608		150,358
1975		226,476		167,989
1976		234,380		167,862
1977	785	237,207	700	168,220
1978	810		760	
1979	924		851	
1980	937		855	
1981		146,555		111,257
1982	928		827	

Source: GWMD No.4, Management Programs, 1977-1983.

Water Resource Board, 1967, Irrigation in Kansas, Report No.16(e), Topeka.

Water Resource Division, 1983.(Writing communication)

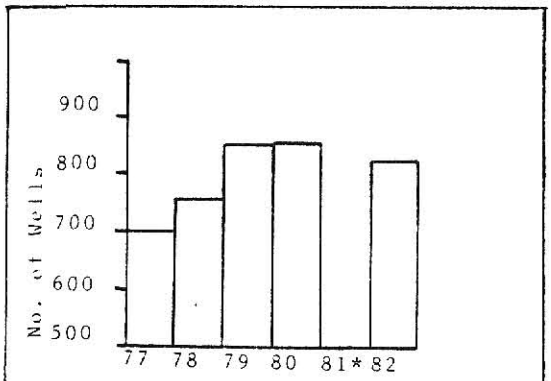
Darling, David D., 1979. Earning Attributable to the Differential Yields from Irrigated Crops, Bulletin 24, Kansas Water Resources Board.



Source : GWMD No.4,1977-1983.

Figure 2.4 : No. of Wells in Sherman County

The number of wells in Thomas County was 700 feet in 1977, 855 feet in 1980, and decreased in 827 in 1982 (Table 2.4 and Figure 2.5).

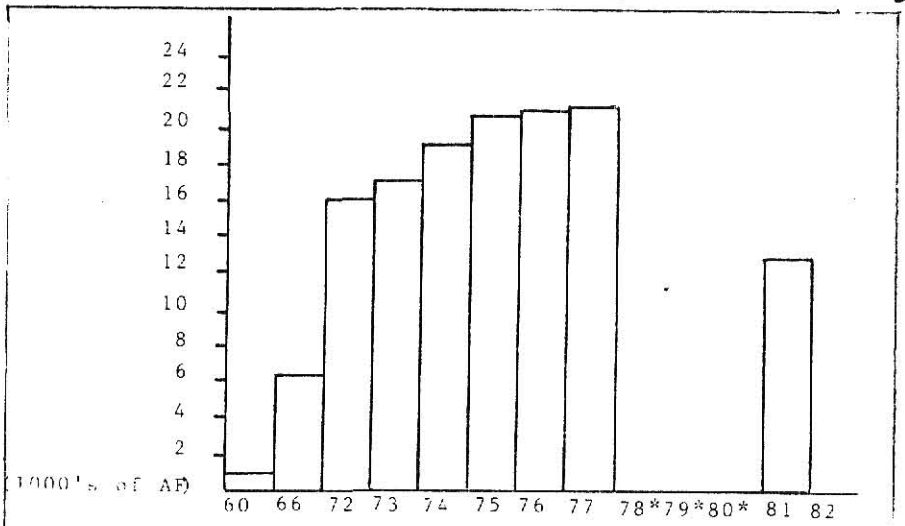


* data not available

Source : GWMD No.4,1977-1983

Figure 2.5 : No. of Wells in Thomas County

Directly related to these other factors is the amount of groundwater use. As the greatest contributor to irrigation, groundwater has been used increasingly. In Sherman County, for example only 20,900 acre/feet of water were used in 1960, while the amount of water use increased to 237,207 acre feet in 1977 (Table 2.4 and Figure 2.6).

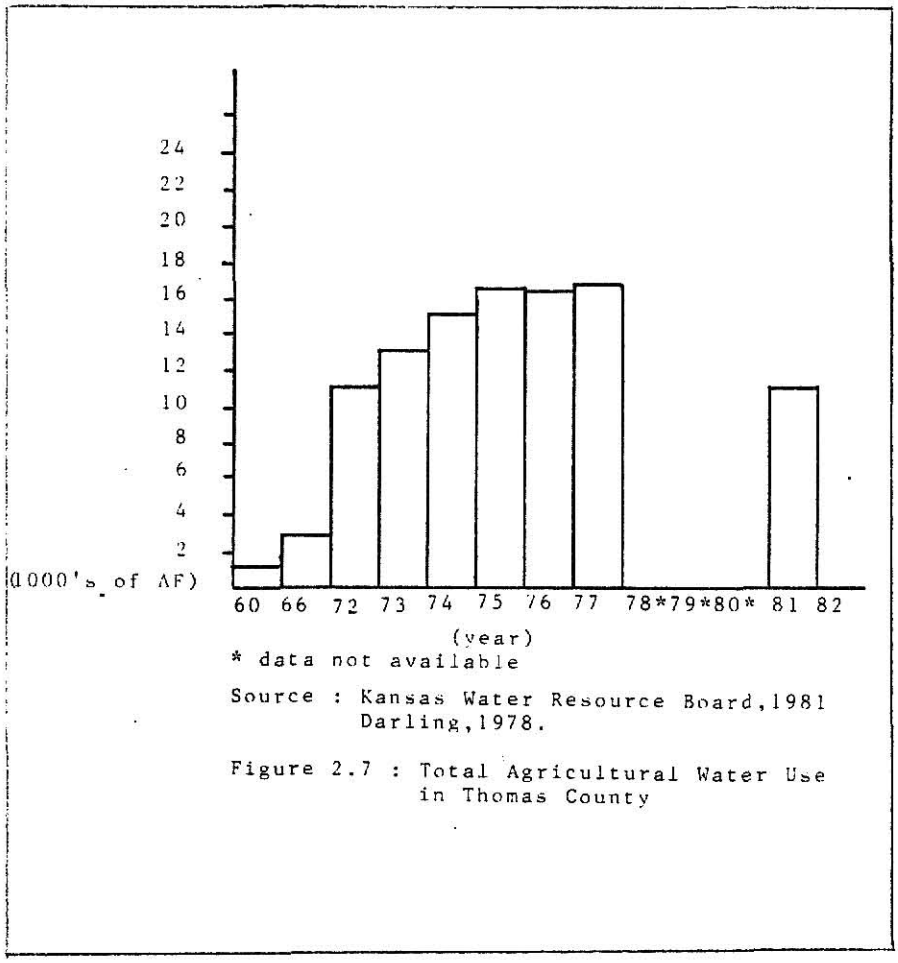


* data not available

Source · Kansas Water Resource Board,1981
Darling,1978.

Figure 2.6 : Total Agricultural Water Use in Sherman County

Thomas County used 13,300 acre-feet of water in 1960, increasing to 167,220 acre feet of water used in 1977. In 1981 the amount of water use decreased to 111,257 acre-feet (Table 2.4 and Figure 2.7)



* data not available

Source : Kansas Water Resource Board, 1981
Darling, 1978.

Figure 2.7 : Total Agricultural Water Use in Thomas County

Although groundwater has been withdrawn in a great amount, the rate of recharge has been very small. It has been determined that a rate of recharge in the aquifer for GWMD No.4 only occurs during those years where annual precipitation exceeds 22.9 inches. The total recharge in Northwestern Kansas from 1920-1978 was somewhere around 35 inches (resulting in approximately 0.6 inches per year over the 59 year period) (Bossert, 1983 and Koelliker, 1983).

Irrigation

Since precipitation is usually inadequate in Northwestern Kansas for intensive crop production (because of high rates of evaporation produced by warm temperatures and high wind velocities) successful farming depends on irrigation, summer fallow, and intensive conservation measures (U.S. Department of Agriculture, 1980). Irrigation also provides additional increments of income to related agribusinesses selling fertilizer, seed, chemicals, machinery, etc. In practicing irrigation, several factors should be considered, including design of the irrigation system, selection of proper crop types, and water management strategies. Water management includes soil moisture measurement, irrigation scheduling, relationship of soil-water-plant information, tillage patterns, etc. (Rogers et al, 1978, Black, 1979). Many irrigation systems are practiced in the study area, but the major systems are center pivot irrigation and gravity irrigation with a tailwater system.

Center pivot is a self-propelled continuous moving sprinkler lateral that rotates around a center pivot point to irrigate a circular area of approximately 130-135 acres out of 160 acres on a field (2,640

feet by 2,640 feet). It may, however, be equipped to water the corners. Large sprinklers and special corner devices can be added to a center pivot to increase the area irrigated, but all of these are expensive and the majority of the center pivot systems do not have such devices.

Center pivots are designed for a fixed rate of flow. A full quarter section system requires about 700 gallons per minute to meet crop demands. The rate of application is also fixed. The depth of water applied with a center pivot is very uniform but the rate of application is not. Near the outer end, the average rate of application is characteristically about one-inch per hour and the instantaneous rate is greater. Runoff may occur on sloping ground with limited soil intake rates. Runoff redistributes the water and causes too much to be applied in the areas of ponding and too little on the runoff area. Center pivots are quite flexible for applying small amounts of water. This is a real advantage at the time of germination. The biggest loss is direct evaporation of the spray and the evaporation from the plant and soil surface. Sprinkling at night or during periods of low wind movement are the most efficient. Strong wind movement distorts the sprinkler pattern and disrupts the uniformity built into the system. During hot, dry, windy weather, the efficiency of the irrigation system may drop 50 percent (Black, 1983).

A popular idea in Northwestern Kansas for improving center pivot efficiency is low pressure sprinkler conversion. In this, the sprinkler pressure is reduced substantially, which saves energy. The smaller drops also reduce soil crusting problems. Lowering the sprinkler system allows for release of the water nearer the crop and soil surface, reducing wind drift and evaporation. The system works best on sandy soils with high

intake rates and must be used cautiously on may upland soils in the state. The investment cost of center pivot irrigation is greater than most other systems, but the labor requirement is the lowest (Black, 1983, Pair, 1970, Hay, 1978, and Teneyck, 1978).

Surface or gravity irrigation systems generally have the reputation of being much less water efficient than sprinkler irrigation. Much of the water that is applied either runs off or seeps below the plant root zone. The most common gravity system is furrow irrigation or flood irrigation, where water runs down furrows between crop rows. Using gated pipes for water conveyance reduced seepage losses and increases irrigation efficiency about 10-15 percent as compared to open ditches. In addition, tailwater management systems offer many potential benefits to the irrigator by conserving water and energy. The collection and reuse of runoff water can help reduce the demand on the water supply and allow for more beneficial use of the water diverted for irrigation. At the same time, energy for pumping additional water is much cheaper than an equal amount of water from a deep well. If fertilizer or other chemicals are distributed to the field in the irrigation water, a tailwater management system is necessary as a pollution control device.

Some tailwater systems have been designed with larger pits, or reservoirs, than usual with the objective of collecting storm runoff and for purposes of artificial recharge. Research has shown that gravity irrigation with a tailwater can achieve efficiencies as high as 85 or 90 percent. The reuse of tailwater can also allow for irrigating of additional land and re-application to the same field.

Investment costs of gravity systems depend primarily on the amounts of pipe and land leveling required. An advantage of gravity systems is

the low energy requirement as compared to most sprinkler systems (Black, 1983, Hay and Pope, 1977 and Kramer, 1977). Comparison of various irrigation systems for initial costs, annual fixed costs, estimated operating costs, and total costs per acre are made in Table 2.5 and Table 2.6.

According to the Engineering Newsletter's Irrigation Survey, (Table 2.7) in 1978 Sherman County had 110,000 acres under gravity irrigation with gated pipe, 29,500 acres under center pivot, 300 acres under tow line and side roll, and 200 acres under other sprinkler systems. There were 325 tailwater pits and 865 wells.

In 1982, the acres practicing gravity irrigation with gated pipe decreased to 108,000 acres and acres irrigated with center pivot decreased to 26,250 in Sherman County. Tow line and side roll increased to 400 acres and other sprinkler systems increased to 350 acres. The number of tailwater pits increased to 400 and the number of wells increased to 937. Although natural gas was still in use, natural gas pumping units decreased to 469, while electrical pumping units increased to 281.

Table 2.7 shows that in 1978 Thomas County farmers practiced gravity irrigation with gated pipe and center pivot irrigation on equal portions of the irrigated land. There were 200 tailwater pits and 900 wells. Natural gas was the major energy source being used on 675 pumping units. In 1982, gravity irrigation with gated pipe (66,000 acres) was practiced on more acres than center pivot irrigation (43,000 acres). Tow line and side roll was practiced on 1,000 acres. The number of tailwater pits remained the same as in 1978 (200) but the number of wells decreased to 855 in 1982. Natural gas was still in great use with 490 pumping

TABLE 2.5 : INITIAL COSTS AND ANNUAL FIXED COSTS FOR VARIOUS IRRIGATION DISTRIBUTION SYSTEMS (EISENHAUER AND FISCHBACH, 1976).

Item	Expected Life	Gated Pipe with Re-use	Skid-tow	Traveling Gun	Center Pivot
Well-150 feet	25 yrs.	$3,300	$3,300	$3,300	$3,300
Pump	18	4,100	4,700	4,900	4,700
Diesel Power Unit	12	5,000	6,500	7,000	6,500
Gearhead	12	1,000	1,250	1,250	1,250
Fuel Tank	20	375	375	375	375
Pipe	15	2,925	4,335	2,595	----
Distribution System[1]	15	13,000	9,200	10,000	30,000
Re-use	15	3,190	----	----	----
Total Initial Cost	--	$ 32,890	$ 29,660	$ 29,420	$ 46,125
Acres Irrigated	--	145	140	100	130
Initial Cost per Acre	--	227	212	294	355
Fixed Costs per Acre per Year Including Taxes and Insurance[2]		$30.10	$30.56	$41.15	$47.61

1. Does not include land leveling

2. Based on 9% interest note

Source : Hay, DeLynn R., 1978. "Selecting an irrigation system", Kansas Water News, Vol.21,No. 1 &2.

TABLE 2.6: ESTIMATED OPERATING COSTS AND TOTAL COSTS PER ACRE FOR IRRIGATION WITH VARIOUS SYSTEMS(EISENHAUER AND FISCHBACH,1976).

	Gated Pipe with Re-use	Skid-tow	Traveling Gun	Center Pivot
Inches of Water applied per Year	15	13	13	12
Fuel-35¢/gallon	$11.98[1]	$15.55	$23.87	$15.52
Oil	1.43	1.84	2.83	1.81
Maintenance and Repairs	2.74	2.88	4.11	3.70
Labor-$3.00/hour	3.00[2]	3.90	5.70	1.50
Total Operating Costs per year	19.15	24.17	36.51	22.5
Total Irrigation	$49.25	$54.73	$77.66	$70.17

1. Includes Costs of pumping reuse water with electric pump at 2¢/kwhr.

2. Based on Solid set of gated pipe.

Source : Hay, DeLynn R., 1978. "Selecting an irrigation system", Kansas Water News, Vol.21 No.1 & 2.

Table 2.7: Irrigation Survey

		Gravity Irrigated (Acres)		Sprinkler Irrigated (Acres)				No. of Tailwater pits	No. of Wells	No. of Surface Pumping Units	Pumping Unit Energy Soureces (No. of Units)				Farmers Irrigating
		Open Ditch	Gate pipe	Center pivot	Tow Line & side Roll	Traveling Big Gun	Other Sprinkler				Natural Gas	Diesel	LP	Electricity	
Sherman County	1978	--	110000	29500	300	--	200	325	865	--	694	69	85	85	250
	1982	--	108000	26250	400	--	350	400	937	--	469	187	--	281	200
Thomas County	1978	--	50000	50000	---	--	---	200	900	--	675	180	--	45	400
	1982	--	66000	43000	1000	--	---	200	855	--	490	209	2	154	300

Source: Co-operation Extension Service, 1978, 1982.

"Irrigation Survey". Engineering Newsletter, KSU, Manhattan.

units, but this was fewer than in 1978. Diesel was used for energy at 209 pumping units, whereas electricity was used at 154 pumping units in 1982. There were only 300 farmers irrigating land in 1982; 100 fewer than in 1978.

Institutional Settings : Kansas Water Laws and Related Land Use Implications

Prior to 1945, Kansas had no single water rights law and various common-law doctrines prevailed. One of the early common law rules followed by the courts was based on the legal maxim: To whomever the soil belongs he owns also to the sky and to the depths. Under this theory, a landowner had an absolute property right to the water underlying his land, and he could take as much of it as he wanted, regardless of the effect on his neighbors. Later, this approach was refined to require a man to use his property in such a manner as not to injure the property of another, which meant that a landowner had no absolute property right to the water beneath his land, but rather a right to use the water reasonably with respect to the rights of others. This so-called ''reasonable use'' doctrine also had its faults, mainly because no one could be exactly sure how much water they were entitled to or how much was reasonable (State of Kansas, 1978).

In the 17 western states, where water has generally been scarce and precious, a different water law doctrine arose, known as the ''appropriation doctrine''. Kansas adopted this doctrine in 1945 through the Kansas Water Appropriation Act. While there are many variations of the doctrine, the Kansas version essentially dedicates all waters in the State (both surface and groundwater) to the use of the people, subject to

control and regulation of the State (through the Chief Engineer, Division of Water Resources). In other words, the first person to apply for a right to ''appropriate'' (meaning ''take'', ''divert'', or ''withdraw'') from any source and use it for beneficial purposes has a better right (a ''prior right'') to continue using the same amount than a person who starts using water from the same source at a later time. This is known as the principle of ''first in time is first in right'' (State of Kansas, 1978).

With increasing concern for water management, laws and regulations both at the state and local level have been issued in recent years. In March 1972, the state legislature enacted House Bill 1706, which provides for establishment and organization of Groundwater Management Districts (GWMD). This was based on the idea that the time had come to impose some restriction or limits on the use of the water resources in order to prevent its undue depletion. The ''Groundwater Management District Act'', as it is commonly known, became effective on July 1, 1972. The purpose of the GWMD Act is to enable the local water user to adopt a management program for conserving and prolonging groundwater resources. It gives some local control over groundwater management and depletion and quality problems (State of Kansas, 1973, GWMD No.4, 1977-1983).

According to this law, the districts have power to adopt and enforce reasonable standards and policies relating to the conservation and management of groundwater within the district, to recommend rules and regulations to the Chief Engineer necessary to implement the policies of the district, to recommend to the Chief Engineer the establishment of ''intensive groundwater use control area'' in locations within a district where there is excessive lowering of the water table, to construct works

necessary for recharge, storage, distribution, or importation of water, and, to assist in the management of storage, groundwater recharge, and surface water (Peck, 1982 and GWMD No.4, 1977-1983).

Groundwater related problems in Kansas fall into two general categories: those associated with groundwater quantity and those connected with groundwater quality. The northwest, west and southwest Kansas GWMD's principal concern is the declining groundwater table. In contrast, the Big Bend and Eques Beds districts primarily are concentrating on maintaining water table conditions and monitoring salt water intrusions (Sloan, 1979).

In order to take active management of their respective areas, the five organized GWMD's are implementing programs and policies for the conservation and management of groundwater. Preparation of the management program is the first and foremost task of a GWMD. This program must be submitted to the Chief Engineer with a request for his approval, and after that is must be submitted to a public hearing process within the district. The management program is the key to sound local groundwater management. All of the other powers listed in the GWMD law are merely supplemental and supportive of the management program.

GWMD's can and do set requirements on well-spacing, depletion allowances, and safe yield formulas, and they exercise other powers that allow the local water users to determine their own destiny with respect to the use of groundwater so long as their rules do not conflict with Kansas Law.

Several of the GWMD's have planned depletion formulas. Under such an arrangement, a water permit will only be granted if it, along with the existing permits, will not cause a certain percent of the aquifer to be

depleted within a set number of years. In GWMD No.4, permits will not be issued if they (in conjunction with past permits) will cause more than two percent (2%) per year depletion of the saturated thickness.

Another option currently available and seeing some use is for the people of a groundwater management district to recommend that the Chief Engineer declare a region within the district to be an intensive groundwater use control area (K.S.A 8 a-1036) (State of Kansas, 1978) when (a) groundwater levels in the area in question are declining or have declined excessively, (b) the rate of withdrawal of groundwater within the area in question equals or exceeds the rate of recharge in that area, (c) preventable waste is occurring or may occur within the area in question, or (d) other conditions exist within the area in question which require regulation in the public interest (State of Kansas, 1978). Upon such a request, the Chief Engineer will hold public hearings on the matter. If an intensive groundwater use control area is declared, the Chief Engineer can then: (1) close the area to any further groundwater appropriations, (2) limit total withdrawal from the area and appropriate the total withdrawal among the valid groundwater rights holders in accordance with the priority of rights (the more senior your right, the more water you recieve), (3) reduce the permissive withdrawal of groundwater by one or more appropriators (4) provide a system of rotation of groundwater use in the area, or (5) apply any other provision as necessary to protect the public interest.

By statute the Chief Engineer has the authority to have any water user install meters or gauges so that the amount of water being consumed can be checked (K.S.A. 82a-706c). The Chief can request the Attorney General to bring suit and enjoin the unlawful appropriation if the

appropriator is using more water than allowed by his permit (K.S.A. 82a-706d). Thus, metering encourages conservation by providing accurate information on the amount of water withdrawal.

In 1973 the State issued another water law, ''The Kansas Groundwater Exploration and Protection Act'' which was enacted and approved on March 31 of that year. The purpose of this act was to provide for the exploration and protection of groundwater for the health and general welfare of the citizens, to protect groundwater resources from waste and potential pollution by requiring proper plugging of abandoned holes, and to provide data on potential water supplies through well logs, well pumping tests, and water quality tests which will permit the economic and efficient utilization and management of the water resources of the State (House Bill No. 1972, State of Kansas 1973). This act requires licensing of water well contractors at the rate of 25 dollars for each drill rig operated by the contractor. The State Department of Health is responsible for the administration and enforcement of the provisions of this act. The department has the power and authority to inspect water wells and to examine applicants for licensing renewal of licenses, etc.

In 1976 GWMD No.4 was organized in Northwestern Kansas. It is the second largest district in the State, covering approximately 3,100,000 acres. The district includes all of Sherman, Thomas, and Sheridan Counties, and portions of Cheyenne, Ralins, Decatur, Graham, Gove, Logan, and Wallace Counties.

In organizing GWMD No.4, the following were identified as major problems: (1) the water table is declining about 1-3 feet annually in many parts of the district, and recharge is limited mostly to the areas

having alluvial deposits. Total decline in the period 1950-1975 varied from less than 10 feet to 40 feet. The rate of decline has increased substantially in the last five years, resulting in well yields decreasing, wells interfering with one another, and drainage problems. Secondly, although water quality of the major supplies is generally very good, other problems in the district include availability of an economical supply of energy and environmental issues (State of Kansas, 1978).

The Management Program of the district has encouraged conservation by demonstrating efficient use of water, weather modification, artificial recharge, and educational programs. Since 1978, many policies have been worked out in line with these conservation goals. The policies include (1) well-spacing, (2) tailwater control, (3) allowable appropriations of reasonable use, (4) creation of an intensive groundwater use control areas, (5) planned depletion, (6) changes in points of diversion, (7) well construction criteria, and, (8) authorized appropriation of water which can be withdrawn in any calendar year.

In 1978, under the Kansas Water Appropriation Act, new regulations were brought into force concerning the drilling and withdrawal of groundwater. Thus, after January 1, 1978 no one could legally drill a well or withdraw water from any source without first obtaining some kind of permit from the Chief Engineer. This new feature of the Kansas Water Rights Law could have far-reaching consequences not only in improving the law but also in making it easier to determine exactly who is using the water and where. The basic information has not been easily obtainable under the current system, which makes the obtaining of water right permits permissive rather than mandatory in the sense that a person has

not had to have a permit to take water. If the irrigator wanted any legal recognition of his right to take water, however, he could utilize the appropriation procedure. Under the new arrangement, the person has to have at least a temporary permit before he can drill a well. Then he can proceed with the perfecting of his water appropriation right if he wishes (State of Kansas, 1978).

In 1979, the Kansas Groundwater Exploration and Protection Act amended the section on licensing of water well contractors through Senate Bill No. 169, Chapter 344 (State of Kansas, 1979). By this Bill, the license fees were increased from 25 dollars annually per contractor and 25 dollars of each drill operated by the contractor to 100 dollars annually per contractor and 25 dollars for each drill rig operated by the contractor (State of Kansas, 1979).

In conclusion, the study area has constraints in physical background, e.g. low annual precipitation, high temperature, moderate to strong winds, high evaporation etc. But to counteract these limits, this area has been blessed with two main natural resources: groundwater and responsive soils. The combination of these two resources through irrigation systems has turned 98 percent of the total area to Sherman and Thomas Counties into cropland. It is natural that more land in irrigated farms meant more groundwater use and groundwater depletion became the main problem in the area. Resulting Kansas Water Laws and Regulations as well as energy costs and other economic pressures have also affected the structure of land use in the study area in recent years. It is these components (groundwater depletion, institutional variables along with energy costs and associated economic factors) impact on land use that is the focus of the next chapter.

REFERENCES

1. Black, Richard, 1983. "Will there be enough ?". Who Will Control Our Water Supply, Cooperative Extension Service, KSU, Manhattan, Kansas: pp. 18-30.

2. Black, R.D., et al., 1979. Soil Moisture Measurements and Aid to Irrigation Water Management, Irrigation Water Management Series, Cooperative Extension Service, KSU, Manhattan, Kansas.

3. Bossert, Wayne A., 1983. (Written Communication).

4. Bouwen, Herman, 1978. Groundwater Hydrology, McGraw-Hill Book Company.

5. Brocker, M.E., McIntyre, H.J.Jr., and McNellis, J.M., 1977. Groundwater Levels in Observation Wells in Kansas, 1971-75, Kansas Geological Survey Basic Data Service Groundwater Releases 6, 562.

6. Buller, Orlan, 1982. Ogallala Aquifer Study in Kansas Linear Programming Model, Kansas Water Office.

7. Cooperative Extensive Service, 1978. "1978 Kansas irrigation survey". Engineering Newsletter, KSU, Manhattan, Kansas.

9. Fetter, C.W. Jr., 1980. Applied Hydrogeology, A Bell & Howell Company, Columbus.

10. Fund, Mary and Clement, Elise Watkins, Dec. 1982. Distribution of Land & Water Ownership in Southwest Kansas, The Kansas Rural Center, Whiting, Kansas.

11. Groundwater Management District No. 4, 1977-1983. Management Programs.

12. Hay, DeLynn R., 1978. "Selecting an irrigation system". Kansas Water News, Vol. 21, No. 1 & 2.

13. Hay, DeLynn R. and Pope, David L., 1977. Irrigation Management System, Extension Engineering in Kansas, Cooperative Extension Service, KSU, Manhattan, Kansas.

14. Kansas Agricultural Experiment Station, Aug. 1980. The Colby Branch Experiment Station and Agriculture in Northwestern Kansas with Special Mention of Soils, Bul. 636, KSU, Manhattan, Kansas.

15. Kansas State Board of Agriculture, 1978. 62nd Annual Report and Farm Facts.

16. Kansas State Board of Agriculture, 1978. 64th Annual Report and Farm Facts.

17. Kansas Water Office, 1982. Ogallala Aquifer Study in Kansas, Summary, Topeka, Kansas.

18. Koelliker, James K., 1983. Evaluation of the Recharge Capability of Level Terraces in Northwest Kansas GWMD # 4, 2nd Annual Report (Primary report) Civil Engineering Department, KSU , Manhattan, Kansas.

19. Kramer, John A., 1977. Gravity System Irrigation Efficiency, Department of Agriculture Engineering, KSU, Manhattan, Kansas.

20. Pair, Claude H., 1970. Sprinkler Irrigation, Leaflet no. 476, U.S. Department of Agriculture.

21. Pabst, Marilyn E. and Jenkins, Edward D., Dec. 1976. "Water-level change in norhtwestern Kansas, 1950-76, Kansas Geological Survey Journal.

22. Peck, Oohn C., 1982. Legal Constraints on Diverting Water from Eastern Kansas to Western Kansas, Kansas.

23. Rogers, Danny H. et al., 1978. Irrigation Water Measurement, Irrigation Water Management Series MF- 468, Cooperative Extension Service, KSU, Manhattan, Kansas.

24. Rogers, Danny H. and Thomas, James G., 1978. Guideline for Use of Irrigation Water Meters, Irrigation Water Management Series MF-468, Cooperative Extension Service, KSU, Manhattan, Kansas.

25. Sloan, Richard F., 1979. "Groundwater reaource management in Kansas". Kansas Water News, Vol. 22, No. 1 & 2, Kansas Water Resource Board, pp. 1-6 and 23.

26. State of Kansas, 1978. Final Report of the Governor's Task Force on Water Resource. Kansas.

27. State of Kansas, 1972-79. 1972-1979 Session Laws of Kansas, Topeka, Kansas.

28. TenEyck, George R., 1978. "Sprinkler system irrigation management", Kansas Water News, Vol. 21, No. 1 & 2.

29. U.S. Department of Agriculture, Mar. 1973. Soil Survey of Sherman County, Kansas, Conservation Services, Washington D.C.

30. U.S. Department of Agriculture, June, 1980. Soil Survey of Thomas County, Kansas, Conservation Service, Washington D.C.

31. U.S. Department of Commerce, 1972-1981. Climatological Data, Annual Summary, Vol. 86, No. 13; Vol.95, No.13, National Climate Center, Federal Building, Ashville, N.C. 28801.

32. Geological Survey, 1980. January 1980 Water Levels, and Data Related to Water Level Changes, Western and South-Central Kansas, Lawrence, Kansas.

33. U.S. Geological Survey, 1982. January 1982 Water Levels, and Data Related to Water-Level Changes, Western and South-Central Kansas, Lawrence, Kansas.

34. Walton, William C., 1970. Groundwater Resource Evaluation, pp. 47-8, McGraw-Hill Book Company.

CHAPTER 3

LAND USE CHANGE ANALYSIS

The findings of this study suggest that the changes of land use in Sherman and Thomas Counties have been very dynamic. Of particular significance has been the decrease in irrigated cropland, the increase in non-irrigated cropland, and the decrease in pasture land. These findings are supported by Buller's Ogallala Aquifer Study (Ogallala Study in Kansas Linear Programming Model, 1982) suggesting that non-irrigated acreage is projected to increase by 63 percent by 2020 in western Kansas compared to 1977.

Of particular interest in this study has been drawing inferences from land use and related data about possible reasons for such land use change in the study area. These reasons include energy costs, groundwater depletion, farm production expenses, and other related factors. These factors are examined in this chapter in relation to changes in the number of farms, farm size, acres of pasture land, acres of cropland, acres of irrigated land, and crop types.

Number of Farms

As mentioned earlier, land in Sherman and Thomas Counties is mostly used for agricultural purposes. The number of farms and land are illustrated in Table 3.1. The number of farms became somewhat cyclical by 1978. In 1978, the year after the lowest crop price in the period of the study, the number of farms in Sherman and Thomas Counties dropped

sharply as compared to the earlier years. This decrease is possibly related to the low crop prices (which surely affected farm income) while some farms were sold or combined with others. Since 1980 the increase in the number of farms has become compatible with the increase in land in farms.

Farm Size Change

The dynamics of farm size are strongly related to studying land use change. In the study area, farm size, whether big or small, depends on the number of farms, land in farms, and farming patterns. For example, of the years studied, farm size was smaller in Sherman County in 1974 and in Thomas County in 1978 (Table 3.1) because of the decline in land in farms, while the number of farms did not significantly change. Farming patterns can also influence farm size. Smaller farm size in the study area may be due to the irrigation systems which enabled existing farms to increase their production capacity.

Land in Farms Change

In analyzing land use change, the data suggests that farmland dynamics in total were not as great as that of pasture land and irrigated cropland. Land in farms in Sherman County has increased since 1974 (from 617,347 acres in 1974 to 661,000 acres in 1982, see Table 3.1), although there was a slight decrease in 1979, which was associated with a decrease of irrigated acres in this year (Table 3.2). Thomas County also has had a decrease of land in farms since 1976. The decrease in 1979 in Thomas County occurred at the same time that pasture land increased (Table 3.3).

Data from aerial photos and field checking of the case study area (Table 3.4) support the census data, suggesting that cropland increased in the sample years (1974, 1976, 1980, and 1983). The increase has been at the expense of pasture land, although some portions of cropland also changed to pasture land. For example, in the Sherman County portion of the sample area, from 1974 to 1976, 3,232 acres were changed from pasture land to cropland and 2,118.4 acres from cropland to pasture land. After balancing these changes, cropland still gained 1,113.6 acres as compared to pasture land (Table 3.5). One finds that changes from 1976 to 1980 in Sherman County and changes from 1974 to 1976 in Thomas County resulted in large acreage increases of cropland in both counties.

Table 3.1 : Farm Size Characteristics and Land in Farms

	Sherman County			Thomas County		
	No.of Farms	Farm Size (Acres)	Land in Farms (Acres)	No.of Farms	Farm Size (Acres)	Land in Farms (Acres)
1969	542	1,146.5	621,409	669	1,081.7	723,771
1972	542			669		
1973	542			669		
1974	544	1,135	617,347	669	1,124	728,330
1975	542			669		
1976	526		623,000	620		728,000
1977	546		633,000	620		703,000
1978	522	1,192	650,964	609	1,095	698,000
1979	520		629,000	610		697,000
1980	540		651,000	610		698,000
1981	560		654,000	640		692,000
1982	560		661,000	631		689,000

Sources : U.S. Department of Commerce, 1981.
Crop & Livestock Reporting Service, 1977-1983.
Kansas State Board of Agriculture, 1973-74 - 1981.
Center for Public Affairs, the University of Kansas, 1975,1979.

TABLE 3.2 Acres Irrigated

	Sherman County	Thomas County
1974	79.000	74.000
1976	130.000	100.000
1977	130.000	100.000
1978	135.000	100.000
1979	120.000	95.000
1980	117.000	95.000
1981	120.000	95.000
1982	124.000	100.000

Source: U.S. Department of Commerce, 1981. 1978 Census of Agriculture. Vol. 1. Crop and Livestock Reporting Service, 1977-1980.

Table 3.3 Pasture Land (Acres)

	Sherman County	Thomas County
1972	146,000	145,000
1973	146,000	145,000
1974	146,000	145,000
1975	146,000	145,000
1976	*	*
1977	*	*
1978	195,000	179,000
1979	*	*
1980	*	*
1981	178,000	146,000
1982	*	*

* data not available

Source: Kansas State Board of Agriculture, 1974-75-1981.

Pasture Land Change

The greatest change in land use within the study area is directly related to pasture land. Census reports and aerial photo interpretation suggest that pasture land in 1981 was greater than in 1972, although it appears that the amount of acreage devoted to this land use practice is extremely variable. As illustrated in Table 3.3, pasture land in 1972-1975 was slightly less (1,000 acres) than 1981 in Thomas County and 3,000

acres less than 1981 in Sherman County. In 1978 the pasture land peaked at 195,000 acres and 179,000 acres in Sherman and Thomas Counties respectively. This increase seems to be related to livestock prices (which significantly increased nearly every month of 1978). The average index level of increase was 23.9 percent of the 1967 base rate, and 35 percent above 1977 (Kansas State Board of Agriculture, 1978).

The interpretation of aerial photos and resulting data support the change of pasture land findings from census data (Tables 3.4 and 3.5) and suggest that most of the pasture land changes took place in margins of cropland acres (Figure 3.1 to 3.3). In addition, some increases of pasture land in Thomas County occurred in areas previously used for pasture.

Where pasture land changed to non-irrigated cropland, two factors seem of particular importance: soil suitability and the desire for increased levels of production. Data from remote sensing analysis showed that the areas of changes have taken place on soils of high fertility and medium-high fertility, although the percentage of highly fertile soils was less than that of soils of medium to high fertility. For example, from 1976 to 1980 in Sherman County, 40 percent of the change in pasture land involved soils of high fertility while 60 percent involved soils of medium-high fertility.

The second reason for pasture land changes was a result of the change from irrigated to non-irrigated farming. As non-irrigated acreages were reduced, total production declined. In order to retain the same level of production formerly received from irrigated cropland, more land was farmed. Needs for additional cropland resulted in the reduction of pasture land. Supporting evidence for this statement appears in the

Tabel 3.4 : Land Use Pattern in the Case Study Area. (Acres)

	Sherman County				Thomas County			
	Cropland	Pasture-land	Urban Area	Total Study Area	Cropland	Pasture-land	Urban Area	Total Study Area
1974	176,196.8 (87.49%)	23,776 (11.81%)	1,408 (0.7%)	201,380.8	176,137.6 (87.14%)	24,793.6 (12.26%)	1,216 (0.6%)	202,137.6
1976	177.310.4 (88.05%)	22,662.4 (11.25%)	1,408 (0.7%)		177,164.8 (87.64%)	23,756.8 (11.7%)	1,216 (0.6%)	
1980	181,079.9 (89.92%)	18,892.9 (9.38%)	1,408 (0.7%)		-	-	-	
1983	183,137.4 (90.94%)	16,835.4 (8.36%)	1.408 (0.7%)		183,537.8 (90.8%)	17,383.83 (8.6%)	1,216 (0.6%)	

Source : 1974,1976,1980 -from interpretaion of aerial photographs
1983 -from frontal traverse field sample

Table 3.5 : Land Use Change in the Case Study Area . (Acres)

	Sherman County		Thomas County
	Change 1974-1976	Change 1976-1980	Change 1974-1976
Change from Pastureland to Cropland	3,232	4,915.2	2.739.2
Change from Cropland to Pastureland	2,118.4	1,145.6	1,702.4

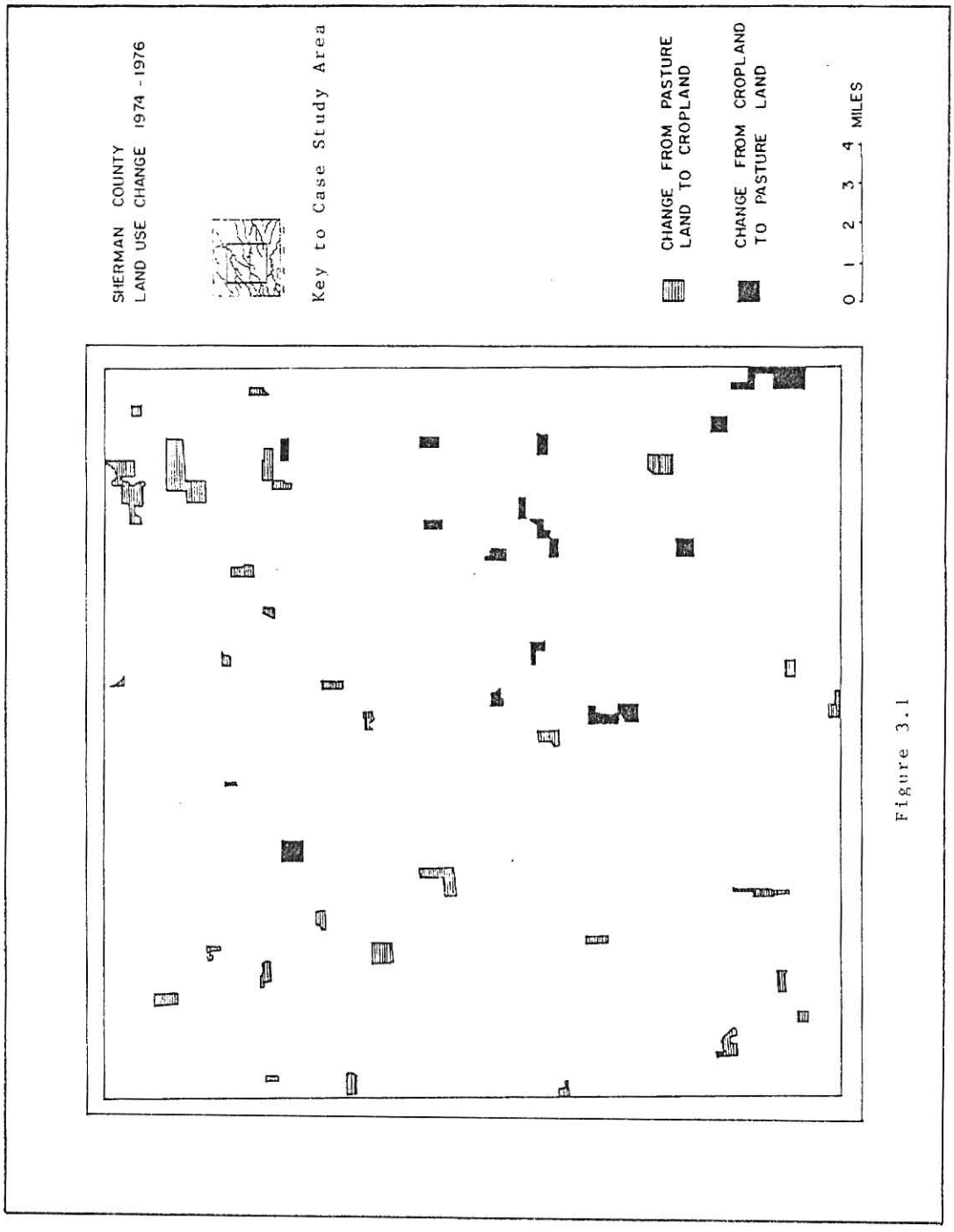

SHERMAN COUNTY
LAND USE CHANGE 1974 - 1976
Key to Case Study Area
CHANGE FROM PASTURE LAND TO CROPLAND
CHANGE FROM CROPLAND TO PASTURE LAND
0 1 2 3 4 MILES

Figure 3.1

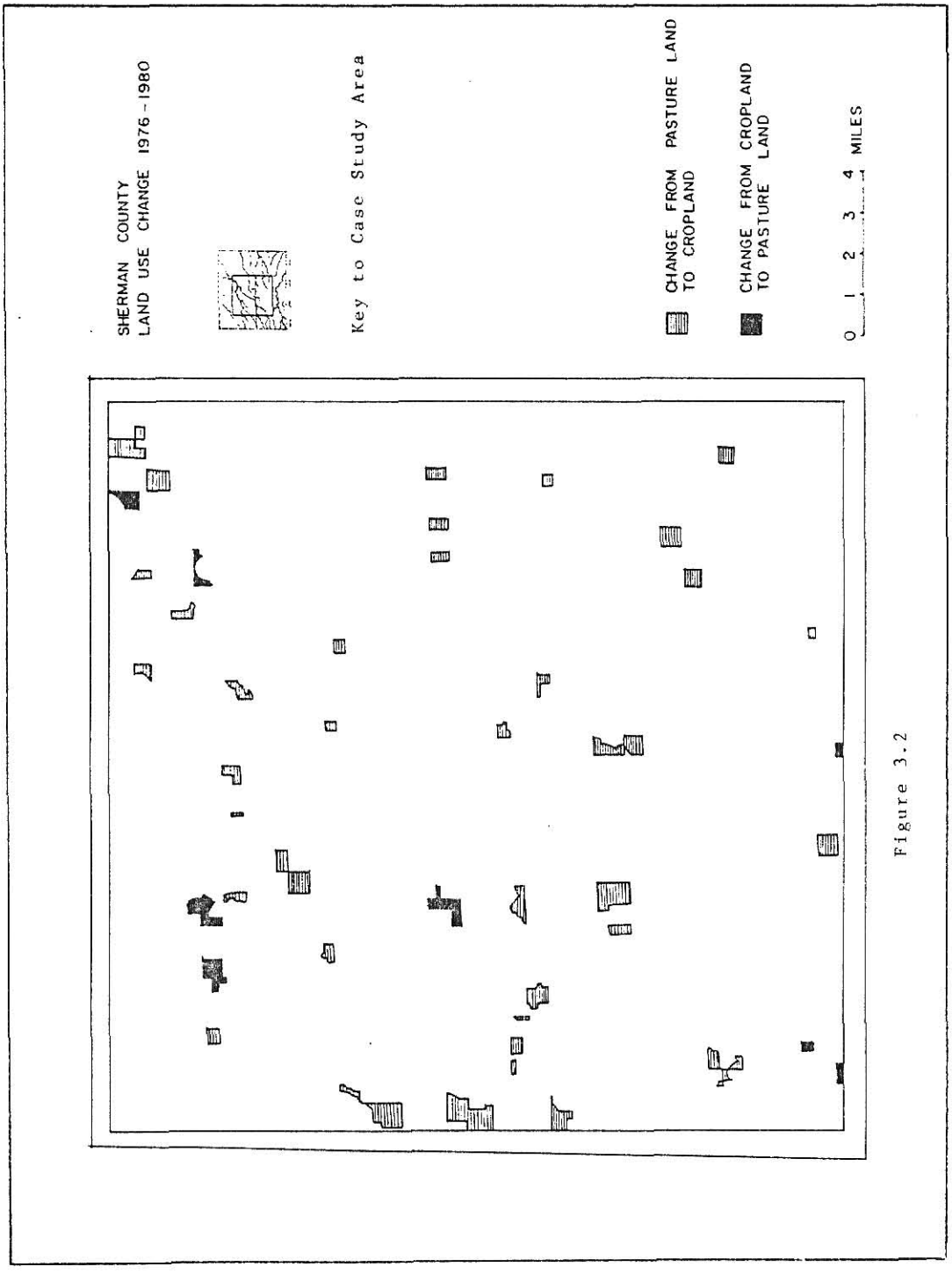

SHERMAN COUNTY
LAND USE CHANGE 1976 - 1980
Key to Case Study Area
CHANGE FROM PASTURE LAND TO CROPLAND
CHANGE FROM CROPLAND TO PASTURE LAND
0 1 2 3 4 MILES

Figure 3.2

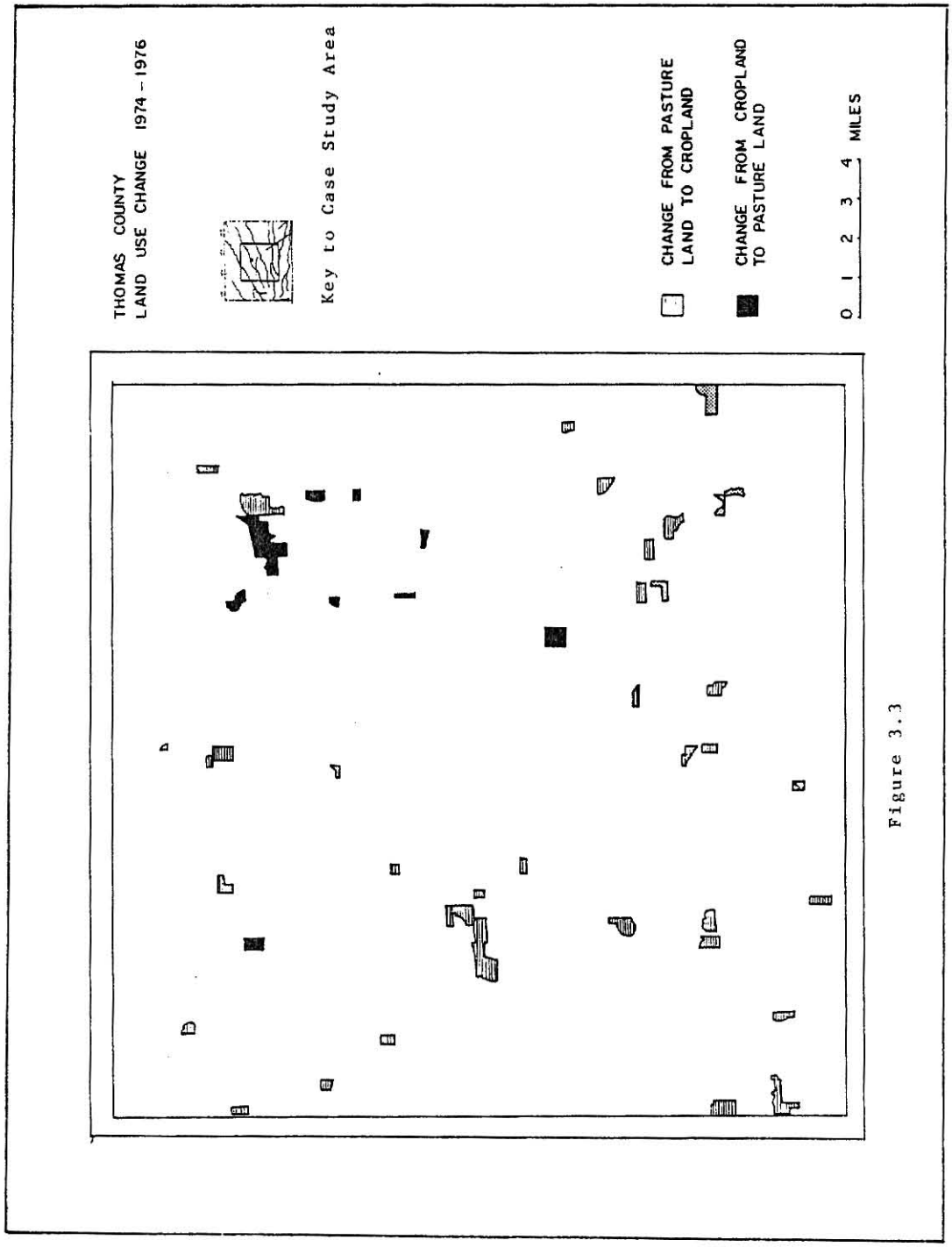

THOMAS COUNTY
LAND USE CHANGE 1974 - 1976
Key to Case Study Area
CHANGE FROM PASTURE LAND TO CROPLAND
CHANGE FROM CROPLAND TO PASTURE LAND
0 1 2 3 4 MILES

Figure 3.3

questionnaire responses. For example, the majority of the farmers believed the increase in acreages of wheat grown on summer fallow in Sherman County (from 171,300 acres in 1980, to 180,300 in 1981) was due to switching from pasture land.

Irrigated Land Change

In discussing changes and the reasons for change in irrigated cropland, some background about the decision-making process for adopting this farming technique may be useful. The introduction of irrigation on any farm requires a reliable supply of water, on-site facilities for controlled distribution, and a farming system which is able to utilize a greater and more reliable supply of water (Figure 3.4). The farmer's decision will depend on the cost and availability of these three basic requirements and on the manner in which he or she perceives the advantages and disadvantages of each. The farmer's assessment of the physical risks involved, with or without irrigation, and the degree of economic and technological uncertainty will influence the perceived advantages. Alternate technologies may be more attractive if the costs of irrigation are high and the benefits are not clearly perceived (Evans and Cant, 1981). Data from census reports and responses from questionnaires in Sherman and Thomas Counties support this idea. Groundwater depletion which influences the physical risk in the study area, and the degree of economic pressures have been major factors affecting decisions on whether or not to irrigate and thus they have influenced land changes. Non-irrigated farming seemed to be more attractive because the costs of irrigation have been high and the benefits are not as perceived before.

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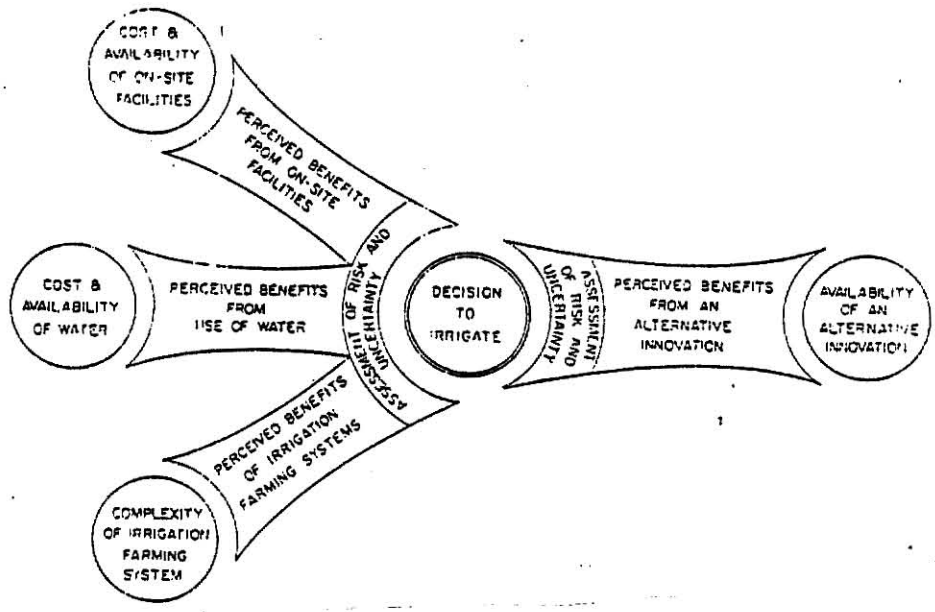

Source: Evans and Cant, 1981.

Figure 3.4: Factors influencing the decision to adopt an irrigated farming system.

From 1979, the turning point in irrigated cropland acreage in the study areas, acres irrigated have decreased while acres non-irrigated have increased. Irrigated crop types have gradually switched from corn to wheat and sorghum. Also since 1979 energy costs associated with irrigation have changed, resulting in further changes in land use.

Farmers in the study area have practiced irrigation for more than 30 years. The irrigated acres have increased since 1955, although rapid increases have occurred only since the late 1960's. The trends of irrigation have been cyclical, especially in recent years (Table 3.2).

In 1978, the total acreage irrigated in Sherman and Thomas Counties was the largest in the past 10 years, with 235,000 acres. This acreage peak was derived from many factors: moderate energy costs, ineffective laws and regulations, low farmland rents, and a moderate farm wage rate. After 1977, a low crop price year, 1978's crop price did not recover much (only 25 cents for corn, 28 cents for sorghum, and 61 cents for wheat). As a result, increases in irrigated land seemed to be the means of increasing yields and associated returns.

In 1979 and 1980, irrigated land decreased 8 percent and 98 percent, respectively, from that of 1978. This change can be considered a product of factors associated with energy costs, farmland rents, and laws and regulations.

The cyclical change of irrigated land occurred once again after 1980. An increase occurred both in 1981 and 1982 with 1.4 percent and 5.7 percent increases, respectively, from 1980. This change was the product of different factors from that of 1978. These important factors were associated with a switch from irrigated corn to irrigated wheat (which is a less water-consuming crop), and increasing efficiency of irrigation systems. In Sherman County, wheat needs only 1.33 acre-feet/acre of water while corn uses 1.731 acre-feet/acre (Darling, 1979). In addition, the irrigation system in recent years has been improved with low-pressure sprinklers added to center pivot irrigation in order to reduce the loss of water while spraying (Black, 1983). Tailwater pit control for gravity irrigation, which was required by GWMD's regulation for water reuse purposes, also made for greater acceptability of irrigated systems.

Change of Crop Types

Many crop types have been grown in the irrigated area of Sherman and Thomas Counties: corn, wheat, sorghum, soybeans, and alfalfa hay are included, although the major crops are corn, wheat and sorghum. Corn is the dominant irrigated crop in the study area although its acreage has been decreasing. Irrigated acres of corn were high from 1972 to 1977 (Table 3.6). Total acres of irrigated corn in Sherman and Thomas Counties was 50,000 acres in 1972 and this figure increased to 124,000 acres in 1977 (the peak year).

The trend of decreasing corn acreage has been taking place since 1978 (Except in 1979, when the acres irrigated increased slightly). The year 1982 was the period of greatest decrease in irrigated corn with a 7.7 decrease from 1981. During the period since 1978, irrigated corn has been replaced by irrigated wheat and sorghum. High energy costs, high irrigation expense, and new regulations have played significant roles in the decrease of irrigated corn and the search for alternative crops.

Sorghum acreage has increased at a relatively slow rate (regarding total acreage) in the study area. In Sherman and Thomas, the greatest increase in sorghum acres irrigated occurred in 1979 with increases of 100 percent and 71.4 percent respectively, however total acreage is still small small (as a percent of the total irrigated acreage).

Irrigated wheat also increased and to a greater extent than sorghum. The significant increase in Sherman County took place in 1980 with a 200 percent increase from 1979 and in Thomas County took place in 1980 with a 200 percent increase from 1980 to 1981. Most of this increase was at the expense of corn acreage (Table 3.6).

Table 3.6. ; Corn, Sorghum, and Wheat in Acreage Irrigated. (1,000's AC)

	Sherman County				Thomas County			
	Corn	Sorghum	Wheat	Total	Corn	Sorghum	Wheat	Total
1972	26	1	1	28	24	3	-	27
1973	40(+53.8%)	-	3(+200%)	43(+53.6%)	29(+20.8%)	3(0%)	1	33(+22.2%)
1974	46(+15%)	-	3(0%)	49(+14%)	30(+3.4%)	2(-33.3%)	2(+100%)	34(+6.1%)
1975	48(+4.1%)	2(+100%)	7(+133%)	57(+16.3%)	42(+26.7%)	2(0%)	4(+100%)	48(+41.2%)
1976	68(+41.7%)	2(0%)	7(0%)	77(+35%)	55+16.7%)	3(+50%)	5+25%)	63(+31.3%)
1977	66(-2.9%)	4(+100%)	11(+57.1%)	81(+5.2%)	58(+5.5%)	7(+13.3%)	4(-20%)	69(+9.5%)
1978	56(-15.2%)	4(0%)	11(0%)	71(-12.3%)	55(-5.2%)	7(0%)	3(0&)	65(-5.8%)
1979	59(+5.4%)	8(+100%)	8(-27.3%)	75(+5.6%)	58(+5.5%)	12(+71.4%)	5(+66.7%)	75(+15.4%)
1980	46(-22%)	9(+12.5%)	24(+200%)	79(+5.3%)	48(-17.2%)	8(+33.3%)	5(0%)	61(-18.6%)
1981	47(+6.5%)	9(0%)	28(+16.7%)	84(+6.3%)	43(-10.4%)	18(+125%)	16(+200%)	77(+26.2%)
1982	34(-27.7%)	8(-11.1%)	29(+3.5%)	71(-15.5%)	38(-11.2%)	15(-16.6%)	15(-6.3%)	68(-14.3%)

Sources: Crop & Livestock Reporting Service, 1977-1983

Wheat, sorghum, and corn were also grown in non-irrigated areas (Table 3.7). Wheat has been the most important non-irrigated crop over the past 10 years, although wheat grown in summer fallow has been somewhat cyclical, depending on normal rotation or because of natural hazards, such as the freeze in May of 1981 (Kansas State Board of Agriculture, 1981). Generally, however, a trend of increase has been clear. Between 1972 and 1982, Thomas County as compared to Sherman County had the largest acreage of wheat in summer fallow. In 1979, Thomas County has 252,000 acres (it was 11.5 percent higher than in 1978 and 18.9 percent higher than in 1972). In 1977 and 1980, Thomas County was the top producer of wheat grown in summer fallow for the state (Kansas State Board of Agriculture, 1977, 1981). Sherman County had its highest acreages in 1982 with 203,000 acres, of 3.1 percent higher than 1981 and 26.9 percent higher than 1972's acreages.

During the study period, wheat in continuous cropland was grown on fewer acres than wheat in summer fallow and sorghum, although continuous cropped wheat in 1982 had fewer acres than in 1972. Sorghum has been grown on non-irrigated land although not to the same extent as wheat. In Thomas County in 1981, sorghum acres were 3,000 acres (or 190.9 percent higher than in 1980). This significant increase was due to the wheat crop freezing out in May of 1981 and sorghum being planted instead of wheat (Kansas State Board of Agriculture, 1981 and responses to questionnaires).

Corn grown in non-irrigated land has been least in acreages over the past 10 years because corn is not a productive dryland crop (as determined by testing under dryland conditions at the Agricultural Experiment Station) (Kansas Agricultural Experiment Station, 1980). The

Table 3.7 : Corn, Sorghum, and Wheat in Acreages Non-Irrigated. (000AC)

	Sherman County					Thomas County				
	Corn	Sorghum	Wheat		Total	Corn	Sorghum	Wheat		Total
			Cont. cropped land	Summer Fallow				Cont. cropped land	Summer Fallow	
1972	-	5	8	160	173	-	12	14	212	238
1973	-	-	4(+50%)	178(+11.3%)	182(+5.2%)	1	15(+25%)	6(-57.1%)	228(+7.5%)	239(+.4%)
1974	3	-	5(+25%)	187(+5.1%)	195(+7.1%)	1(0%)	6(-73.3%)	8(+33.3%)	222(-2.6%)	237(-.8%)
1975	1(-66%)	-	6(+20%)	183(-2.7%)	190(-2.6%)	2(+100%)	10(+18.7%)	7(-12.5%)	219(-6.3%)	238(+.4%)
1976	1(0%)	3(+40%)	4(-33.3%)	177(-3.3%)	185(-2.6%)	1(-50%)	12(+20%)	4(-42.9%)	232(+5.9)	249(+4.6%)
1977	-	1(-66.7%)	4(0%)	197(+11.3%)	202(+9.2%)	-	10(-16.7%)	3(-25%)	231(-.43%)	244(-2%)
1978	-	-	4(0%)	183(-7%)	187(-7.4%)	-	7(-30%)	8(+166.7%)	226(+2.2%)	241(-1.2%)
1979	-	2(+100%)	1(-75%)	190(+3.8%)	193(+3.2%)	1(0%)	11(+57.1%)	1(-87.5%)	252(+11.5%)	266(+10.37%)
1980	-	1(-50%)	1(0%)	186(-2.1%)	188(-2.6%)	1(0%)	11(0%)	4(+300%)	251(-.4%)	267(+.4%)
1981	2(+100%)	4(+300%)	1(0%)	197(+5.9%)	204(+8.5%)	-	32(+190.9%)	4(0%)	219(-12.7%)	255(+4.5%)
1982	2(0%)	1(-75%)	4(+300%)	203(+3.1%)	210(+2.9%)	2(+100%)	21(-34.4%)	12(+200%)	213(-2.7%)	248(-2.7%)

Sources : Kansas State Board of Agriculture, 1973-74 -1981.
Kansas Crop & Livestock Reporting Service, 1977-1983.

acreages of dryland corn in 1982 was only 2,000 acres in each of the counties.

Significant Factors Influencing Land Use Practices in the Study Area

From this study of land use practices, especially related to changes in irrigated cropland and crop types, inferences can be made about the influence of groundwater depletion, energy costs, high farm expenses, laws and regulations, and benefits from non-irrigated farming.

Groundwater Depletion

Water reliability can influence increases or decreases of irrigated land when water depletion is a factor. During initial irrigation development there was plenty of water available to encourage expansion of irrigation in the study area, but later, as groundwater depletion emerged as a problem, restrictions were placed on irrigation development. Water depletion in the study area can be seen in an increased depth to water. In 1979, Sherman County had a 146 foot depth to water, as compared with a 151 foot depth to water in 1982. Thomas County had a 127 foot depth to water in 1979 and 128 feet in 1982. Depth to water has caused more hours of energy pumping and more expenses in irrigation (especially when considering increase in energy prices). Response from water management officials stated that groundwater depletion has been one of the most important problems affecting the crops planted in the study area.

Energy Costs

In this study, water depletion and energy costs are stongly related when considering land use changes. Energy prices have increased

considerably in recent years. Natural gas, which has been a very important energy source for irrigation, had a price of one dollar per million cubic feet (for post 1967 gas and 80 cents for pre 1967 gas) in 1977 and increased to two dollars per million cubic feet (for post 1967 gas and one dollar, 99 cents pre 1967 gas) in 1982. Other energy sources have increased in costs as well (Table 3.8).

Because groundwater depletion and higher energy costs have occurred simultaneously, irrigation acreage has been affected. For example, in 1979, acres irrigated was 20,000 acres lower than in 1978. This trend continued through 1981. Although acres irrigated increased a bit in 1982, it was still lower in acres than that of 1978. The sequence of change which followed the decrease in irrigated land was increases in acres of non-irrigated land (from 48,000 acres in 1978 to 459,000 acres in 1979). In addition, as was mentioned earlier, irrigated crop types also changed. Irrigated corn (which is the most water-consuming crop) has been grown less, while irrigated wheat and sorghum (which consume less water) have larger acreages.

Many responses from the questionnaires mentioned that energy costs were the major problem in changing from irrigated land to non-irrigated. The farmers questioned suggested that high irrigation expenses (which surely included energy cost) along with other expenses caused fewer farmers to irrigate in the study area.

Crop Price

Crop prices received by farmers have been a factor in land decisions and land use change. As an example, in the case of high irrigation expense, irrigation farming may not be changed if the crop

Table 3.8 : Energy Costs

	Natural Gas $/mcf	Electricity $/Kwhr	Diesel $/gal	Gasoline $/gal	L.P.Gas $/gal
1972	.42 for post 1967 gas and .32 for pre 1967 gas	.0225	.165	.303	.052
1973		.0212	.212	.340	.063
1974		.0357	.357	.462	.108
1975		.032	.375	.491	-
1976		.034	.387	.528	-
1977	1.00 for post 1967 gas and .80 for pre 1967 gas	.04	.435	.571	-
1978		.045	.456	.598	.343
1979		.048	.692	.813	.383
1980		.05	.976	1.148	.560
1981		.058	1.135	1.265	.616
1982	2.2 for post 1967 gas and 1.99 for pre 1967 gas	.0585	1.096	1.204	.603

Source : Crop & Livestock Reporting Service, 1972-1981 and Bossert, 1983.

prices received by the farmer have been high enough to offset the capital investment. But from 1977, which was the year of a sharp decrease in crop prices (Table 3.9), such prices have not recovered at the rate that can offset the higher irrigation expenses.

Table 3-9 : Prices Received by Farmers for the Three Major Crops ($/bu)

	Corn	Sorghum	Wheat
1972	1.23	1.91	1.58
1973	1.97	3.15	3.08
1974	2.85	4.43	4.23
1975	2.67	4.17	3.43
1976	2.44	3.88	3.00
1977	1.96	3.02	2.12
1978	2.21	3.30	2.73
1979	2.48	3.75	3.49
1980	2.86	4.54	3.74
1981	3.05	4.60	3.84
1982	2.60	4.02	3.52

Source : Crop & Livestock Reporting Service, 1972-1982

In 1979, the price of corn was $2.48/bu, sorghum $3.75/bu, and wheat $3.49/bu. These prices were lower than the 1974 level, yet irrigation expenses have steadily increased. Even in 1983, responses from questionnaires strongly stressed low crop prices (especially for irrigated crops) as the cause of irrigated land change in the recent years. For example, most farmers believed that decreases in irrigated corn from 58,000 acres in 1979 to 46,000 acres in 1981 in Sherman County was caused by low crop prices.

Farm Expenses

Since 1979, which was the period of decrease in acres irrigated, higher farm production expenses have existed. Water costs, seed prices, farm machinery, fertilizers, farmland rent, and farm wage rates have all increased.

Water costs seemed to be an important part of the irrigation expenses, at least as perceived by farmers. According to published material, the board of GWMD has assessed an annual water use charge against every person who withdraws groundwater from within the boundaries of the district. This charge is not to exceed thirty cents (30¢) for each acre-foot (325,851 gallons) of groundwater withdrawn within the district (House Bell No. 1706, approved March 17, 1972). This annual rate increased to sixty cents (60¢) for each acre-foot in 1978 (House Bill No. 649, approved March 30, 1978).

In communicating with the manager of GWMD No.4, it was discovered that the rate of charge as stated in the House Bill are only maximum rates. In practice, each GWMD sets up the rate according to the budget needed in each year. For example, in recent years the charge rate in GWMD No. 4 has been at an average of 4 cents (per-acre foot). Thus, the groundwater manager did not think that water cost was a farm expense problem.

Seed retail price, especially corn seed, increased from $43.00/bu in 1978 to $50.00/bu in 1979 and to $66.00/bu in 1981 or at an average of 15 percent increase per year (Table 3.10). Wheat seed was much less expensive than corn and sorghum. It was $5.60/bu in 1979 and $7.30/bu in 1981.

Table 3.10 : Seed (Retail) Price Paid by Farmers ($)

Seeds	1976	1977	1978	1979	1980	1981
Alfalfa,Certi-fied, per cwt	110.00	167.00	195.00	200.00	200.00	190.00
Alfalfa, Uncer-tified, per cwt	76.00	124.00	135.00	131.00	130.00	125.00
Wheat, per bu	5.50	5.60	5.60	5.60	7.10	7.30
Corn, per bu	39.00	42.00	43.00	50.00	56.00	66.00
Grain Sorghum, per cwt	39.00	38.00	47.00	42.00	50.50	57.00
Forage Sorghum, per cwt	19.00	27.50	21.00	22.00	22.50	33.50
Soybean, per bu	6.80	13.00	10.50	11.50	11.00	13.50

Source : Kansas State Board of Agriculture, 1978,1981.

Table 3.11 : Farm Machinery ($/Unit)

	1957-59 average	1972	1973	1974	1975†
Tractors, wheel					
30-39 belt hp	3,073	4,298	4,700	5,575	6,500
50-59 belt hp	5,040*	6,425	6,725	7,900	9,350
70-79 belt hp		8,375	9,575	10,650	†
90-99 belt hp		10,500	12,125	14,750	18,000
Plow, moldboard 5-bottom		1,575	1,775	2,475	2,900
One-way disc tiller 14-16'		1,800	2,000	2,300	2,300
Field cultivator, 10-12'	377	900	960	1,250	1,250
Disc harrow wheel, tandem 12-14'	860	1,475	1,725	2,200	2,675
Spring tooth harrow, 3 section	180	335	358	465	590
Grain drill, 18-20 tube	828	1,500	2,075	2,600	3,400
Rotary hoe, 4 section		810	850	1,150	1,350
Combine, self-propelled 12'	5,960	12,000	14,000	17,750	20,250
Corn planter and fertilizer attachment, 4-row	760	1,800	1,900	2,200	4,150
Cultivators, 4-row, mounted	680*	1,000	1,100	1,150	1,350
Forage harvesters, shear bar-type, PTO	1,567	3,825	4,300	5,250	6,000
Farm wagons, less box and tires	184	290	340	505	550
Tractors manure loaders	423	1,200	1,225	1,550	1,850
Mowers, tractor drawn 7'	400	800	810	980	1,200
Hay conditioners		1,200	1,100	1,500	1,750
Pickup balers, PTO	2,425*	2,700	2,850	3,450	3,700

Source : Kansas State Board of Agriculture, 1973-75.

Tabel 3.12 : Fertilizer Price Paid by Farmer

Fertilizer $/ton	1975-59 average	1971	1972	1973	1974	1975	1976
Anhydrous ammonia	143.00	73.00	72.00	84.00	185.00	223.00	168.00
Ammonium nitrate	79.00	58.50	59.50	69.50	142.50	162.50	123.00
Super phosphate 45% P205	77.30	76.50	75.50	87.50	152.50	180.00	-
Mixed fertilizer 18-46-0	-	88.50	92.00	107.50	187.50	225.00	-

Source : Kansas State Board of Agriculture, 1973-74-1976.

Farm machinery and fertilizer were other farm expenses which have increased in price since 1972. Examples of farm machinery prices and fertilizer prices are illustrated in Table 3.11 and Table 3.12. Although these tables only show the data from 1972-1975 and 1976, it is the researcher's belief that the prices of these items have increased since 1976. For example, increases of fertilizer prices can be directly related to increases in the natural gas price (Buller, 1982).

Farmland rent rates and farm wage rates are also included in farm expenses. Farmland rent rate for irrigated land has had a significant increase since 1979, when the rate was 58.80 per acre. To illustrate, the rate in 1981 increased to 64.00 per acre (Table 3.13).

Table 3.13 Farmland Rents in Kansas

Year	Rent per Acre	
	Irrigated	Non-irrigated
1976	59.10	23.30
1977	57.50	24.80
1978	51.70	25.40
1979	58.80	27.90
1980	60.90	30.60
1981	64.00	31.70

Source : Kansas State Board of Agriculture,1981.

Farm wage rate (e.g., of all hired) has increased on an average of 18 cents in 1979 to 22 cents per hour in 1980 (Table 3.14).

Table 3.14 Farm Wage Rates ($ per hour) in Kansas.

Year	January			April			July			October		
	All hired	Per hour cash	Field	All hired	Per hour cash	Field	All hired	Per hour cash	Field	All hired	Per hour cash	Field
1976	2.89	2.72	2.77	2.93	2.71	2.77	2.86	2.52	2.76	3.00	2.95	2.90
1977	3.13	2.75	3.00	3.08	3.12	2.98	2.90	2.80	2.90	3.12	3.00	2.95
1978	3.47	3.10	3.10	3.47	3.16	3.15	3.30	3.24	3.00	3.39	3.40	2.90
1979	3.43	3.45	3.20	3.70	3.60	3.25	3.61	3.63	3.55	3.60	3.73	3.65
1980	3.93	4.00	3.68	3.72	3.75	3.60	3.70	3.76	3.48	3.73	3.90	3.62
1981	4.10	3.78	3.70	3.89	3.69	3.85	.....					

Source : Kansas State of Agriculture, 1981.

All these farm expenses: water costs, seed, farm machinery, fertilizers, farmland rent, and farm wage rates have affected the change of irrigated land and irrigated crop types. Responses from the questionnaires stated that irrigation expenses were the most important cause for decrease in number of farmers irrigating in Sherman and Thomas Counties (from 250 and 400 in 1978 to 200 and 300 in 1982, respectively).

Laws and Regulations

Although laws and regulations did not have direct impacts on the changing or irrigated land or irrigated crop types, they have had indirect effects on decisions in choosing irrigated crop types that use

less water. Responses to questionnaires did not mention laws and regulations as important factors in the land use decision making process or in land use change, but the laws and regulations enforced in recent years had had some evident impacts that are reflected in census data, e.g., fewer numbers of water appropriation applications and changes of irrigated crop types.

Kansas water laws and regulations have been the main cause of increasing water costs. But in practice the rate of groundwater withdrawal in GWMD No. 4 has been at the average of only 4 cents (4¢) per acre-foot in the recent years, (4.5¢ per acre in 1982) (Bossert, 1983). Yet, these regulations have evidently affected expenses for irrigation and associated land use practices. The responses from the questionnaires revealed that the higher cost of water was one of the important factors affecting change of irrigated land in the study area in recent years. For example, farmers in Sherman and Thomas Counties felt that high irrigation water costs were the cause of change from irrigated sorghum to non-irrigated sorghum in 1980 and 1981.

In response to Kansas water laws and regulations, GWMD No.4's Management Programs have had other impacts on the study area. The management tools of the districts consists of well-spacing, tailwater control, allowable appropriations, reasonable use, establishment of intensive groundwater use control areas, planned depletion, well construction criteria, and legal maximum limits of water withdrawal. These programs haveen effective tools for water conservation.

Since 1979, when these programs were implemented, the number of water appropriation applications decreased from 91 in both counties in 1978 to 53 in 1979 (Table 3.15). In conjunction with this was a

reduction in the amount of irrigated land and changes in irrigated crop types.

Table 3-15 : Water Appropriation Applications

	Sherman County	Thomas County
July1,73-June30,74	40	70
July1,74-June30,75	52	75
July1,75-June30,76	94	90
July1,76-Dec.31,76	24	27
Jan.1,77-Dec.31,77	61	79
Jan.1,78-Dec.31,78	29	62
Jan.1,79-Dec.31,79	13	40
Jan.1,80-Dec.31,80	18	40
Jan.1,81-Dec.3181	12	20

Source : Kansas State Board of Agriculture, 1974-1981.

The sequence of occurrence after these programs were implemented can be seen through change in irrigated crop types. Irrigated corn has decreased, while irrigated wheat and sorghum have increased. Responses from the questionnaires revealed that the decrease of irrigated corn acreages from 58,900 in 1979 to 46,600 in 1981 in Sherman County was caused by switching from corn to a crop which consumed less water. In addition, farmers said that increases of irrigated wheat acreages from 7,700 in 1979 to 23,100 in 1981 and 26,400 in 1982 in Sherman County, and the increase of irrigated sorghum from 8,000 acres in 1980 to 18,200 acres in 1981 in Thomas County, were caused by switching from irrigated corn to irrigated wheat and sorghum (which are less water consuming crops).

The change of irrigated land to non-irrigated land is not only the result of these factors but also is a product of attractive alternative farming patterns, primary non-irrigation. In recent years, the crop yield (acre/bu) of irrigated and non-irrigated wheat and sorghum farming has not been significantly different (Table 3.16). For example, in 1982 in Sherman County, crop yield (acre/bu) or irrigated wheat and sorghum was 46.5 and 80.9 respectively while crop yield (acre/bu) or dryland wheat (grown on summer fallow) and sorghum was 36.1 and 56.0 respectively. Although irrigated crops have still provided more production than non-irrigated crops, irrigated crops require more capital than dryland crops, which save water cost, energy costs, etc. From the study of Darling's, (1979) average irrigated earnings were compared with dryland earnings from 1972 to 1977 (Table 3.17). This study showed that, during earlier years (from 1972-1975), irrigated earnings have been larger than dryland earnings. Since 1976, however, dryland earnings have

Table 3.16: Irrigated and Dryland Crop Yield (Acre/bushel)

	Sherman County							Thomas County						
	Irrigated			Dryland				Irrigated			Dryland			
	Corn	Wheat	Sorghum	Corn	Wheat		Sorghum	Corn	Wheat	Sorghum	Corn	Wheat		Sorghum
					Cont. cropped land	Summer fallow						Cont. cropped land	Summer fallow	
1972	-	37.0	87	-	14.0	21.0	34.0	-	-	89.0	-	16.0	30.0	54.0
1973	122.0	51.0	-	54.0	24.0	36.0	-	132.0	53.0	77.0	54.0	20.0	37.0	42.0
1974	108.2	38.7	-	24.2	28.1	35.2	-	93.6	55.0	58.8	31.4	20.1	34.8	33.4
1975	100.6	42.2	-	21.0	26.0	31.5	-	108.9	43.3	62.0	24.0	26.4	31.1	40.0
1976	111.0	41.5	68.4	26.0	21.1	26.3	26.2	108.0	42.3	77.4	18.0	26.1	35.8	30.0
1977	101.0	44.2	82.2	52.0	15.8	35.9	51.6	121.0	44.9	92.0	45.0	23.6	35.9	51.4
1978	117.1	43.6	65.0	38.0	20.0	31.1	20.5	115.4	40.0	71.8	-	25.5	36.4	36.5
1979	122.0	53.8	88.6	46.0	29.3	32.5	50.9	127.7	51.6	93.0	65.8	36.0	44.2	52.6
1980	105.1	44.5	82.1	-	28.0	39.2	38.0	118.8	50.7	76.0	27.5	42.0	44.4	44.1
1981	126.4	38.4	94.2	98.1	17.3	21.5	48.7	148.5	26.1	99.4	-	12.0	12.0	56.9
1982	113.9	46.5	80.9	56.5	29.2	36.1	56.0	128.0	51.1	87.0	69.0	38.4	35.7	48.0

Source :

Kansas State Board of Agriculture , 1973-74-1981

Table 3-17 : Average Irrigation Earnings and Dryland Earning

	Sherman County		Thomas County	
	Average Irrigation Earnings ($/AF)	Earnings Dryland ($/AC)	Average Irrigation Earnings ($/AF)	Earnings Dryland ($/AC)
1972	77.43	47.13	97.72	53.32
1973	124.12	133.19	139.73	133.79
1974	179.12	140.29	151.12	132.92
1975	120.16	209.27	135.56	105.38
1976	109.56	192.77	115.03	193.18
1977	83.02	144.09	117.71	198.01

Source : Darling, David D., 1979.

been larger than irrigated earnings. Responses from the questionnaires showed that 23 percent of the farmers sampled in the study area felt that the benefit associated with dryland farming caused the increase of wheat grown in summer fallow in 1981. This attractive trend associated with earnings has become an important factor in the farmers' assessment of irrigation and non-irrigation.

Reflections on Questionnaire Responses

In analyzing any problem, more data and information will surely aid in confirming reflections made by the researcher. In analyzing the structure of land use change in this study, apart from data and information received from census reports and aerial photo interpretation, data derived from questionnaires was very significant. Questionnaire's responses, although small in number (twenty-five of sixty farmers or 42 percent responded to the questionnaires while four of four management officials responded), provided significant insights into reasons for changes in land use.

Of the farmers responding, the majority practiced dryland farming with an average farm size of 700 acres (characteristic of the study area). The number of farmers who own and rent farmland was about 50-50 percent. The flood irrigation system was the major system used by the responding farmers. This again is characteristic of the study area.

Responses to questions on the questionnaire were very consistent. Energy costs, low crop price, and high irrigation expenses were factors mentioned as resulting in irrigated land conversions, laws and regulations had lesser impact than these other factors. Commodity price

and marketing were the most important problems affecting the crops planted.

Although the responses of the farmers and the officials on land use change was similar, there was in interesting difference. Farmers sensed the change of acres irrigated and irrigated crop through economic variables. For example, a farmer in Sherman County reasoned that the decrease in irrigated corn was due to low crop prices as well as a switch to less water-consuming crops, while the official was more concerned with the latter factor.

Officials also sensed the changes through economic variables as well as the resource supply variables. For example, an official felt that the most important problems affecting the crops planted were groundwater depletion and commodity prices and marketing, while no farmer felt groundwater depletion was a reason for changing crop type. Response from the officials provided a stronger resource management perspective for the basis of change. For example, officials were concerned about the long-term depletion of groundwater.

In the section of the questionnaire on laws and regulations, farmers tended to be more interested in answering than the officials. For example, a farmer owning 1,760 acres and practicing both dryland and irrigated farming, expressed his ideas on Kansas water laws, suggesting that water laws are adequate now, but need improvement in the future. Another farmer would like the local government to keep up the good work with farmers around the area but give every farmer an equal chance. Yet most farmers were satisfied and thought that Kansas water laws are adequate in their area, although most of them did not feel that Kansas water laws have had any effect on their land use decisions. Farmers and

officials (who gave the response on this section) agreed that local government should be involved more in water management than the State or Federal government.

Data from questionnaires provided a deeper insight into factors affecting the changes of irrigated and non-irrigated land and crops. These data supported census reports and remote sensing interpretation of land use change.

REFERENCES

1. Bossert, Wayne A., 1983. (Written Communication and Telephone).

2. Buller, Orlan, 1982. Ogallala Aquifer Study in Kansas Linear Programing Model, Kansas Water Office.

3. Center for Public Affairs, the University of Kansas, 1975-1979. Kansas Statistical Abstract, Lawtence, Kansas.

4. Crop & Livestock Reporting Service, 1972-1982. Kansas State Board of Agriculture, (Written Communication).

5. Darling, David D., 1979. Earning Attributable to the Differential Yields from Irrigated Crops, Bul.24, Kansas Water Resources Board.

6. Evans, Marry and Cant, Gart, Oct. 1981. "The effect of irrigation on farm production and rural settlement in mid-Canterbury : a comparison of the irrigated and dryland farming zones in the Lyndhurst_paendarves area, 1945-1976". New Zealand Geographer, Vol.37,No.2.

7. Groundwater Management District No.4, 1977-1983. Management Program.

8. Kansas Agricultural Experiment Station, Aug. 1980. The Colby Branch Experiment Station and Agriculture in Northwestern Kansas with Special Mention of Soils, Bul. 636,KSU, Manhattan, Kansas.

9-15. Kansas State Board of Agriculture, 1973-1981. 58th Annual Report -65th Annual Report and Farm Facts.

16. U.S. Department of Commerce, 1981. 1978 Census of Agriculture, Vol.1 State and County Data, Part 16, Kansas AC 78-a-16.

CHAPTER 4

SUMMARY AND RECOMMENDATIONS

The study area, Sherman and Thomas Counties, is located on land averaging 3,000 feet above sea level in Northwestern Kansas. This area has been influenced by a continental climate which causes constraints in physical background, e.g., low annual precipitation, high temperature, moderate to strong winds, and high evaporation. But this area has been blessed with two key natural resources: groundwater and suitable soils. The combination of abundant groundwater from the Ogallala aquifer and the soils well suited to either dryland or cropland use through irrigation systems have turned 98 percent of the total area of Sherman and Thomas Counties into cropland.

It is natural that more land in farms meant more groundwater use. Groundwater depletion has occurred in this area along with the associated influences of Kansas Laws and Regulations, higher energy costs and farm expenses, etc. Due to these occurrences, the trend of land use for cropland as well as the pattern of dryland and irrigated land has been changing.

The purpose of this study was to examine changes that have occurred in the study area over the past 10 years (1972-1982) and to draw some conclusions about possible reasons for these changes. Procedures used in this study consisted of two component parts, data acquisition and the analytical process.

Data was derived from census reports, questionnaires, and remote sensing interpretation. Census reports provided background of the study

area and information variables that have had some impact on land use patterns. Responses from questionnaires revealed the awareness and ideas of farmers and officials in the study area. These responses clarified and confirmed data received from census reports. Information from remote sensing interpretation also supported census data and questionnaire responses regarding aspects of land use. Information interpreted from aerial photographs and film positives were formed into land use maps of 1974, 1976 and 1980. Land use change maps which showed the changed areas of cropland and pasture land were prepared through these land use maps. In order to aid the interpretation process, ground truthing was also performed after the interpretation of land use change. A frontal traverse land use sampling technique was used to compile this information.

In the analytical procedure, the acreage changed in land use deduced from the data were portrayed in tabular and map form for analysis. Pre-conversion and post-conversion land use and the continuity of converted parcels were determined by land use change mapping. The impacts of changes were examined, using physical characteristics and other variables, e.g., energy prices, crop prices, etc.

The findings of this study suggest that the structure of land use in Sherman and Thomas Counties has been very dynamic. Of particular significance was the decrease in irrigated cropland, the increase in non-irrigated cropland, and the decrease in pasture land.

One of the greatest changes in land use within the study area was directly related to pasture land which changed to cropland (especially to non-irrigated farming). The suitability of soils for cultivation and needs of more land for non-irrigated farming were the two important

factors influencing pasture land change. Decrease of pasture land has meant larger acreages of land in farms (although some portions of cropland also changed to pasture land).

The year 1978 marked the peak in irrigation acreage. Acres irrigated have decreased while non-irrigated acres have increased since 1979. Change of irrigated to non-irrigated cropland is of great concern to state officials because is has been estimated as a tremendous economic setback for the GWMD No. 4 and the entire state (GWMD No.4, 1978). Although irrigated land increased once in 1981 and 1982 due to the change from irrigated corn (most water-consuming crop) to irrigated wheat (less water-consuming crop), the net increase was still lower than 1979. In addition, since 1979 other components associated with irrigation have resulted in further changes in land use, e.g., energy costs, farm expenses and laws and regulations.

Irrigated land change was primarily related to crop type changes from irrigated corn to irrigated wheat and sorghum. Trends of decreasing irrigated corn have been taking place since 1978. The year 1982 was the point of greatest decrease in irrigated corn.

In summary, reasons for changes in irrigated land and irrigated crop types were due to a few major factors associated with physical constraints such as groundwater depletion, economic pressures like water cost and farm expenses, laws and regulations, and attractive alternative, non-irrigation farming which is perceived to offer more benefits. As a result of these factors, trends of land use in the study area have also changed. Irrigated corn has been grown in larger acreages. Wheat and sorghum seem to be the significant crops of the future.

This study was enchanced by questionnaire responses which provided interesting insights into reasons for changes in land use. Energy costs, low crop prices, and high irrigation expenses were major factors suggested by respondents as affecting changes in land use. The differences in attitude of farmers and officials in perceiving changes were based on economic variables for farmers and both economic and resource supply variables for officials.

Recommendations

When assessing conditions of groundwater depletion and economic pressure, less water use and less capital investment for farming are indeed necessary. As water depletion has not been perceived as the important factor by farmers in this area, the means of conserving groundwater should be introduced through economic means. Research for increasing production on non-irrigated cropland should be of great interest and easy to introduce. Efficient irrigation systems will also play a significant role in conserving groundwater. Cooperation between farmers and officials should support these processes and strengthen the awareness of farmers concerning groundwater depletion at the same time.

BIBLIOGRAPHY

BIBLIOGRAPHY

Agricultural Experiment Station, Dec. 1975. From Desert to Breadbasket : Developing Kansas Land Resources, KSU, Manhattan.

Anderson, James R. et al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, Geological Survey Professional Paper 964, U.S. Government Printing Office, Washington.

Black, Richard, 1983. "Will there be enough?". Who Will Control Our Water Supply, Cooperative Extension Service, KSU, Manhattan, Kansas: pp. 18-30.

Black, R.D., et al., 1979. Soil Moisture Measurements and Aid to Irrigation Water Management, Irrigation Water Management Series, Cooperative Extension Service, KSU, Manhattan, Kansas.

Bossert, Wayne A., 1983. Information on groundwater withdrawal, recharge rate, number of wells, irrigation, and energy. (Written Communication).

Bouwen, Herman, 1978. Groundwater Hydrology, McGraw-Hill Book Company, pp.9.

Bowen, Robert, 1980. Groundwater, Applied Science Publication Ltd., London.

Brocker. M.E., McIntyre, H.J. Jr., and McNellis, J.M., 1977. Groundwater Levels in Observation Wells in Kansas, 1971-75 , Kansas Geological Survey Basic Data Service Groundwater RElease 6,562.

Brown, Merl J. and Bark, Dean, Mar 1971. Drought in Kansas. Bulletin 547, Agricultural Experiment Station, KSU, Manhattan, Kansas.

Buller, Orlan, 1982. Ogallala Aquifer Study in Kansas Linear Programing Model, Kansas Water Office.

Burnside, C.D., 1979. Mapping from Aerial Photographs, Granada Publishing.

Campbell, James B., 1983. Mapping the Land: Aerial Imagery for Land Use Information, Resource Publication in Geography, Commercial Printing Inc. State College, Pennsylvania, pp. 10-11.

Center for Public Affairs, the University of Kansas, 1970-1981. Kansas Statistical Abstract, Lawrence, Kansas.

Cooperative Extension Service, 1978. "1978 Kansas irrigation survey". Engineering Newsletter, KSU, Manhattan, Kansas.

Cooperative Extension Service, 1982. "1982 Kansas irrigation survey". Engineering Newsletter, KSU, Manhattan, Kansas.

Cromley, Robert G., 1982. "The Von Thunen model and environmental uncertainty". Annals of the Association of American Geographer, 72 (3), ppl 404-410.

Darling, David D., 1979. Earnings Attributable to the Differential Yields from Irrigated Crops, Bulletin 24, Kansas Water Resources Board.

Estes, John E., et al., 1982. Monitoring land use and land cover changes. In Remote Sensing for Resource Management, ed. J. Johannsen and James L. Sanders, pp. 100-10. Soil Conservation Soceity of America.

Evans, Marry and Cant, Gart, Oct 1981. "The effect of irrigation on farm production and rural settlement in mid-Canterbury: a comparison of the irrigated and dryland farming zones in the Lyndhurst-Pendarves area, 1945-1976. New Zealand Geographer, Vol. 37, No.2, pp.58-65.

Fetter, C.W. Jr., 1980. Applied Hydrogeology. A Bell and Howell Company, Columbus, pp.4-17.

Fund, Mary and Clement, Elise Watkins, Dec., 1982. Distribution of Land and Water Ownership in Southwest Kansas, the Kansas Rural Center, Whiting, Kansas 66552.

Furuseth, Owen J., May-June 1979. "The Structure of agricultural land conversion in Washington County". Journal of Soil and Water Conservation, Vo. 34, No. 3, pp. 138-141.

De Garis De Lisle, D. 1982. "Effects of distance on cropping patterns internal to the farm". Annals of the Association of American Geographers, 72, (1) 88-98 .

Grigg, David, 1983. "Agricultural geography". Progress in Human Geography Vol.7, No. 2, pp.255-260.

Groundwater Management District No. 4, Feb 1977, Jul 1978, Dec 1978, Jan 1980, Dec 1980, Dec 1981, and Mar 1983. Revised Management Program, Colby, Kansas.

Hay, DeLynn R., 1978. "Selecting an irrigation system". Kansas Water News, Vol. 21, No. 1 and 2, pp. 22-26.

Hay, DeLynn R. and Pope, David L., 1977. Irrigation Tailwater Management System, Extension Engineering in Kansas, Cooperative Extension Service, KSU, Manhattan, Kansas.

Hay, DeLYnn R. and Axthelm, Larry S., 1978. Drilling an Irrigation Well in Kansas, irrigation 8, Extension Engineering in Kansas, Cooperative Extension Service, KSU, Manhattan, Kansas.

Hay, DeLynn R. and Pope, David L., 1974. Groundwater Management Districts in Kansas, Cooperative Extension Service, KSU, Manhattan, Kansas.

Hutchins, Wells A. et al. 1957. The Kansas Laws of Water Rights, U.S. Department of Agriculture, Topeka, Kansas.

Kansas Agricultural Experiment Station, Aug 1980. The Colby Branch Experiment Station and Agriculture in Northwestern Kansas with Special Mention of Soils, Bulletin 636, KSU, Manhattan, Kansas.

Kansas Crop and Livestock Reporting Service, 1977-1980. Irrigation County Estimates, Kansas State Board of Agriculture, U.S. Department of Agriculture, Topeka.

Kansas State Board of Agriculture, 1973-74-1981. 57th Annual Report - 65th Annual Report and Farms Facts.

Kansas Water Office, 1982. Ogallala Aquifer Study in Kansas, Summary, Topeka, Kansas.

Kansas Water Office, 1982. Rainfall-Runoff Relations and Expected Streamflow in Western Kansas, Bulletin No.25.

Koelliker, James K., 1983. Evaluation of the Recharge Capability of Level Terraces in Northwest Kansas GWMD # 4, 2nd Annual Report (Primary report), Civil Engineering Department, KSU, Manhattan, Kansas.

Kramer, John A. 1977. Gravity System Irrigation Efficiency, Department of Agricultural Engineering, KSU, Manhattan, Kansas.

Krommm David E. and White Stephen E. 1982. Response to Groundwater Depletion in Southwestern Kansas, the Kansas Water Resource Research Institute, Kansas.

Lee Linda K. 1979. "Interpreting land use change through satellite imagery". Agricultural Economic Report No,442, U.S. Department of Agriculture.

Lillesand, Thomas M. and Kiefer, Ralph W., 1979. Remote Sensing and Image Interpretation, John Wiley and Sons, pp.96.

McKnight, Tom L., Jan 1983. "Center pivot irrigation in California". The Geographical Review, Vol. 73, No. 1, pp. 1-14.

National Oceanic and Atmospheric Administration (NOAA), 1981. Narrative Summaries, Tables and Maps for each States.

O'Connor, Howard, Oct 20, 1981. Kansas Water Resources and Supplies : A Statewide Perspective, A paper presented to the Kansas Farm Bureau Water Conference, Dodge City Community College, Dodge City, Kansas.

O'Connor, Howard G., McClani, Thomas J., 1982. Ogallala Aquifer Study in Kansas Geohydrology, Kansas Water Office, Topeka.

Pabst, Marilyn E. and Jenkins, Edward D., Dec. 1976. Water-level changes in northwestern Kansas 1950-76, Kansas Geological Survey Journal.

Pair, Claud H., 1970. Sprinkler Irrigation, Leaflet no. 476, U.S. Department of Agriculture, U.S. Government Printing Office, Washington D.C.

Pattison, William D., 1971. "The four traditions of Geography". In Geographical Research and Writing by Robert W. Durrenberger, Crowell, N.Y.

Peck John C. 1982. Legal Constraints of Diverting Water from Eastern Kansas to Western Kansas.

Revisor of Statutes of Kansas, 1981 & 1982. 1981 & 1982 Cumulative Supplement to the Kansas Statutes Annotated, Vol. 6 Division of Printing, Dept. of Administration, Topeka, Kansas.

Rhind, David, and Hudson, Ray, 1980. Land Use, Methuen & Co. Ltd., New York.

Robel, R.J., 1982. Energy Sources and Supply: Future Costs to Water Users, Cooperative Extension Service, KSU, Manhattan, Kansas.

Rogers, Kanny H. et al., 1978. Irrigation Water Measurement, Irrigation Water Management Series MF.468, Cooperative Extension Service, KSU, Manhattan, Kansas.

Rogers, Danny H. and Thomas, James G., 1978. Guidelines for Use of Irrigation Water Meters, Irrigation Water Management Series MF.467, Cooperative Extension Service, KSU, Manhattan, Kansas.

Schmidt, Glen M.m 1977. Energy Use in Irrigation in Kansas: a computer simulation, KSU, Manhattan, Kansas.

Self, Huber, Dec 1972. "Irrigation farming in Kansas". Transactions of the Kansas Academy of Science, Vol. 74,Nos. 3 and 4.

Shurtz, Earl B., 1967. Kansas Water Law, Water Resources Board, Topeka, Kansas.

Sloan, Richard F.m 1979. "Groundwater resource management in Kansas". Kansas Water News, Vo. 22, No.1 and 2, Kansas Water Resource Board.

State of Kansas 1978. Final Report of the Governor's Task Force on Water Resource.

State of Kansas, 1977. Kansas Statures Annotated Vol. 6a, Office of Revisor of Statutes of Kansas, Topeka, Kansas.

State of Kansas,1978. Opinion of the Attorney General, Vol XI, Opinion of Curt T. Scheider, Attorney General, Kansas State Printing Plant.

State of Kansas, 1980. Opinion of the Attorney General,Vol XIV, Opinion of Robert T. Stephen, Attorney General, Kansas State Printing Plant.

State of Kansas, 1972-1979. 1972-1979 Session Laws of Kansas, Topeka, Kansas.

Steener, J.L., Kanemasu, E.T., Powers, W.L., and Pope, David L., 1981. "Legal aspects of diverting water". Kansas Water News, VOL. 24 and 25, No.1 and 2, Kansas Water Resource Board.

TenEyck, George R., 1978. "Sprinkler System irrigation management". Kansas Water News, Vol. 21 No.1 and 2 pp. 27-29.

U.S. Department of Agriculture, Sept 1949. Physical Land Conditions Affecting Use,Conservation, and Management of Land Resources, Sherman County, Kansas, Soil Conservation Service, Manhattan, Kansas.

U.S. Department of Agriculture, Nov 1950. Physical Land Conditions Affecting Use, Conservation and Management of Land Resources, Thomas County, Soil Conservation Service, Manhattan, Kansas.

U.S. Department of Agriculture,Mar 1973. Soil Survey of Sherman County, Kansas, Washington, D.C.

U.S. Department of Agriculture, June 1980. Soil Survey of Thomas County, Kansas, Washington, D.C.

U.S. Department of Commerce, 1972-1981. Climatological Data, Annual Summary, Vol. 86, No. 13 - Vol. 95, No. 13, National Climate Center, Federal Building, Ashville, N.C. 28801.

U.S. Department of Commerce, 1981. 1978 Census of Agriculture, Vol.1 State and County Data, Part 16, Kansas. AC 78-A-16 pp. 656,686.

U.S. Geological Survey, 1980. January 1980 Water Levels, and Data Related to Water-Level Changes, Western and South-Central Kansas, Lawrence, Kansas.

U.S. Geological Survey, 1982. January 1982 Water Levels, and Data Related to Water-Level Changes, Western and South-Central Kansas, Lawrence, Kansas.

U.S. Geological Survey, 1980. "Water Resources Data for Kansas", Vol. 1 Missouri River Basin, U.S.Geological Survey Water Data Report, KS-79-1 Water Year 1979 pp.286-292.

Walton, William C., 1970. Groundwater Resource Evaluation,McGraw-Hill Book Company, pp.47-48.

Water and Power Resources Service Project, 1981. Kansas, U.S. Department of the Interior, pp. 3.

Water Resources Board, Sept 1967. Irrigation in Kansas, Report No. 16 (e).

Wiese, Allen F., and Unger, Paul W., May-June 1983. "Irrigation + dryland farming + limited tillage : a profitable combination". Journal of Soil and Water Conservation, Vo.. 38, No.3, the Soil Conservation Society of America.

APPENDIX A

1. What type of farming activity are you involved ?
   _____ irrigation farming acres (_____)
   _____ dryland farming acres (_____)
   _____ pasture land acres (_____)
   _____ fallow acres (_____)
   _____ other (specify)_____acres (_____)

2. Of the total area you are farming,
   how much do you own ? acres (_____)
   how much do you lease ? acres (_____)

3. If you irrigate land, what type of irrigation system do you practice ?
   _____ center pivot acres (_____)
   _____ side-roll acres (_____)
   _____ flood irrigation acres (_____)
   _____ other (specify)_____acres (_____)

4. In recent years, the amount of irrigated land in your area has been cyclical, increasing then decreasing. What do you believe were the causes of this occurance ?
   _____ irrigation water costs
   _____ energy costs
   _____ low crop price for crops irrigated
   _____ strict water laws
   _____ higher economic dryland farming benefit
   _____ other (specify)_____

5. In Sherman county in 1980, the wheat grown on summer fallow was 171,300 acres, yet in 1981 the wheat grown on summer fallow was 180,300 acres, what do you feel caused this increase ?
   _____ more benefit
   _____ pasture land was swithced to summer fallow
   _____ other (specify)_____

6. In 1979 in Sherman County, irrigated corn acreage was 58,900 acres; in 1981, 46,600 acres. What do you feel caused this decrease ?
   _____ low crop price
   _____ switched to less water consuming crop
   _____ change to corn dryland
   _____ other (specify)_____

7. In Sherman County in 1980, sorghum non-irrigated acreage was 700 acres, in 1981 it was 3,800 acres, what do you feel caused this increased ?
   _____ sufficient yields could be obtained without irrigation
   _____ irrigation water costs were too high
   _____ greater demand for sorghum as cattle feed
   _____ other (specify)_____

8. In Sherman County in 1979, irrigated wheat acreage was 7,700 acres, in 1980 23,100 acres and in 1981 26,400 acres, what do you feel about this increase ?
   _____ desire for more yield per acre over that of dryland farming
   _____ other (specify)_____

9. In 1982 the number of farmers irrigating in Sherman County was 200, decreasing from 250 in 1978. Why do you feel this change occured ?
   _____ less benefit for irrigation farming
   _____ high irrigation expenses
   _____ impact from water laws
   _____ other (specify)_____

10. In Thomas County in 1979, the sorghum irrigated acreage was 12,400; in 1980 8,000; and in 1981, 18,200. What do you think caused this cyclical change ?
   _____ sorghum is a less water consuming crop
   _____ cyclical market demand
   _____ other crops gave less benefit during high sorghum acreage periods
   _____ other (specify)_____

11. In Thomas County in 1980, the sorghum non-irrigated acreage was 10,900 acres, while in 1981, that same non-irrigated crop had an acreage figure of 31,800, what do you feel caused this dramatic increased in acreage ?
   _____ sufficient yields could be obtained without irrigation
   _____ irrigation water costs were too high
   _____ greater demand for sorghum as cattle feed
   _____ other (specify)_____

12. In Thomas County in 1979, irrigated corn acreage was 58,000, yet in 1981 the irrigated corn acreage decreased to 42,800. What do you feel caused this decrease in corn acreage ?
   _____ a change to more water efficient crop
   _____ crop prices
   _____ other (specify)_____

13. Irrigated wheat acreage in Thomas County increased from 5,000 to 11,400 acres from 1980 to 1981. What do you feel caused this increase in irrigated wheat acreage ?
   _____ more yield per acre
   _____ land was changed from dryland farming, or pasture land to irrigated land
   _____ other (specify)_____

14. In Thomas County wheat grown on summer fallow decreased from 240,000 acres in 1980 to 143,900 acres in 1981. What do you feel caused this decrease ?

_____ increased acreage of irrigated crops
_____ increased acreage of other dryland crops
_____ lower crop prices
_____ other (specify)_____

15. In 1982 the number of farmers irrigating in Thomas County was 300, decreasing from 400 in 1978. What do you think caused this change ?

_____ less benefit from irrigation farming
_____ high irrigated expenses
_____ impact from water laws
_____ other (specify)_____

16. Do you think that Kansas Water Law is adequate or inadequate in your area ? _____Yes. _____No.
Explain :_____
_____
_____

17. Do the Kansas Water Laws have any effect on your land use decisions?
_____Yes. _____No.
If yes, what laws appear to have an impact on your land use decision?

_____ Water Appropriation Act
_____ Groundwater Management District Act
_____ Groundwater Exploration and Protection Act
_____ other (specify)_____
In what way ? _____

18. What do you feel are the most important problems affecting the crops planted in Thomas County ?

_____ groundwater depletion
_____ energy costs
_____ advanced technology costs
_____ commondity prices and marketing
_____ other (specify)_____

19. In what way has this (these) problems affected you ?

_____ increased amount of irrigated land
_____ decreased amount of irrigated land
_____ continued to irrigate but changed to more water efficient crops
_____ change to more water efficient dryland crops
_____ other (specify)_____

20. Do you feel the federal, state, or local government should be involved in water management ?

_____ federal
_____ state
_____ local
In what way ? _____
_____
_____

CHANGING STRUCTURE OF RURAL LAND USE IN NORTHWESTERN KANSAS

by

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B.A., Chulalongkorn University, 1968

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

The study area (Sherman and Thomas Counties) has been the most intensively irrigated area of GWMD No.4 (Groundwater Management District), due to the contributions of groundwater and soils. In recent years, the structure of land use in this area (e.g., pasture land, cropland, and the pattern of farming) has changed. Occurrences of groundwater depletion, economic pressure, and issues of laws and regulations have all contributed to land use changes. These changes in land use within a period of 10 years (1972-1982) were studied and examined by using census reports, questionnaires and remote sensing interpretation.

The findings suggest that the results of physical constraints (e.g., groundwater depletion), economic pressure (energy costs, farm expenses), laws and regulations, and attractive alternatives (e.g., non-irrigation farming which is perceived to offer more benefits) have resulted in certain trends of land use. Pasture land has decreased while acreages of land in farms has increased. Land used for irrigated cropland has decreased with greater areas of non-irrigated cropland. Within irrigated cropland, crop types have also changed. Less water-consuming crops (wheat and sorghum) have been grown in larger acreages than more water-consuming crops (irrigated corn), and seem to be the significant crops of the future.