FACTORS INFLUENCING THE CHANGING PATTERNS OF FIELD WINDBREAKS IN SOUTHWESTERN KANSAS

BY

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INTRODUCTION

Wind is an often-present atmospheric phenomena on the plains regions of the world. When coupled with a cultivation type land use and semiarid climate wind can culminate in disastrous effects of wind erosion and ultimately desertification. For many centuries, humans have realized the need for diverginary strategies against the wind to protect the fragile soil and thus, themselves. Windbreaks, or shelterbelts as they are often known, provide an excellent barrier against these prevailing forces. A shelterbelt as defined by Shah, is "a wind barrier of living trees and shrubs maintained for the purpose of protecting farm fields from wind" (1962).

The major advantage of windbreaks is the reduction in wind velocity which in turn results in reduction of soil loss, an increase in soil moisture, protection for livestock and farmsteads, and in temperate climates, provides an effective snow barrier. Although these advantages are proven, many farmers in recent years have expressed dissatisfaction with allotting acreage for windbreaks due to concerns about decreased yields, shading, root competition, and incompatibility with farm machinery and modern methods of irrigation.

This study of windbreak dynamics in Gray and Clark counties of Southwest Kansas presents characteristics and beliefs in practices of area farmers concerning the field windbreak, and the windbreaks role in dryland and irrigation farming.

Background

The control of soil erosion in Western Kansas has been a major concern for many individuals as well as state and federal agencies since early settlement days. The initiation of windbreak planting in the Great Plains to reduce wind erosion began soon after settlers arrived, with planting programs encouraged under a number of state and federal acts (Shultz 1983). As the economic incentives for these plantings diminished in the early 1900's so did the number and frequency of these shelterbelts. This trend of decreased shelterbelt planting continued until the early 1930's, when poor cropping practices and a number of unusually dry years culminated in what is now known as the dust bowl days or the dirty thirties. During the 1930's and early 40's, the Plains States experienced irreparable erosion, with millions of tons of top soil transported by the winds. Then in 1935, a massive Federal windbreak effort was launched under the "Prairie State's Forestry Project". Within an eight year period, approximately 220 million shrubs and trees were planted in strips known locally as shelterbelts (Shultz 1983). After the termination of this project due to the onset of World War II, the planting continued with the help of the Soil Conservation Service (SCS), individual state extension services, and individual state forestry extension programs. Again, today, with help from state and federal agencies windbreaks are planted for many of the initial reasons. Field windbreaks are planted primarily to protect the area from wind erosion, to protect crops, orchards, livestock, or simply to increase the natural beauty of an area. The number of shelterbelts needed in a particular area depends upon many variables. These include climatic factors, soil type, cultivation and irrigation patterns, and the design of the shelterbelts themselves.

A general rule established for adequate crop protection states that 5 percent of the cropland area should be used for the establishment of shelterbelts (Shultz 1983). Research done by the SCS has shown that this percentage will show no net reduction in cropland productivity. Nonetheless many farmers, fearful of decreased yields due to competition and shading, have removed plantings. This growing trend of shelterbelt removal has been sweeping many of the plains states including Kansas (USDA 1977).

Additional reasons given for removal of the windbreaks seem to vary a great deal. However, one reason seems to be the incompatibility with large expanses of irrigated land. The onset of large scale irrigation operations in Western Kansas can be directly tied to the exploitation of the Ogallala aquifer. From 1959 to 1982, the number of irrigating farms in Kansas jumped from 4,529 to 7,257 (U.S. Census of Ag. Kansas 1982), whereas total irrigated acreage increased to 2,675,167 acres within the same time frame (U.S. Census of Ag. Kansas 1959-1982).

The potential for critical wind erosion exists if the removal of these windbreaks continues. This then opens up the possibility for a return to the dust bowl days as well as widespread reduction of yields, economic disaster for western Kansas farmers, and possible long-term environmental impacts.

Statement of Problem

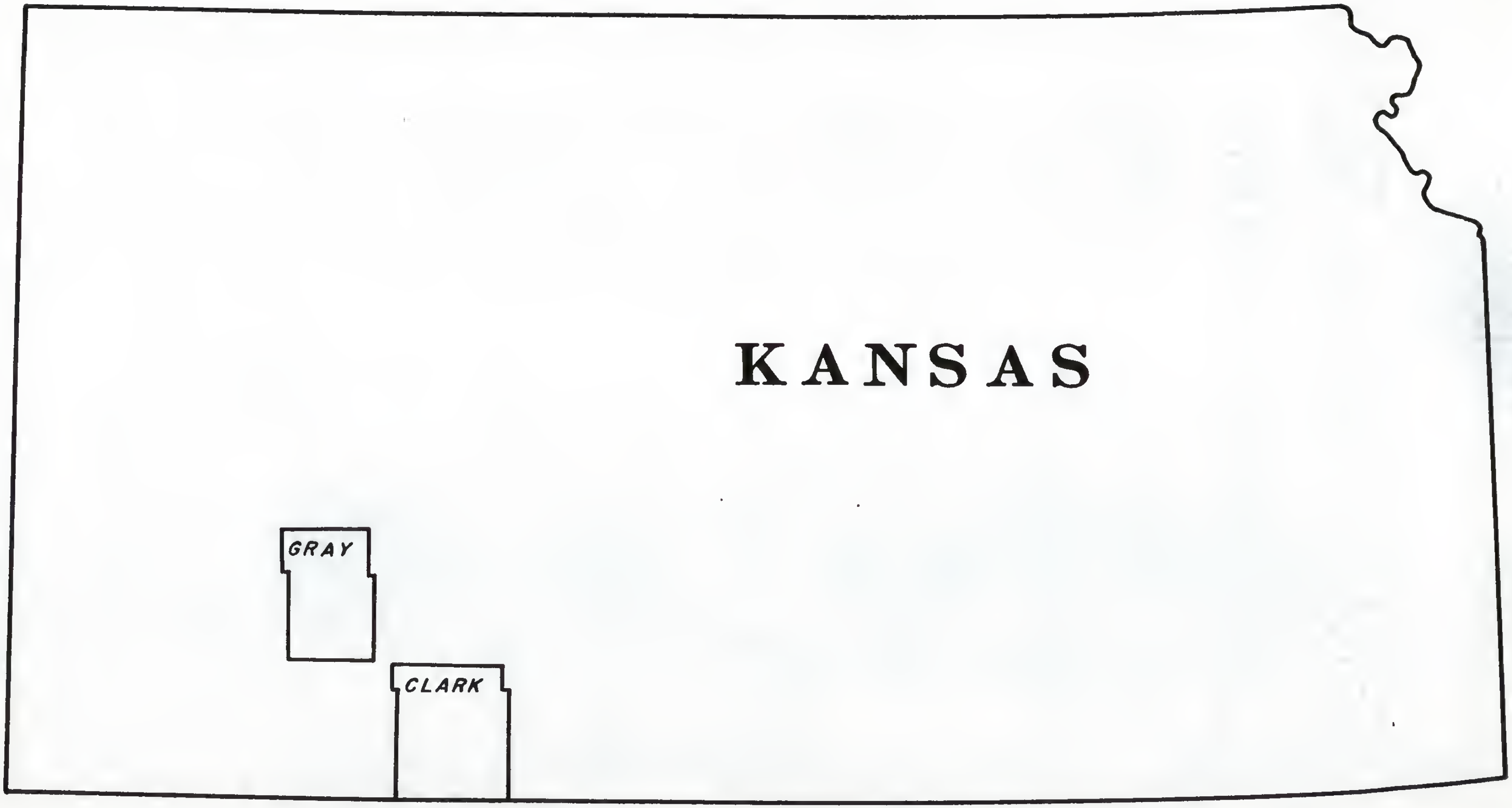
Southwest Kansas is a region experiencing tremendous land use changes associated with agriculture. An important part of the dynamic agricultural system in this area is the location and role of windbreaks. The research had two primary objectives. The first was to map spatial and temporal changes in windbreaks for Gray (predominately irrigated), and Clark (predominately dryland) counties in southwest Kansas. By utilizing photo index sheets for the dates 1960, 1961, and 1981 existing windbreaks were inventoried and mapped for both study counties. The second research objective was to document reasons for and contrasts in the changes in windbreaks for the above area using a mailed questionnaire instrument. The hypothesis examined was based on the premise that increased irrigation is the primary factor responsible for reduced field windbreaks in this region.

Location of Study

The general location of the study site can be assigned to the southern High Plains portion of western Kansas, with specific influences from the Sand Hills and Red Hills regions and the Arkansas and Cimarron River basins (Figure 1). The topography consists of uniformly eastern sloping plains with an elevation of approximately 2,500 feet in extreme western Gray county to approximately 2,000 feet at the Clark/Commanche county line. The gradual eastward slope averages about 10 to 15 feet per mile (Soil Conservation Service 1968, 1982). The eastern limits of the High Plains can be delineated by a line along the Smoky Hills and Great Bend prairie regions of central Kansas. Although constantly flat, the region is marked by deep cut stream beds, areas of erosion and deposition, and areas of wind scour. The climate of this region is defined as semi-arid, where the annual water loss through evaporation exceeds the annual water gain through precipitation (Self 1978). The average annual precipitation received in the area is approximately 20 inches in the West to approximately 24 inches at the Eastern most limits. In this region, precipitation is consistently unreliable and droughts are a common occurrence. Temperatures in the area range from a January average of 27°F. to a July average of 80°F. establishing a growing season of about 200 days in the south to about 170 days in the north (Soil Conservation Service 1968, 1982).

The soils of this region are of the Ustoll suborder with the parent material consisting largely of a wind deposited loess material containing high amounts of silt. In addition to this, alluvium, eolian sand and residuum of sandstone or shale is present, thus forming a general distribution of sand silt loams (Soil Conservation Service 1968, 1982).

The native vegetation covering these soils is a mixed short grass prairie composed primarily of Grama (boutelous), Buffalograss (Buchloe), Sandsage (Salvia), and Little Bluestem (Andropogon), all of which contributes only a small amount of organic matter and hence, less of a nitrogen source for the soil (Anderson & Owensby 1969). Approximately, 34-40 percent of the acreage in this short grass prairie is used for cultivated crops. The crops best suited to the study region are wheat (which accounts for about 50 percent of the cropland)



(study counties shown)

figure 1

sorghum (on 10 percent) and alfalfa, barley, rye, and corn (on 3 percent) (Kansas Farm Facts 1986). The remaining acreage is left to summer fallow, a practice applied to dry farmed areas where the soil is kept free of plants, or left in residue during one crop season to catch and hold moisture for the following season.

Approximately 60 to 65 percent of the remaining acreage for the study area is in rangeland. Area livestock operations are principally cattle with cow-calf and stocker ranches about equal in extent (Soil Conservation Service 1968, 1982). On most ranches, the forage produced on rangeland is supplemented by crop residue, protein supplements and small grain. The most productive areas of rangeland occur on subirrigated soils of the flood plains and terraces where a seasonal high water table provides additional moisture. Production potential is lowest in areas of shallow soils where the water capacity is low.

The natural wooded lands of the region occur in narrow corridors along the Cimarron and Arkansas river systems. Some scattered stands of trees and shrubs can be found in protected wet areas along canyons and breaks or alongside intermittent stream channels. These areas support mainly Eastern Cottonwood (Populus deltoids), Black Willow (Salix nigra), Hackberry (Celtis occidentalis), American Plum (Prunus), and Tamarisk (Tamarix). Some of this woodland is used as a source of firewood but is too scattered to be of any economic value, and so is left to wildlife habitat or other miscellaneous purposes.

One of the most important aspects of the region, and significant to this study, is the presence of the Ogallala aquifer. This aquifer underlies much of the western one-third of the state and ranges in thickness from one to 600 feet. The specific area of this study consists of two extremes: Gray County represents one of the highest concentrations of irrigation for the region, while Clark County indicates one of the lowest concentrations. A final significant point to be made here is that these are both counties in which the SCS windbreak planting projects have been traditionally active (Conner 1987).

Justification

By exploring human modification of the land through the factors of agriculture and windbreaks, this thesis can be linked to man-land studies, one of Pattison's four traditions of geography (Durrenberger 1971). Historically, some geographers have been involved in forest resource studies, and the dynamics associated with the resource. In the January 1985 issue of the Journal of Forest History, S.L. Stover of Kansas State University explored "Silviculture and Grazing in the New Forest: Rival Land Uses Over Nine Centuries." In this article, Stover explored the ancient and present day practices of silviculture and grazing combined with the new pressures of recreation in the new forests of South England. In the October, 1984 issue of the same journal, S.H. Olson, a geographer from McGill University, contributes "The Robe of the Ancestors: Forests in the History of Madagascar," here Olson looks at demands on the forested remnants of Madagascar due to population and landuse pressures.

Forestry studies utilizing remote sensing techniques are also widespread among geographers. In the April, 1985 edition of Applied

Geography, Charles Watkins article, "Sources for the Assessment of British Woodland Change in the Twentieth Century," documents the use of black and white low altitude aerial photography to track woodland dynamics in the British countryside. And again, in the April, 1984 edition of the same journal, A.K. Tiwari and J.S. Singh employ the same type of sensing for their study, "Mapping Forest Biomass in India through Aerial Photographs and Non-destructive Field Sampling." A more in-depth review of remote sensing techniques is included in Chapter 2 of this thesis.

Within this study region, only minimal work has been done in the area of windbreak inventory. And, although there have been studies done dealing with individuals use of both groundwater and the effectiveness of windbreaks, little has been researched into correlations between the two. This study will address the correlation between groundwater development and windbreaks and also help to clarify for state and federal agency officials reasons for windbreak removal in these southwestern counties. This research presents needed information on human adaptation to nature and ways in which people have modified the natural system.

Methodology

Three methods of obtaining data were employed in this study. The first method was to review all pertinent literature involving the study of windbreak dynamics and farmers perceptions as to windbreak establishment on their land. Along with these, studies involving remote sensing techniques in forest inventory were reviewed as well. The next method was to procure low altitude black and white air-photo mosaics for both Clark and Gray counties for the years 1960, 1961 and 1981. Then, using a remote sensing magnifier, field windbreaks for the two respective dates were inventoried and mapped. The resulting spatial and temporal changes were analyzed to assess dynamics of change within each counties windbreak system. In addition, each photo-mosaic was inspected in an attempt to uncover additional reasons for change. Figures 2 and 3 illustrate the use of this technique and show the effects of installation of a pivot sprinkler irrigation system on field windbreaks.

The third method used in gathering data entailed the use of a mailed survey consisting of questions pertaining to both agricultural practices and field windbreaks. Using information obtained from the county Soil Conservation Service offices, names of 150 land managers who currently, or within the past 27 years have had windbreaks on their property were determined. The 27 year time frame revealed changes in windbreak and farming practices from the pre-irrigation period of the early 1960's to the high point of irrigation in the late 1970's. Information on farm organization, irrigation methods, and reasons for windbreak alteration or addition were gathered using this survey. The questionnaire results were then coded and analyzed using chi-square statistical operations which provided information on the significance of correlation and relationship among variables. Examples of associations with windbreaks include age of farm operator, years of operation, amount of acreage irrigated, and years of windbreak alteration.

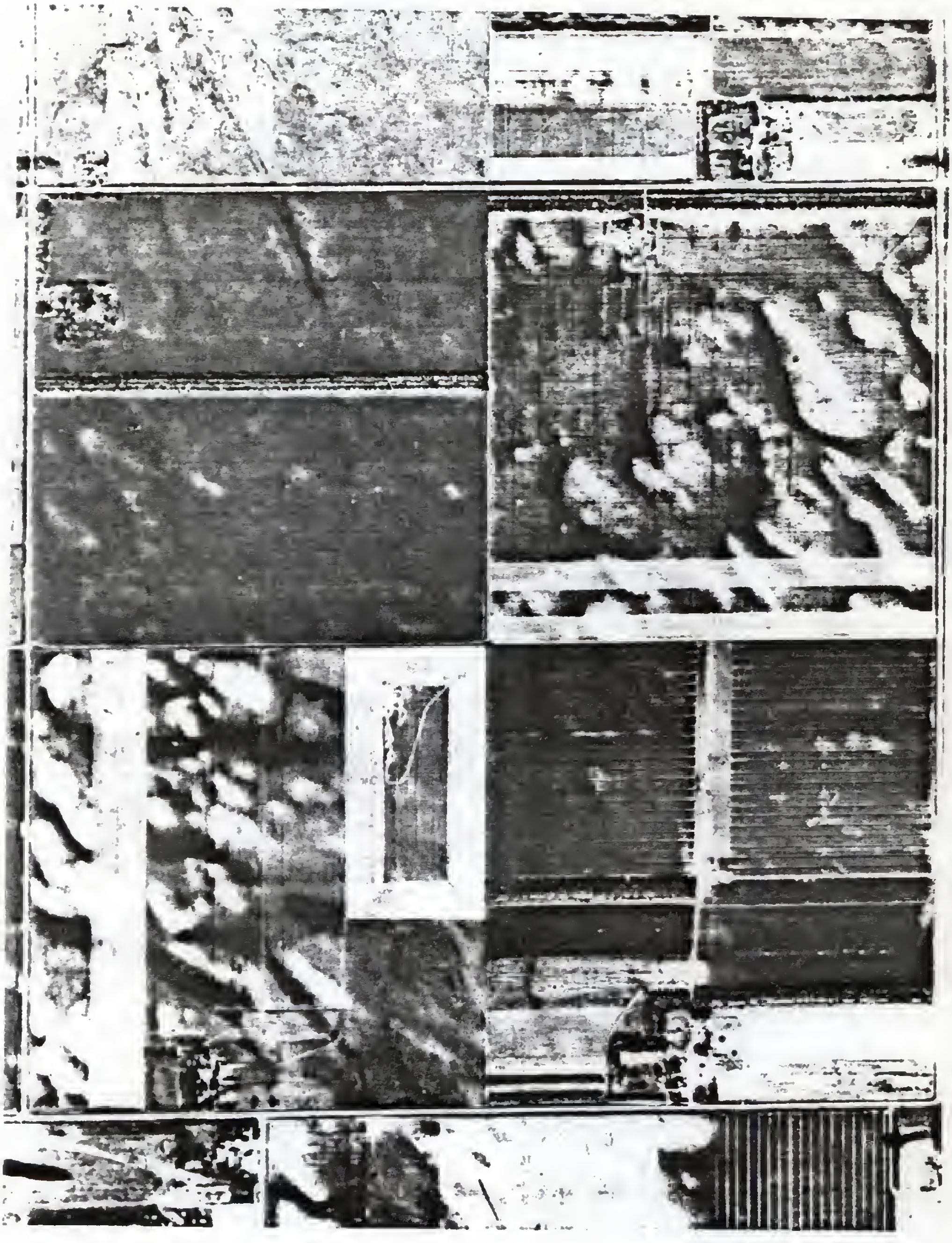


Figure 2

This is a 1967 aerial photo of 640 acres containing four farmsteads and 4 wide field windbreaks. Three of the field windbreaks offer some farmstead protection.

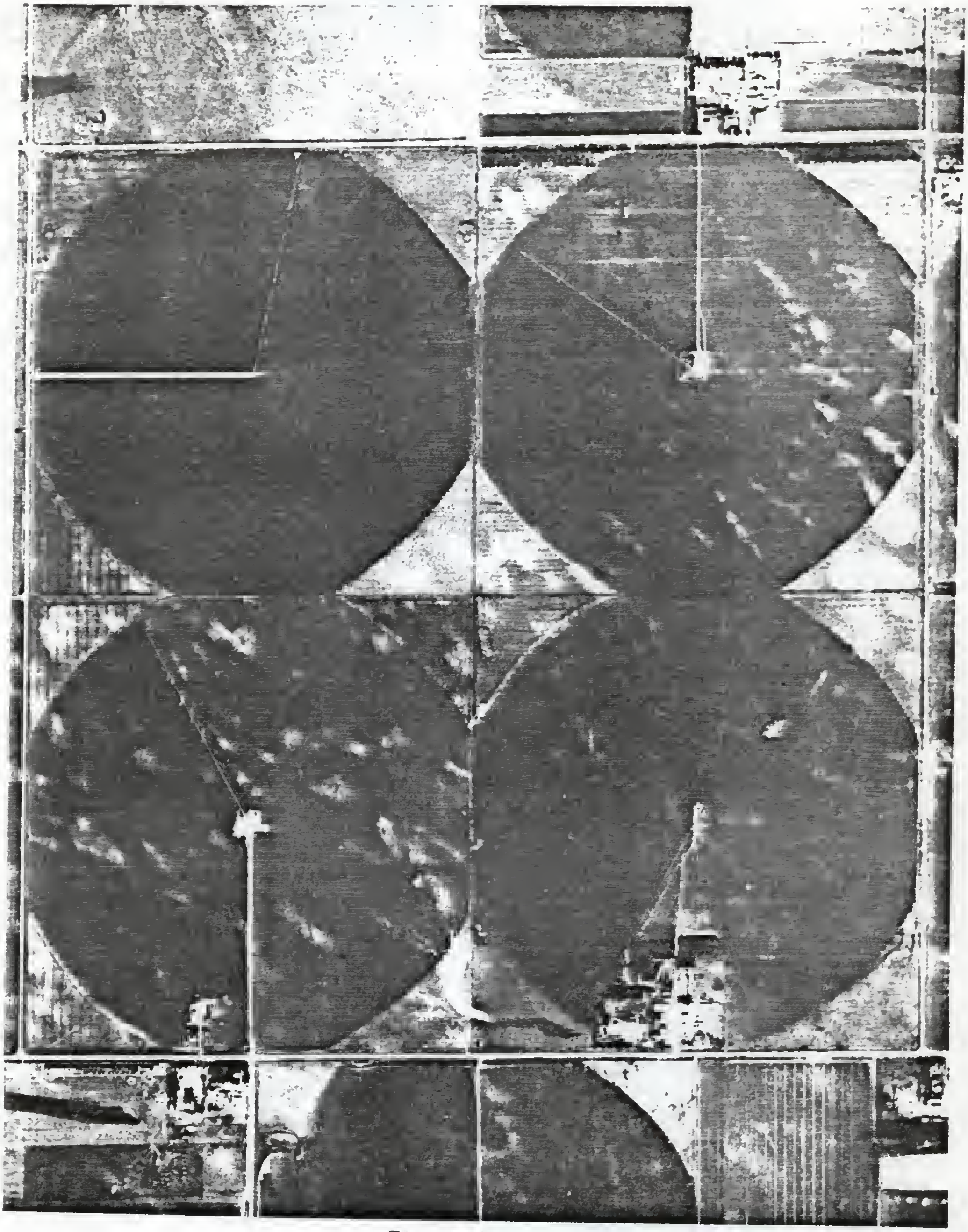


Figure 3

This is a 1974 photo of the same 640 acres shown in Figure 2. Four pivot sprinkler systems are present. Two of the windbreaks have been completely removed. Most of the ones in the southeast quarter is gone. The middle third of the windbreak in the northeast quarter has been reduced to a single row. Two farmsteads have been eliminated.

The reasons for having chosen these two counties are threefold. First, this procedure allowed data to be taken from counties with relatively equivalent amounts of land area. Second, by using a set number of counties possessing equally high and low irrigation development, it permitted the researcher to discern whether or not high instances of irrigation are related to high instances of windbreak removal. And thirdly, these counties provided a manageable scale for intensive survey research.

It must be noted that the information obtained from this study is representative of windbreak changes that have occurred in only these two test counties, and is not necessarily indicative of the entire state. However, it would seem likely that counties showing similar physical and economic conditions would not differ significantly from those studied. Also, many of the newer windbreaks, those less than three years old, could not be detected using this remote sensing technique due to the size of the young trees and the limited resolution of the photographs.

Plan of Study

A review of literature pertaining to windbreaks, pertinent irrigation practices and forest inventory through remote sensing techniques is discussed in chapter two. Chapter three involves the theory and practice of field windbreaks and how they relate to farming practices in Clark and Gray counties. Chapter four investigates changes in windbreak patterns observed through research methodology. And finally, a conclusion and summary are offered in chapter five.

Chapter 2

REVIEW OF PERTINENT LITERATURE

A number of studies have contributed to an understanding of the significance of windbreaks and the role that remote sensing can play in monitoring vegetation change. This chapter reviews relevant literature from three themes: (1) information in the theory and principle of windbreak establishment and function (as well as, a review of some previous studies citing research into shelterbelts); (2) a review of literature pertaining to irrigation practices and associated water and land use adjustments in southwestern Kansas; and, (3) a look at forest inventory and measurement studies utilizing remote sensing techniques.

Windbreak Establishment and Function Studies

Studies dealing with the establishment, function, and effects of windbreaks have been a favored line of research for many academics as well as government agency officials for a number of years. In an international forestry aid publication by Ffolliott and Thames (1983) general guidelines are discussed for the establishment of windbreaks. It is stated that shelterbelts are most often planted so they will develop a triangular cross-section, consisting of taller trees in the middle flanked by smaller trees and shrubs on both sides. In considering density, a general rule cited for efficiency in both humid and dry climates is a 5 row windbreak. Windbreaks consisting of more rows may be desirable but those consisting of less than three run the risk of developing holes that may actually funnel the wind. Spacing within rows as stated depends in part upon the tree and shrub species to be planted and the type of management to be followed once the shelterbelt matures. A general rule offered is that seedlings are closely planted to achieve early closure. Then, as plants mature every other one is removed. The final spacing should be 1 to 1.5 meters for shrubs and 2 to 3 meters between trees. Spacings between rows should range from 3 to 4 meters to allow maximum wind reduction (Ffolliott and Thames 1983).

A publication by Logginov (1964) elaborates on the benefits to agricultural productivity brought about by the establishment of windbreaks. It was found by Byallovich (1940) that increased yields in the Kiev, USSR were evident west of planted shelterbelts equal to a distance 25 times the height of the tree stand. And then East of the planting, equivalent to 15 times such height. As to actual increase in grain crop yield, according to the same analysis, it amounted to approximately a 25 percent increase as compared with average yields on unsheltered fields. The same study states that the maximum effect is usually not seen at the crop/tree interface but at a distance equal to 3 to 5 times the height of the tree stand. Therefore, it is the misconception of many that the immediate vicinity of the shelterbelt is detrimental to crop yield. In actual fact, however, the yield at the forests edge is still usually higher than on open, unsheltered fields.

In a publication by Caborn (1965) an emphasis is placed on microclimate enhancement brought about by the presence of windbreaks. He states windbreaks perform many roles: controlling the ravages of wind; improving environmental conditions for plants, animals, and people; increasing the output from arable farms and upland grazing; checking light soils from blowing; reducing heat loss from houses; and, in some cases yielding timber as well as shelter. He goes on to offer examples of wind abatement and climate alteration attributed to shelterbelts. In areas where moderately dense shelterbelts are present, wind abatement up to 20 percent for 20 yards windward and 150 to 200 yards leeward may be achieved. Air and soil temperatures and humidity within the area tend to increase, whereas water loss from soils and plants (through evaporation and transpiration) tends to decrease. In looking at benefits to human habitation, experiments conducted in the U.S. at four different locations, where indoor temperatures were maintained at $70^{o}F$, realized a savings of 20 percent in fuel consumption based on maintenance of northerly shelterbelts.

In his study on wind protection, Shah (1962) also discounts the misconceptions held by many farmers concerning decreased crop yields resulting from field windbreaks. In reviewing the various advantages and disadvantages of field windbreaks, he states, "there is no doubt that the benefits from the protection of wind by means of living wind barriers outweigh the few detrimental effects". Research conducted by Shah in the Netherlands on soybean and maize crops proved noticeable differences in crop development from protected fields versus unprotected ones. As Shah determined, the protected zones were leading in growth over the unprotected zones to a considerable extent until the onset of unfavorable weather conditions in the controlled zone. However, even under unfavorable climatic conditions, the protected bean crop still showed a 12 percent increase in yield. In the analysis of maize crops, he found the greatest differences in growth acceleration on protected fields in the early stages of development. This later leveled off to roughly equal that of the unprotected field, but still resulted in a 17 percent to 18 percent yield increase.

Konstantinov and Struzer (1969) set about to disprove the theory of soil moisture loss resulting from field windbreaks. It was found that for an average sized field of 100 to 250 acres, the evapotranspiration dropped by 10 to 20 percent under the influences of shelterbelts. This meant that the decrease in the evapotranspiration from sheltered crops alone saved one half to one inch on soil moisture annually in semi-arid zones. This additional water can then lead to a considerable increase in the yield in the regions considered.

In a study done by Skidmore and Hagen (1977), reducing wind erosion through trees, shrubs, tall growing crops and grasses were explored; with results seen through mathematical model application. In an experiment using wind data from Dodge City, Kansas, Bismark, North Dakota, and Great Falls, Montana, influences of a 40 percent porous wind barrier on erosion forces at various distances from the barrier were calculated. Different barrier orientations were also taken into consideration. When the barrier was parallel to prevailing wind erosion direction, the wind erosion forces were less than 25 percent that of an open field at 25 acres leeward of the barrier and less than 50 percent open field at a distance of 37 acres leeward. Because of seasonal variations in wind direction and speed (a phenomena seen best at the Dodge City test site), the need and degree of protection was also seen to vary seasonally. In the example given in the Skidmore and Hagen study, the March winds of the Dodge City area were much stronger than the August winds, showing that East-West oriented barriers afford greater protection on the South side. While the August winds being more southerly resulted in wind reduction more on the barriers North side.

In a 1977 study done by the Soil Conservation Service, field windbreak removals in North and South Dakota, Nebraska, Kansas and Oklahoma were reviewed for the years 1970 to 1975. During this study period, it was found that the number of field windbreaks increased by a total of 2.5 percent. However, the total area coverage saw a decrease of 2.0 percent for the same time frame illustrating a trend towards narrower plantings. Total length of field windbreaks showed an increase of 1.8 percent over 1970. Of the five states sampled, only Oklahoma showed serious windbreak loss by all three measures (of total number of windbreaks, total area of coverage and total length). Over the five year period, Oklahoma had a windbreak decrease of 3.9 percent by number, 3.9 percent by area, and 4.1 percent by length. The principally identified reason for windbreak removals was the installation of irrigation systems. Under the research system used, reasons for removal could not be determined in about two-thirds of the cases. Of the ones for which removal was determined, irrigation was the cause of 53 percent of the numbers removed, 72 percent of the area removed, and 60 percent of the length removed.

Irrigation Practices and Associated Water and Land Use Adjustments in Southwest Kansas

Water and land use adjustment studies, especially those concerning irrigation, have commanded much attention from researchers in many disciplines. In an article by Tomayko (1983), the changing of the southwest Kansas environment through irrigation is explored. Dr. Toymako states the appearance of the Southwest Kansas environment has been changed by large scale irrigation. The earlier practice of ditch irrigation helped to green marginal areas, but modern day pump irrigation has made even the most unproductive areas bountiful, taking with it most any remnant of earlier agricultural practices, to include shelterbelts and woodlots. Tomayko goes on to say that without more conservation practices (wind and water) the period of irrigation in Southwest Kansas will probably cease before the middle of the 21st century.

In a 1984 publication by Nellis, land-use related adjustments to aquifer depletion in Southwestern Kansas are discussed. In this study, three major observations are made which could directly influence the presence of shelterbelts in the research area. First, Nellis states the structure of land transformation has been strongly influenced by the availability of water for irrigation; thus, indicating a disruption of past land use as a result of recent exploitation of groundwater. Second, he states that during the past decade, the country wide growth rate for center pivot usage was twelve times that of all other forms of irrigation. This is of major importance when it is realized that center pivot systems are the dominant form of irrigation for this region; and the least compatible with planted shelterbelts. And thirdly, he brings to light the fact that the amount of irrigated land has increased by 124 percent since 1972 for the study area, again, directing attention towards inevitable land alteration due to irrigation.

In an article by Kromm and White (1984) irrigation and land use adjustments resulting from the depletion of the Ogallala aquifer in Southwest Kansas are discussed. Again, results of this research provided useful information concerning possible windbreak alterations. According to Kromm and White, the 13 southwest counties studied makeup only 13 percent of the states area but account for over half of the states irrigated acreage; averaging about 1,700,000 acres. Along with this, over 90 percent of the water withdrawn from the Ogallala in southwest Kansas is applied to the land for irrigating crops. This illustrates the potential for windbreak alterations due to incompatibilities between the wooded strips and large bulky irrigation equipment. The results of the survey used in this study show a tendency of farmers to favor continued irrigation. The major adjustment focused on improving efficiency of water use, thus indicating an unwillingness to forego irrigation practices.

In a 1983 publication by Marotz, human's ceaseless desire to modify the landscape of the western frontier is discussed. Emphasis is placed on the early plantings of farm woodlots and the later windbreak row plantings. He also illustrates how the onset of pump irrigation has altered these traditional practices. Marotz states that with the development of center pivot irrigation systems in the mid 1960's, alteration of the existing landscape ensued. Early rigs required a field clear of trees. Since up to 720 acres could be irrigated at one time, there was little room for shelterbelts or tree rows of any kind. He continues in stating that many shelterbelts had to be removed to accommodate the rigs, a factor that some people believed led to a decrease in shelterbelt totals in many Kansas counties in the 1950's and 60's. Marotz extends his view of microclimate alteration into the 1980's when changes in farming practices brought about by economic factors may also have had an effect on tree planting practices. He states that shelterbelts around fields took up valuable acreage in a farm economy that favored maximum total production and farmers contemplating a shelterbelt may have chosen to put crops in that acreage instead.

In a 1977 article by Sorenson and Marotz, changes in shelterbelt mileage statistics over four decades in Kansas was investigated. The authors tabulated the number and location of shelterbelt removals over a 40 year period in 13 Kansas counties. Attempts were also made in determining reasons for changes in shelterbelt mileage. The results showed that about 20 percent of the shelterbelts present in the years 1956 to 1962 had been removed by 1970. The main reason found for this removal was continued deterioration of the original plantings. Additional reasons given were the increased instance of center-pivot irrigation and the desire for larger expanses of cropped land.

In a 1979 publication, again by Marotz and Sorenson, the depletion of a "Great plains resource: the case of the shelterbelt" is researched. It was found by the researchers that by converting the linear totals studied to aerial estimates a shelterbelt 1.67 kilometers or one mile long would cover 6.3 to 6.5 hectares or about 16 acres. Converting kilometers to hectares and then to acres 17,391 acres of trees were present in the thirties, with additions amounting to 30,635 acres from the thirties to the fifties, with an average loss of about 9,306 acres between the fifties and the seventies. The researchers noted with extrapolation to the entire Kansas shelterbelt zone on a proportional basis would produce a disappearance figure of some 8,405 hectares or 20,764 acres or 89.2 square kilometers of trees. Reasons offered by the authors for shelterbelt loss are: development of new soil and moisture conservation practices, utilizing open fields; the drop in farm income due to low commodity prices and rising production cost encouraging planting of more land; a negative perception concerning shelterbelt usefulness; active removal fostered by the introduction of center pivot irrigation systems; and, simple deterioration of the original plantings.

In a paper presented at the 34th annual meeting of the U.S. Forest Service committee, Scholten (1982) addressed the issue of shelterbelt and center pivot irrigation incompatibility. Scholten states that increasing numbers of windbreaks in the great plains are removed or topped to accommodate the center pivot machinery, and with exposed fields subject to wind erosion an urgent need is seen for a modification to the traditional windbreak system. The author suggests the adaptation of lower growing shrub species in place of trees that would still afford some protection and yet create less of an obstacle for center pivot irrigation equipment. Out of 16 shrub species tested approximately 8 showed adequate survival rates, with 4 species exhibiting what was termed an excessive amount of spreading. In the preliminary results an average of five species proved to have good to excellent potential for shelterbelt replacements. However, it was pointed out that several years of additional testing must be seen before farming recommendations can be made.

Remote Sensing for Forest Inventory and Measurement

Applications of various remote sensing techniques to forest resource studies have become increasingly widespread in recent years. In an article by Watkins (1985) the different sources for the assessment of British woodland change were explored. The paper considered the sources available to geographers and others for the study of woodland change in Britain, particularly within the twentieth century. One technique he explores is the use of black and white aerial photographs at a scale of 1:10,000. He states that many types of vegetation can be usefully mapped using aerial photographs, especially where there is extensive land area to be covered or where rough terrain presents difficulty in cross country travel.

In a 1984 publication of Applied Geography, Tiwari and Singh used black and white aerial photographs and other non-destructive field sampling techniques to map forest biomass in India. The study area was mapped through the interpretation of black and white aerial photos (1:40,000). By using a double scanning mirror stereoscope and a photo interpretation key (developed through earlier reconnaissance surveys), different forest types were delineated on the aerial photographs on the basis of crown characteristics. Interpreted details from the photographs were then transferred to a base map of the study area, providing a spatial analysis of forest type and cover class.

In the proceedings from the Pecora 10 Conference (1985), a symposium dedicated to remote sensing research as it pertains to forest and range resource management, several articles are offered dealing with large scale photography and forest mapping. In R.C. Heller's article, "Remote Sensing" Its State-of-the-Art in Forestry", Mr. Heller states that "Today, photointerpretation of aerial photographs remains the principal source of information for forest management, protection, and assessment. Again from the same proceedings, H.R. Stoin discusses small format aerial photography use for monitoring southern U.S. pine plantations. Here he states that large scale photographs are especially useful in sampling, analyzing, and measuring small trees and ground vegetation in greater detail than is possible with conventional medium to small scale aerial photos. Also from the same proceedings, Theodore Setzer and Bert Meads article "Aerial Photo Stand Volume Tables for Southeast Alaska" assesses reliable timber volume estimates using low altitude aerial photographs to augment ground measurements. Here, the authors state that reliable aerial photos can improve volume sampling errors.

Conclusions

Research into the areas of windbreak establishment, function, and alteration as well as a look at land use adjustments in southwest Kansas are widespread. Not so prevalent are studies utilizing low altitude remote-sensing techniques in the practice of forest inventory; however, as technology advances so does the feasibility and practicality of these studies. It is the belief of this researcher that with the help of these earlier studies and implementation of my own research through low altitude imagery and mailed surveys, new conclusions in windbreak adjustments can be drawn, and the external influences that may be the cause of those adjustments revealed.

Chapter 3

LAND RESOURCES OF GRAY AND CLARK COUNTIES

To understand the dynamics of windbreaks in southwest Kansas requires background about the rural geographic system, with a particular concern for the land resource base and institutional framework in which farmers operate. This chapter, therefore, provides a more complete look at the existing resource base, land use characteristics and institutional framework in Clark and Gray counties. As such, the chapter addresses spatial similarity and the diversity between the two study counties to set the stage for reasons for change in windbreak land use addressed in the subsequent chapter.

History and Physiography of Gray County

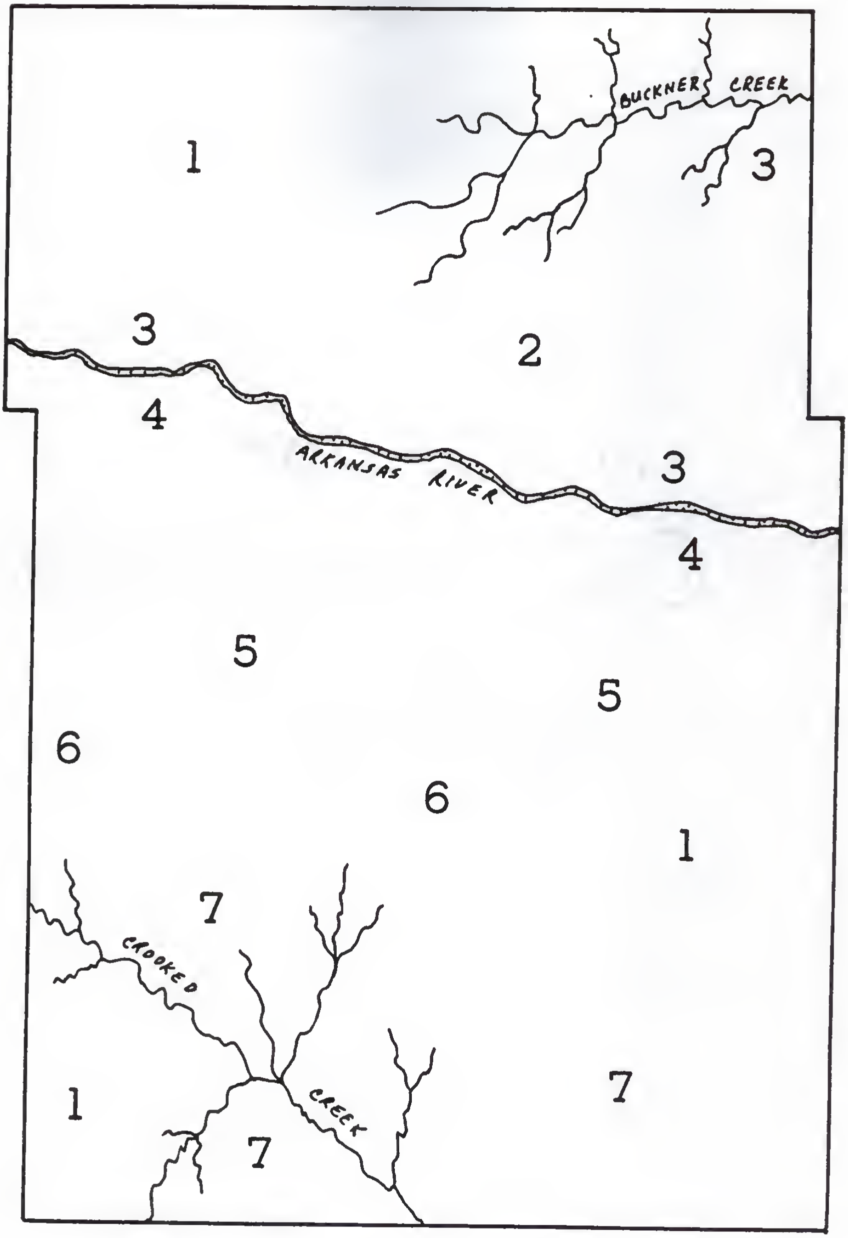
Parts of what is now Gray county has been successively held by Spain, France, Mexico, Texas, and the United States (which gained control of the area in 1854). The Santa Fe Trail in its earlier days passed through the present towns of Cimarron, Ingalls, and Charleston, but by 1830 the majority of traffic crossed the Arkansas River near Cimarron (Rennie 1961). The area began to see major settlement by the early 1870's with the construction of the Atchinson, Topeka and Santa Fe railway which provided a lifeline to the East for new farmers and ranchers. The county itself was organized in 1887 and was named for Alfred Gray, the first secretary of Kansas State Board of Agriculture. The population of Gray county has fluctuated since 1887 with rapid decreases seen in times of prolonged drought, but significant increases when there was enough rainfall to produce successful crops. The present day population stands at 5,436 with approximently 2,310 of those being rural residents (County Clerk, Gray County 1987). Population centers for the county are Cimarron, the county seat, Montezuma, Ingalls, Ensign, Copeland and Charleston, in respective order of size (County Clerk, Gray County 1987).

Gray county is located in the High Plains portion of the Great Plains physiographic province. Elevation in the county ranges from about 2,900 ft. above sea level in the Northwest corner to about 2,550 ft. in the Southeast part of the county. In general, most of the county consists of nearly level to gently sloping plains, a feature typical of the High Plains. The Arkansas river which bisects the county is bordered on either side by upland plains which are nearly level and exhibit poorly defined drainage patterns. The area of uplands south of the Arkansas River is bordered on the north by hummock sandhills and on the south by the drainage basin of Crooked Creek. The areas of more steeply sloping land lie between the upland areas of the flood plains of the Arkansas River, Crooked Creek and their respective tributaries. The surface of these steeper areas is more dissected than the plains. A prominent band of hummocky sandhills and stationary dunes lies south of and adjacent to the floodplain of the Arkansas River. This band is about 2 to 4 miles wide and extends across the county, roughly parallel to the river (Soil Conservation Service 1968). The Arkansas River flows east southeast across the Northern one-third of the county, and Crooked Creek, crosses the southwestern part. The flood plain of the Arkansas River is nearly level and ranges in width from 1 to 1.5 miles. On the north is a fairly continuous line of low bluffs; on the south are sandhills. Numerous intermittent streams empty into the river from the north, but only one short stream, which is in the extreme eastern part of the sandhills, empties into the river from the south.

Soils of Gray County

To determine the quality of the land to support crops and shelterbelts, this section addresses the soil characteristics of Gray County. The materials from which the soils of Gray County developed consist mainly of 1) loess deposited in Pleistocene time, 2) outwash sediments of late Pliocene or of Pleistocene time, 3) eolian sand deposited in Pleistocene time, and 4) alluvium deposited in recent time (Soil Conservation Service 1968). The loess deposits consist of almost grit free materials that were deposited by pre-historic winds of the Wisconsin stage of glaciation during the Pleistocene time. Loess deposits of the High Plains generally range from about 10 to 30 feet in thickness. Spearville, Richfield, and Harney are the dominant soil series in Gray County which developed from these loess deposits (Soil Conservation Service 1968). Found in the rolling erodible uplands, in the East-central part of the county, are limy outwash sediments of the Pliocene and Pleistocene time. In most places these sediments consist of unconsolidated, stratified, silt, sand and gravel. In other places the sediments are of weakly cemented, limy sand, silt and clay. These deposits can contain beds of caliche, which are exposed in places. The Potter soil is the only soil in Gray County developed entirely of these outwash sediments (Soil Conservation Service 1968). In the erodible

SOILS OF GRAY COUNTY



1 SPEARVILLE-RICHFIELD
2 SPEARVILLE-HARNEY
3 MANSIC-ULYSSES
4 LASANIMAS-LESHARA-LESHO
5 PRATT-TIVOLI
6 MANTER-SANTANA
7 RICHFIELD-ULYSSES

(FIGURE 4)

valleys below the summits here, the loess is thin and wind has mixed much of it with the more sandy outwash materials. The Mansker and .pa Mansic soils can be found in these areas (Soil Conservation Service 1968). Several soils have developed in eolian sand in a band that extends across the county south of the Arkansas River. The deposition of this sand began in late Pleistocene time and continued into recent time. The hummocks and dunes of this sand are steep and choppy near the river, but towards the south they gradually become less steep. Tivoli and Pratt soils are dominate in this sandy material (Soil Conservation Service 1968). The soils of Gray County that developed in alluvium are young. The alluvium ranges from clays to sands in texture and is lighter colored in areas of silt and sand. The Bridgeport and Dale soils, on the more stable deposits have a more distinct profile than the LasAnimas and Lincoln soils, on the less stable deposits (Soil Conservation Service 1968).

The soils of Gray County are well suited to farming and range management. Although much of the farming traditionally has been dryland, increased irrigation development has been abundant in recent years. Most of the soils in Gray County are typical prairie soils; deep, sandy to clayey loams. Of the seven major soil associations found, two, the Spearville-Richfield and the Spearville-Harney associations make-up approximately 56 percent of the land area for the county. These soils are classified as nearly level, deep, clayey and loamy soils. Most of the acreage in this association is used for cash crops of wheat and sorghum. An area near Montezuma makes up the major part of the land irrigated in Gray County. Wind or water erosion are hazards to this association and water conservation measures are needed for profitable crop production.

The Mansic-Ulysses association is found primarily along the northern bank of the Arkansas River, and in a small portion of the northeast corner of the county. This association is predominantly sloping to steep, and makes up only about 3 percent of the counties land area (Soil Conservation Service 1968). Most of this association remains in native grasses and is utilized for grazing. On gentler slopes, cash grains such as wheat and sorghum are grown, however, crop failures are numerous. Both wind and water erosion is a serious hazard on the cultivated areas, and both water and soil conservation practices are advised.

The LasAnimas-Leshara-Lesho Association is level, deep to shallow, moderately drained soils that are found in the flood plains along the southern borders of the Arkansas river. This association makes up about 4 percent of the county land area (Soil Conservation Service 1968). Some areas of this association are cultivated under irrigation but the majority are left to grazing due to a high water table.

The Pratt-Tivoli Association is found in the broad band of sandhills that are south of and adjacent to the Arkansas River Valley. This association makes up about 14 percent of the county (Soil Conservation Service 1968). These soils are fine to heavy sandy loam with good drainage. Most of this association is used for rangeland, however, some areas of Pratt are used for cash crops of sorghum and wheat. Although wind erosion is the main hazard on this soil, proper management can control this.

The Manter-Satanta Association is found in areas adjacent to the sandhills and consists of level to gently undulating loamy soils. This association makes up approximately 11 percent of the counties land area (Soil Conservation Service 1968). Most of this association is used for cash crops of wheat and sorghum. Wind erosion is a threat throughout the association, and water erosion is an additional hazard on the more sloping soils.

The Richfield-Ulysses-Mansic Association consists of two areas in the southern part of the county. The association amounts to about 12 percent of the county, and is sloping to steep in some valley areas (Soil Conservation Service 1968). Much of the association that is gently sloping is cultivated with wheat and sorghum, while steeper areas are left to grazing. Wind and water erosion are serious hazards and water conservation practices are needed for profitable crop production.

History and Physiography of Clark County

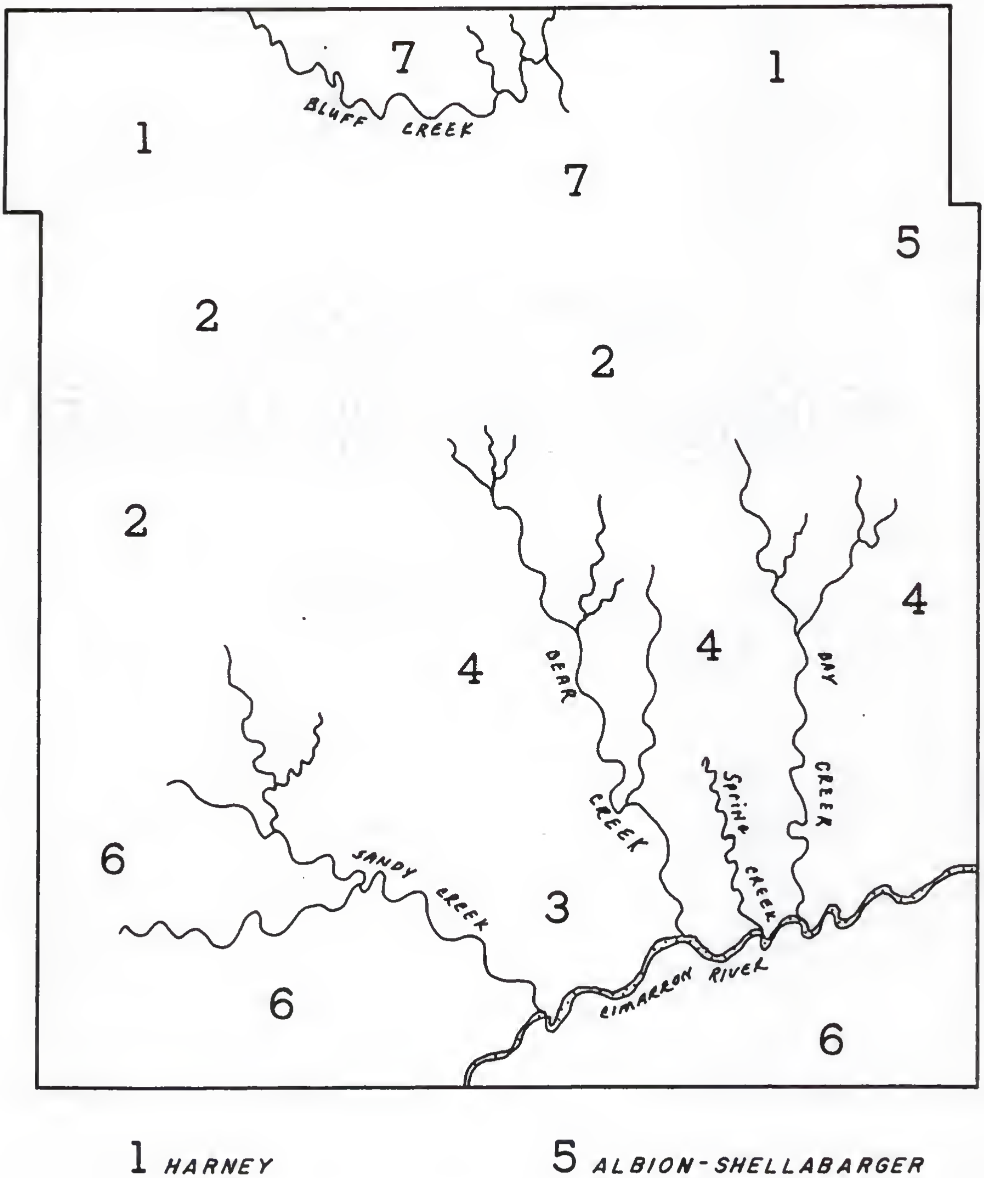
The early history of Clark County can be tied directly to the expansion of the U.S. Army and to the success of the 19th century cattle industry. Throughout the 1870's supply wagons from Ft. Dodge traversed Clark on their way to Camp Supply, Indian Territory, established in 1868 by General Custer (Wood 1973). This spawned the settlement of several small towns along the trailway, the most prominent of which still exists today as the county seat of Ashland. Further settlement of Clark was seen with the growth of the Texas cattle drives in the mid-1870's. The Western and Tuttle cattle trails both bisected the entire south to north length of Clark, on their way to Dodge City in preparation for relocation to Eastern Kansas or for stocking the central and northern ranges of the Great Plains. Trail herds slowly declined after 1885, when the Kansas legislature restricted the herding of disease-carrying cattle into the state except during December, January, and February (Wood 1973). With the demise of the cattle trails, the residents of Clark County settled into farming and ranching, which along with the development of the Atchinson, Topeka and the Santa Fe railway, hastened the births of smaller communities such as Minneola, Englewood, and Sitka. The county was established in 1885 and as of 1987 had a population of 2,674 with approximately 1,173 of those residing in Ashland (County Clerk, Clark County 1987). As with Gray County, the population of Clark has fluctuated over the years with the rural economy (both of which have recently shown a notable decline).

Unlike Gray County, Clark is bisected by two distinct physiographic provinces. The northern portion of the county is a part of the High Plains, while the southern half belongs to the small Red Hills province. Although the boundary can be indistinct in some areas it is primarily defined by the prominent scarp formed from the Ogallala formation of Teritary age south of the Arkansas River (Self 1978). Elevation in the county ranges from about 2,600 feet above sea level in the northwest to approximately 1,730 feet in the southeast portion of the county. The western and southern parts of the county are drained mainly by the Cimarron River and its tributaries, while the northeastern part is drained by Bluff Creek. The northern portion of the county is characterized by the gently eastward sloping plains typical of the High Plains province. The southern and eastern portions of the county become deeply dissected by the drainage basins of Bluff Creek, Bear Creek, Sandy Creek, and Keiger Creek. Here, the topography becomes increasingly more rugged until the appearance of the Cimarron breaks just north of the Cimarron River flood plain. These breaks make-up a highly dissected border where local relief may amount for more than 300 feet (Whittemore 1954). South of the Cimarron River the landscape becomes a steeply rolling mixture of gypsum capped buttes, pasture land, and red hills influenced by the red colored sandstone that served as parent material for the regions development (Whittemore 1954). The Cimarron River, although bordered by steep embankments, maintains a relatively level floodplain which averages 1 to 1.5 miles in width through it's cross section of the county. An interesting feature of the Red Hills physiography is the effect of Karst topography on the landscape. The solution effect of groundwater on the underlying rock structure has resulted in the development of basins, sinks, caves and natural bridges. A series of subsided basins are located northwest of Ashland, one of which contains a locally famous sink named St. Jacob's well.

Soils of Clark County

Again, to determine the quality of the land to support crops and shelterbelts, this section addresses the soil characteristics of Clark County. The soils of Clark County are formed of alluvium, eolian sand, loess, and residue of sandstone, shale or caliche. Soils that have

SOILS OF CLARK COUNTY



1 HARNEY

2 PENDEN-CAMPUS-CANLON

3 LINCOLN-KRIER-WALDECK

4 CAREY-WOODWARD-QUINLAN

5 ALBION-SHELLABARGER

6 PRATT-TIVOLI-KINGSDOWN

7 PENDEN-HARNEY-ULY

(FIGURE 5)

formed in old alluvium are on the uplands, and are generally loamy or sandy in texture. Examples of these are Albion, Penden, and Shellabarger soils (Soil Conservation Service 1982). The recent alluvial sediments can be found on the floodplains of major streams in the county. Krier, Leosho, Lincoln, Roxbury, Waldeck, Yahola and Zenda soils are all formed of this material (Soil Conservation Service 1982). Eolian sand is a gritty-sandy material transported by wind which is generally found on the rolling sand hills in Clark County. The Pratt and Tivoli soils are formed of this sandy material. Loess, a fine silty wind deposited material, can be carried hundreds of miles from its source, the uplands of the northern part of Clark contain the Harney and Uly soils which are formed from this material (Soil Conservation Service 1982). The oldest soils in the county are the loamy Quinlan and Woodward soils formed in residues of calcareous sandstone in the southern portions of Clark. Lastly, the clayey Owens soil and the Canlon soils formed from decaying shales and weathered caliches, are again found in the southern most part of the county (Soil Conservation Service 1982).

Like Gray County, the predominant land use in Clark County is agriculture, with the majority of the land used for livestock range. Due to somewhat poorer quality soils and more uneven topography, irrigation development has not been as abundant in Clark County. Most of the irrigation that has occurred has been confined to the southern portions of the county.

The first of the county's soil associations, the Harney association is a deep, level to gently sloping, well drained soil, with a silty subsoil. This grouping makes up about 12 percent of the county land area (Soil Conservation Service 1982). The soils of this association are used mainly for cultivated crops of wheat and sorghum, with small areas of range interspersed. Erosion, moisture conservation, and soil fertility are management concerns for the Harney association.

The Penden-Campus-Canlon association can be deep to shallow and is found on level to steep terrain. This soil makes up approximately 25 percent of the county (Soil Conservation Service 1982). Due to the high amount of relief most of this association is rangeland, however, some areas sustain crops of wheat and sorghum. The control of blowing soil and maintaining soil fertility are the main hazards for this association.

The Lincoln-Krier-Waldeck association is comprised of deep, nearly level, moderately drained soils, that have sandy to loamy subsoils, and are found on flood plains and terraces. This association makes up about 5 percent of the county (Soil Conservation Service 1982). The majority of this association is range, however, on the better drained sites some stands of wheat, sorghum and alfalfa are seen. Soil erosion and the maintenance of tilth and soil fertility are the main concerns on these soils.

The next association is the Carey-Woodward-Quinlan association, making up approximately 29 percent of the land in Clark County. These soils are deep to shallow, nearly level to strongly sloping, and well drained that contain a loamy subsoil (Soil Conservation Service 1982).

About half of this association is used for cultivated crops, while the steeper areas are left as range. Wheat, sorghum and alfalfa are the main crops. The control of wind and water erosion and conserving soil moisture are the primary concerns in managing the cultivated areas.

The Albion-Shellabarger association is a deep, strongly sloping, well drained grouping that makes up about 5 percent of the county (Soil Conservation Service 1982). The majority of this land is range and the maintenance and vigor of the native range grasses are the main concerns on these areas.

The next association is the Pratt-Tivoli-Kingsdown association and is found on nearly level to hilly terrain. The soils are well drained to excessively drained and have sandy or loamy subsoil. This association makes up about 16 percent of the soils in the county (Soil Conservation Service 1982). Most of this association is grazed, however, some areas are used for crops such as wheat and sorghum. Controlling wind erosion and conserving soil moisture are the primary concerns on the cropped areas.

The last soil association in Clark County is the Penden-Harney-Uly association. This grouping makes up about 8 percent of the counties land area. Soils of this association are deep, nearly level to strongly sloping, and well drained having loamy to silty subsoils (Soil Conservation Service 1982). About half of the association is rangeland and the other half cropped. Wheat and sorghum are the main cultivated crops. The control of erosion and maintenance of soil structure and fertility are the main hazards connected with these soils.

Climates of Gray and Clark Counties

The continental climate of Gray and Clark counties is typical of the climate in the High Plains. It is characterized by an abundance of cloud-free days, low amounts of annual precipitation, and great variations in daily and yearly temperature. The wide variations in temperature are the result of high altitude and relatively low humidity, both of which allow for marked heating by solar radiation during the day, and large losses of heat from the ground at night. The climate of Gray County is affected by the orographic principles created by the Rocky Mountains, which are approximately 275 miles to the west. As storm systems move inland from the Pacific, the mountains create a physical barrier forcing the air to rise rapidly upward, thus cooling and loosing it's ability to hold moisture. As the now drier air reaches the windward side of the mountains, the rapid decline in altitude creates swift moving wind currents which warm in temperature and possess almost no moisture by the time they reach the High Plains. Upwelling low pressure systems from the Gulf of Mexico are the primary source of precipitation for the area.

Precipitation for these two counties varies widely from year to year, but is generally inadequate for optimum growth of most crops. In addition to this, the type of crops that can be dryland farmed are limited due to high rates of evapotranspiration which outweigh annual precipitation. The average annual rainfall for the counties ranges from 19 to 20 inches for Gray to 20 to 21 inches for Clark (NOAA 1986). The driest period of the year is November through March when the average is less than one inch of precipitation per month. On the average, three-fourths of the counties precipitation falls from the months of April through September with a dramatic tapering of precipitation in August and September (NOAA 1986). Snowfall is sparse in most years. The average for the two counties as a whole is between 20 to 24 inches, with Gray County seeing the greater portion of this (NOAA 1986).

Droughts can be frequent and severely affect yields in some years. Especially damaging drought periods for both counties were seen from the years 1931 to 1940, 1952 to 1957 and from 1980 to 1981. Warm season drought periods are aggravated by abnormally high temperatures which tend to further weaken the already stressed crops. Because cultivated soil in the counties are subject to wind erosion, the extended periods of rain accompanied by strong surface winds of spring and summer can result in tremendous soil loss. The change of seasons is often rapid in the area, as can be seen in the March to April and October to November temperature averages. March has an average temperature of 43°F to 44°F for Gray and Clark, while April sees an average of 54°F to 55°F for each (NOAA 1986). The change is even more apparent between October with an average of 57°F to 58°F and November with a temperature average of 42°F to 43°F for the respective counties (NOAA 1986).

Surface winds are generally moderate for the counties, but do see an increase in speed during the months of March and April. The average wind speed for these months is approximately 15 mph with average gusts of up to 22 to 24 mph. The prevailing winds are southerly, but northerly and northwesterly winds are frequent, particularly during the winter months. Clear to partly cloudy skies and abundant sunshine are dominant in Gray and Clark Counties. The percentage of possible days of sunshine averages about 70 for the year, but jumps to nearly 80 during July and August (Soil Conservation Service 1968, 1982).

Water Sources for Gray and Clark Counties

In both Gray and Clark Counties, water for domestic use is obtained from drilled wells, while water sources for livestock are obtained mainly from surface water impoundments on intermittent streams. However, these impoundments are not replenished during extended periods of drought, and therefore livestock also become dependent on well water.

Since the institution of irrigation in these two counties, sufficient water to irrigate field crops was pumped from shallow wells that were drilled into the alluvium along the Arkansas and Cimmarron Rivers and their tributaries. However, due to over pumping and increased upstream usage and impoundment, an alternative source was created by exploitation of the Ogallala aquifer.

The Ogallala formation underlies approximately 225 thousand square miles of Kansas, Nebraska, Colorado, Oklahoma, Texas, New Mexico and small portions of Wyoming and South Dakota. The formation was deposited in Pleistocene times by streams flowing eastward from the Rocky Mountains. These fluvial deposits gradually filled the pre-Ogallala valleys and formed an alluvial plain. Rocks of the Permian, Jurassic and Cretaceous periods comprise the majority of the water rich Ogallala formation. Those of the lower Permain age Blaine formation which also underlie much of the area do not contain fresh water (O'Conner and McClain 1982). The Permain rocks of the Ogallala are characterized by red siltstones and shales, and very fine grained sandstones and beds of gypsum, which underlie and outcrop in Clark County. The Jurassic rocks of the aquifer are made up of grayish and greenish shales and very fine to medium grained sandstone with some thin limestone beds interspersed, and directly underlies the Ogallala in Gray County. The lower Cretaceous rocks consist of gray, black and vari-colored shales, claystones and fine to medium grained sandstones and are found in both study counties. The upper Cretaceous rocks are largely light and dark gray to black shales, chalk and limestone which are found in Gray County (O'Connor and McClain 1982).

Periodic rejuvenation of streams in the area following the deposition of the Ogallala formation resulted in extensive erosion and redeposition of the deposits during the Pleistocene period. In southwestern Kansas, the deposits were widely eroded and redeposited by streams, thought to be partly resulted by dissolution and subsidence of underlying Permian salt beds.

The geologic structure of the Permian, Jurassic and Cretaceous bedrocks of the formation create a largely unconfined aquifer (O'Connor and McClain 1982). The structure of these three rock groups have significant effects on the direction of groundwater flow in this aquifer system. The hydrologic significance is that the rock units dip or slope generally north-eastward 10 to 20 feet per mile with the rocks being higher to the west and southwest of the Kansas-Colorado border, creating a slight northeastward movement of the water. Although the Ogallala is by far the largest and hydrologically most important aquifer in the area, there are also a number of other confined and unconfined aquifer deposits in the area which are too numerous for discussion. The Ogallala aquifer is generally defined to include the rocks of the Ogallala formation together with the overlying saturated and undifferentiated Pleistocene deposits which are hydraulically connected and form a single groundwater reservoir (O'Connor and McClain 1982).

The bedrock underlying the aquifer contains beds of sandstone which have pore space between grains through which groundwater can percolate, beds of chalk that are fractured and partially dissolved by percolating groundwater, through which groundwater can move; and beds of gypsum and anydrite that have partially dissolved to form the aquifer (O'Connor and McClain 1982).

The depth of the aquifer varies over it's range from only a few feet to several hundred feet. More accurate accounts of water volume are given in groundwater storage units by acre-feet (1 acre foot equals the amount of water it would take to cover one square acre with 1 foot of water). For Kansas as a whole, the storage of the Ogallala aquifer is 245,163,000 acre-feet, and for Clark and Gray Counties, the numbers are 1,328,000 and 13,800,000 acre-feet, respectively (Buller 1982).

The rates of groundwater discharge through pumpage from wells, effluent seepage to streams where they intersect the water table, and by subsurface flow out of the area, has dramatically increased over the past twenty years, with the exception of seepage into streams due to a decrease in the water table. Out pumpage of Ogallala water for agricultural purposes presents by far the greatest demand on the aquifer. For the southwest subregion, including both Gray and Clark Counties, the pumpage rate for 1982 was 175,208,000 acre feet. Since the recharge rate for the aquifer through local precipitation and hydraulic movement was only 321,000 acre-feet, a deficit of 174,887,000 acre-feet occurred for that year (Buller 1982). The estimated recharge rate for the southwest counties varies, however it is approximated to be less than 0.5 inches per year (Buller 1982).

Land Use Practices of Gray and Clark Counties

The following section of this chapter will address the present day land use practices of the study region; paying particular attention to irrigation and irrigation methodology, types of crops grown, average farm size and percent farmland, and the presence of windbreaks for each county.

One of the most important factors influencing the extent and type of irrigation an area experiences is the depth to water and well yields, or gallons per minute. The depth to water directly affects the cost of pumping, so as depth to water increases, the cost of lifting the water increases as well. Therefore, the pump efficiency decreases resulting in more hours of pumping to deliver a specified amount of water. With an increase in hours spent pumping, the culmination is an increased cost for irrigation. Not only does well yield effect cost of irrigation, it also effects the number of acres that can be irrigated per well. As well yields decrease, a change must be made from the high water consumptive crops such as corn and alfalfa to crops that are better able to withstand the stress of drought, such as wheat and sorghum. Consequently, the profit margin per acre may decline. Well yield is directly related to saturated thickness of the aquifer, permeability of the water bearing material, depth to water in well while pumping, radius of cone depression, and radius of the well. Well yields in western Kansas show large variations because of differences in saturated thickness of the Ogallala aquifer and it's varying permeability. The number of active wells for Clark and Gray Counties as of 1982 were 43 and 1,529 respectively, with an estimated well yield average for the region set at over 1,000 gallons per minute (Buller 1982).

Of the several forms of irrigation found in southwest Kansas, two types tend to predominate; that is the gravity method and the self propelled center pivot system. Variations of the gravity method have been popular since the 1950's and in nearly all cases consist of flooding furrows through the use of lateral pipes or hose set along the margins of the field. The principle is fairly consistent on areas of incline, however, even distribution of water is difficult to attain on level fields or fields with irregular topography. Gravity systems are fairly easy to maintain and are compatible with most types of farming systems, but the irregularity of water flow and distribution as well as limitations on field size has prompted many farmers to look towards the center pivot systems over the last two decades. The self propelled center pivot system consists of a single lateral mounted on wheels, spaced on approximately 100 foot centers and supported by towers with cable or truss supports. Each tower has a device to provide power to the wheels. The speed of rotation for these systems may vary from 12 hours to a week, however, the average rotation speed is 60 to 72 hours per revolution, with an average water application per rotation of 1 inch (Merriam and Keller 1978). The dicumbunt or downset direction of the sprinklers reduces evaporation and allows for more even coverage on the field. The advantage of the center pivot systems lies in the amount of land that can be equally irrigated at one time and the minimum amount of operating labor required. However, the disadvantages are seen with the need of circular or square fields with little or no relief and free of vegetative obstruction for operating equipment ease.

For Gray County, the primary crops are wheat and grain sorghum. Under dryland farming conditions, the crops are usually grown in a sequence of crop and fallow. During the fallow period, weeds are controlled so moisture can be conserved for use by the crops. On the sandy sites, sorghum is generally grown continuously in an effort to control blowing soil during periods of fallow. Under irrigation, large acreages of wheat, alfalfa and some corn are grown. These crops have seen a dramatic increase in acreage with the irrigation boom of the 1970's and early 1980's. The average annual harvest for wheat in Gray County is 7,107,378 bushels while grain sorghum is 4,853670 bushels and corn and alfalfa are 8,720,968 bushels and 61,686 bushels respectively (Census of Agriculture 1982).

Pasture and rangeland in Gray County amounts to approximately 100,000 acres. Most of this acreage is not suited for farming or is found in conjunction with areas that cannot be cultivated conveniently. The sandhill region south of the Arkansas River is one such area. This large area is used exclusively for grazing and supports many tall and mixed native grasses, such as big bluestem, indian grass and switch grass mixed with sage brush. The uncultivated uplands support many mixed and short grasses common to the prairie regions. Examples of these are little bluestem and buffalo grass. The bottom lands along the Arkansas River supports great quantities of water tolerant grasses and sedges.

The 1982 Census of Agriculture lists 552 farms in Gray County, with a total farm acreage of 536,969 acres (Census of Agriculture 1982). The average size of farm is calculated at 973 acres with the percent of land area in farms at 96.7 percent for the county. As of 1982, 328 farms were irrigating, a figure suspected to increase in more recent years; with a total of 191,175 acres of land under irrigation (Census of Agriculture 1982).

The dominant crops of Clark County are much the same as for Gray. About 34 percent of the acreage in Clark County is used for cultivated crops or is summer fallowed. As of 1982, wheat was grown on about 50 percent of the cropland, sorghum on 10 percent and alfalfa, barley, rye and corn on 2 percent. As in Gray County, crops in Clark are grown in a sequence of crop and fallow to conserve moisture and soil nutrients. Some primary concerns affecting cultivated land in Clark is water erosion and blowing soil due to extensive periods of barred soil. Some measures used to control wind and water erosion are minimum tillage, terracing, contour farming, the use of shelterbelts and cropping systems that include close growing crops as well as row crops to reduce run-off rates and help control wind erosion. Again with the use of irrigation practices in recent years, Clark County has seen an increase in harvest since the days of dryland farming. The average annual harvest for wheat is 2,683,999 bushels, for sorghum it is 292,140 bushels and for alfalfa it is 22,374 bushels (Census of Agriculture 1982).

Pasture and rangeland makeup about 63 percent of the land area in Clark County. A much less arable county than Gray, nearly 65 percent of the total value of local farm products is in the form of livestock or livestock products. On most of the rangeland, the natural forage of short to mixed grass prairie is supplemented by crop residue and small grain. Sand bluestem and big bluestem are more common on the lowlands, while buffalo grass is common to the uplands. Saline tolerant grasses are found in areas of high water table or sub-irrigated areas.

As of 1982, there were 308 farms in Clark County with an encompassing farm acreage of 588,288 acres for the county as a whole. The average size of farm for Clark is 1,910 acres, with the percent of land area in farms at 94.3 percent. As of 1982, 27 farms were irrigating with a total of 5,605 acres in irrigation, again these are numbers which probably saw some increase in more recent years (Census of Agriculture 1982).

In both Gray and Clark Counties, landowners have planted trees at various times on the ranches and farmsteads creating windbreak networks which flourish and deteriorate over time. Examples of common trees used in plantings for both counties are Siberian elm (Ulmus pumila), Eastern red cedar (Juniperus Virginiana), Austrian pine (Pinus nigra), Tamarisk (Tamarix), Russian olive (Eleagnus angustifolia), and Lilac (Syringa). Field windbreaks or shelterbelts provide many purposes on the agricultural sites of Gray and Clark Counties; the next chapter will explore the legal aspects and various governmental programs which helped to institute these plantings. An overview will also be provided offering planting theory and practice as it exists in Gray and Clark Counties today.

Chapter 4

WINDBREAK PROGRAMS AND GOVERMENTAL POLICY: PAST TO PRESENT

The settlers who first inhabitated the Plains States had migrated west from the more heavily wooded states of the east, and in many cases had immigrated from tree dependent cultures of northern and eastern Europe. So, along with the common desire to establish great expanses of cultivated land also came a strong desire to plant trees. Likewise both the Federal and Kansas State government, for economic, cultural, and physical reasons, strongly promoted this wave of tree planting. The covering of the newly barred land, the replacement of those trees that had already been felled, and the hope of climate enhancement all spurred a flurry of acts and bills encouraging the planting of woodlots and windbreaks. The first of these acts appeared in 1865. In that year the state legislature passed an act providing a bounty of 50 cents an acre for anyone planting and cultivating five or more acres of trees for wood crops and wind-water damage control. This bounty was to be paid annually by the county treasury in which the planting was located (Louck 1984). In 1868, an act was passed providing a bounty of $2 per 40 rods of Osage Orange or Hawthorn to be used as fences. This bounty again was paid by the county and went into effect from the time the trees would resist livestock. During this period, many plantings were established to delineate property boundaries. A few still are in existence today. Then in 1874 probably the most popular timber act of the time was presented on the federal level. This was the Timber Culture Act. This act stated that a settler could plant 40 acres into trees and in return be given 160 acres of land for his own use by the government. The acreage requirement was reduced in 1878 to only 10 acres, however, throughout the 17 years of its enactment over two million acres were established in Kansas which translated to roughly 125,000 acres of trees. The act was repealed in 1891, being judged unsuccessful as a result of poor quality stock, fraud, and lack of experience among many settlers (Winters 1950). The 1870's saw a boom in tree planting for other reasons as well. Many of the railroads which now bisected the country conducted experiments and demonstrations on species tolerance, longevity and care. Many areas in Kansas, most notably areas west of Hutchinson were used as experimental plots; probably the first of their kind in the midwest. By 1887, Kansas had established a commissioner of Forestry and two seedling nurseries (one in Ogallala, the other at Dodge City) which resulted in the production of 4.23 million trees through 1892, primarily for firewood and windbreaks. In this same year, a bill was passed authorizing county commissioners to reduce property taxes for tree plantings (Louck 1984).

With the turn of the century and the onset of World War I, interest in tree planting programs on all governmental levels wained. Without incentive plans, many farmers and landowners discontinued planting programs and ceased upkeep on existing ones. It was not until the Clark-McNary Act of 1924 that real interest in continued planting programs resurfaced. This act established a plan with the young United States Forest Service to bolster seedling production in state nurseries (Stoddard 1978). The program was only mildly successful, and deterioration of the Plains States land which was initiated in the late teens accelerated in the 20's and 30's. Through poor land management, over cultivation, overgrazing, and denudation of the land, the midwest saw the bleakest years it had yet experienced in the early 1930's. During this time, millions of tons of top soil were stripped away from the land. Along with soil loss went any hope of self-rejuvenation for the ecosystem. Finally, in 1935 the Prairie States Forestry Project was initiated by Franklin D. Roosevelt. The original plan was to create a 100 mile wide belt of trees from the Gulf of Mexico to Canada. It was to run North-South through west central Kansas, with 10 to 21 row belts running east-west at least every mile. The purposes for this plan were stated at the time to be economic relief, soil stabilization, and to increase rain. Although the plan fell short of its original goal, it did provide the Prairie States with much needed soil stabilization plantings. The project was terminated in 1942 with the onset of World War II. By this time, however, Kansas alone had planted 3,541 miles or 44 thousand acres on 5,960 farms with 26.5 million trees plus 13.4 million replacements (Louck 1984). These plantings together with improved cropping and grazing practices led the way to ecological recovery for much of the midwest.

This recovery found insurance in 1935 with the establishment of the Soil Erosion Service, the forerunner to the Soil Conservation Service, which worked together with State and Extension Foresters, as well as other State and Federal agencies on field and farmstead windbreak maintenance. Today, the Soil Conservation Service is responsible for maintaining the Great Plains Program; a cost sharing program designed to act as an incentive for farmers and ranchers to establish environmental plantings by partially subsidizing the seedling and planting costs. The Great Plains or G.P. Federal Program was instituted on a county by county basis, and individual program policy as well as subsidy percentages may vary from one county to the next. Since the Great Plains Program is comprised of many types of establishment policies not all counties may have a windbreak policy. In some counties throughout the state, individual establishment policies are more popular than others and therefore the less used policies are eventually deleted from the program as a whole. An example of this is seen in the two study counties. Clark County's G.P. Program contains a windbreak policy. A 70 percent - 30 percent cost ratio has been established for the county with the program paying 25 cents per tree and 57 cents per cost of planting with the landowner obligated to pick up the remaining 18 cents balance (Gentry 1987). Gray County on the otherhand has never initiated a windbreak policy in its program, although planting support for trees is provided if native grasses are also established. Plant materials used in the Great Plains Program are furnished by State Forestry Extension nursery's and the Soil Conservation Service plant materials farm. In the cases of both Clark and Gray counties, SCS officials confirm that no windbreak plantings have occurred within the last five years under the Great Plains Program policy (Gentry 1987).

Another Federal government subsized program which has promoted the planting of woodlots and the shelterbelts in all counties, is the Conservation Reserve Program implemented in 1985. Although this program cannot be regarded as a true incentive program, some increase in woodlot and windbreak acreage has been reported in Kansas. The primary focus of the Conservation Reserve Program or CRP is the reduction of farm commodities, especially cash grains. The farmer is paid by the government to take cropland out of production for a 10 year time period and plant it back into any one of a number of program sanctioned options, to include woodlots and windbreaks. Due to the work and cost involved in the planting process, as well as the time span required to produce visible benefits many farmers are opting for other options such as native grass stands. The Soil Conservation Service and the Agriculture Stabilization and Conservation Service both estimate the percentage of CRP land which has been planted into woodlots and windbreaks to be well below 1 percent of the total possible (SCS, ASCS 1987).

A final program, again not regarded by professionals as a true incentive program, is the State Forestry Extension offer of tree seedlings at the cost of production. Farmers and ranchers from all over the state may obtain seedlings from state forestry nurseries for only the price of what it costs the nursery to produce that seedling. The rate offered is $12.50 per bundle of 50 bare root seedlings; and $25.00 per 30 container grown plants (Louck 1987). Most of the success in this program has been seen in the establishment of wildlife plots rather than windbreaks, and state forestry officials admit cheaper seedlings may be obtained from private nurseries if the nurseries maintain a lower production cost than the state.

Soil Conservation Service, and State Forestry officials presently feel there is a decrease in planting practice and/or lack of interest in establishing new field windbreaks. Some reasons offered by these agencies are incompatibility with irrigation and/or farming practices, consolidation of add-on farms, and the increasing mean age of farmers who may find planting, maintenance and time requirements to be too demanding. Although the same officials also felt that farmstead windbreak plantings have seen an increase in the past several years due to increased energy costs and rising fuel prices.

Windbreak Planting and Maintenance Practices

Windbreak planting and maintenance practices for Clark and Gray counties are much the same as for the rest of the High Plains. Many characteristics of an individual site must be taken into consideration when establishing field windbreaks. Soil characteristics, tillage and irrigation practices and climatic conditions must all be calculated for each individual field to obtain maximum benefits. However, generally speaking, many individuals prefer to compromise the ideal system with windbreak intervals of 20 times the height of the plants or about 660 feet (Extension Bulletin 1985). Combined with proper farming practices of cropping and tillage, this spacing provides an effective erosion control system. Although windbreaks are planted for a variety of reasons and in a variety of patterns, field windbreaks on the High Plains are generally planted in an east-west direction to obtain maximum benefits of wind reduction. In southwestern Kansas, for a three to five row windbreak, the recommended plant spacing between rows is 12 to 18 feet for slow growing coniferous or deciduous trees. The recommended plant spacing within rows for a single row belt is 6 feet between trees then thin to 12 feet, or 8 feet between trees without thinning which applies to pines, redcedar and deciduous trees. For spacing within multiple row plantings, the distance is recommended the same for pines and cedars and increases to 10 to 14 feet between plants for deciduous trees (Extension Bulletin 1985).

Thinning, coppicing, pruning and grass control are all methods needed to promote vigor and growth and to develop windbreak structure of maximum effectiveness. By thinning out a heavy concentration of trees in a windbreak, the more sturdy, long-lived species can thrive. Therefore, special attention should be given to the fast growing, short-lived species popular to southwest Kansas such as Siberian elm, Cottonwood, and Russian olive so they will not dominate windbreaks and reduce productivity. The practice of coppicing, or cutting trees and shrubs back at ground level and managing the results is also a popular enhancement practice in the region. This provides an effective way to control growth of large plantings and improve low level density, because the regrowth is much denser than the original growth. Pruning of windbreaks is to be confined to only dead branches. Many individuals mistakenly prune out the lower branches of trees, especially coniferous to allow field trash, thistle and sage brush to blow through the planting. This practice drastically reduces the effectiveness of the windbreak. If it becomes open enough for trash to pass through, it is too open to be an effective wind barrier. Perennial grasses that compete with trees and shrubs for space, moisture and nutrients can drastically lower the vigor of a windbreak. Control of these grasses can be done either by mechanical cultivation or herbicides. Protection for the windbreak is needed throughout its existence. Whether it is from pruning injury, insects or disease, wildlife or livestock damage, mechanical injury or simple neglect, windbreaks cannot be expected to provide the maximum benefits with minimum or no care.

Chapter 5

WINDBREAK DYNAMICS OF GRAY AND CLARK COUNTIES

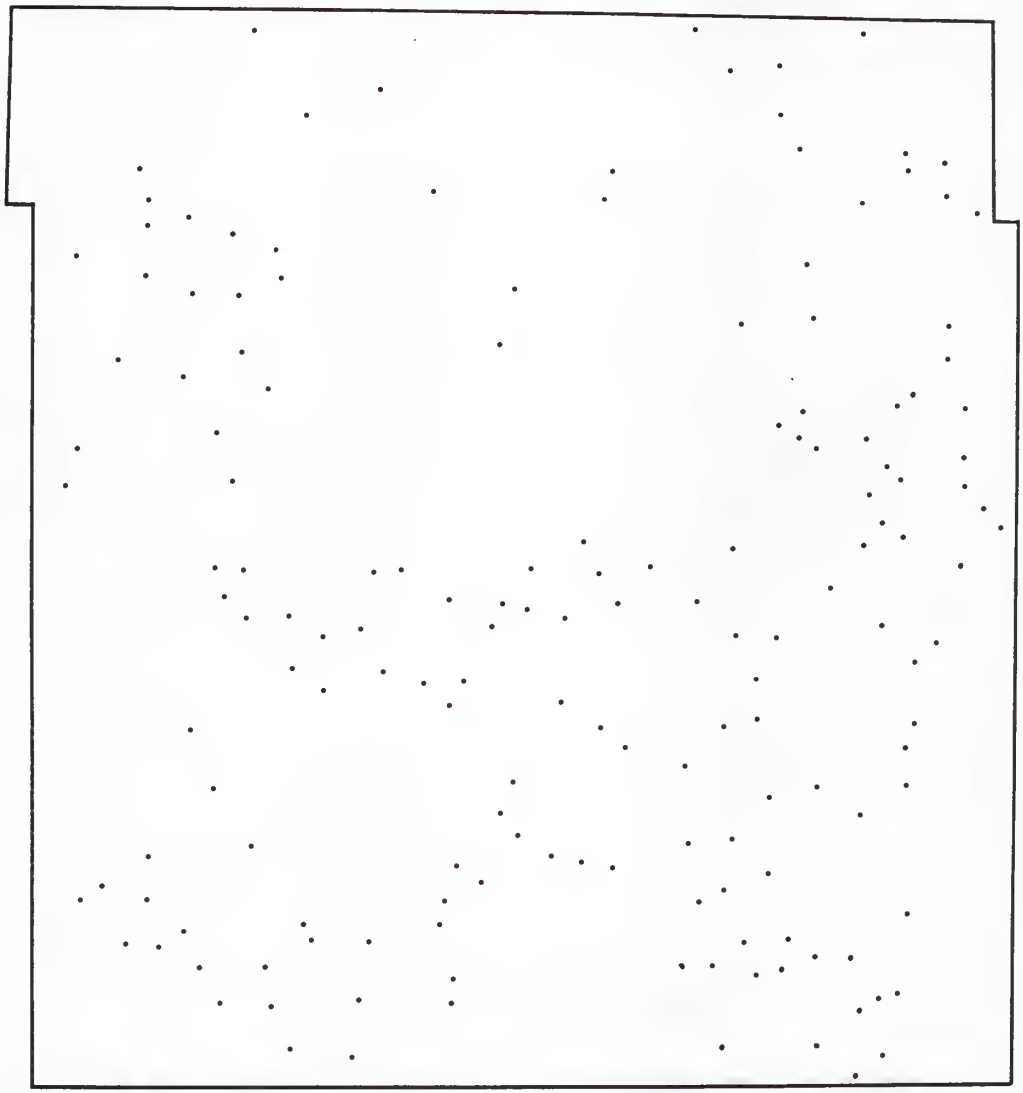
Notable spatial and temporal changes have occurred within the windbreak networks of Gray and Clark Counties. The nature of these changes were examined using low altitude air-photo mosaics to inventory and map spatial dynamics for two differing dates for the two respective counties. This process was also used to monitor center pivot irrigation development to discern whether or not any relationship exists between this development and any noted windbreak change. In addition, statistical observations were made in an effort to disclose reasons for the changes, using data derived from mailed questionnaires sent to residents of the study counties. The statistical method used for analysis was Chi-square which measures the significance of correlation and relationship among variables. The Chi-square test was chosen for this analysis because it was felt by the researcher that it was an effective means of comparing more than one sample to variables that contained more than two categories. It also allowed the researcher to interrelate nominal scales with differing categories.

Inventory and Mapping Analysis

The visual analysis of spatial changes within the windbreak networks of the two counties were carried out by means of air-photo interpretation. Low altitude black and white air-photo index sheets were obtained from the Aerial Photography Field Office, User Services in Salt Lake City, Utah. The available index dates varied somewhat for the study counties as did scale of the mosaics, however the approximate

21 year time lapse between mosaics was maintained. For Gray County, the air-photo dates involved were 1961 and 1981, while for Clark County, they were 1960 and 1981. The scale of photography for the indexes used were 1:20,000 for the earlier dates, with the later mosaics being shot at a scale of 1:40,000. The air-photo mosaics were produced by shooting individual photographs which comprise a series of parallel flight lines. These flight lines were arranged in such a manner as to create an overlap which allows for steroviewing and continuity of the overall mosaic. Generally, aerial photographs were taken sequentially to provide a 60 percent forward overlap, while adjacent flight lines are spaced to give a 25 percent to 30 percent sidelap (Richason 1978). After acquisition of the mosaics, careful inspection was made of each individual sheet to discount photo flaws and other non-landscape materials used in the reproduction process, i.e. staples, pins and tacks. To avoid duplication of count in the overlap areas, the individual sheets were then spliced together to form a single continuous map of each county. With the use of a remote sensing magnifier, careful scrutiny was given to the location and placement of each windbreak delineated within the counties boundary. Then, using a wax cartography pen each windbreak was marked and its location recorded on an overlying duplicate map of drafting paper. This process was repeated for all four maps with the exact number of windbreaks identified being recorded on the drafting paper. From these drafting paper maps, a series of dot maps accurately portraying the number and location of windbreaks within each county for each date was developed (Figures 6 and 7). In addition to the dot maps, a concise

CLARK COUNTY 1960



EACH DOT REPRESENTS ONE WINDBREAK

figure 6

CLARK COUNTY 1981

EACH DOT REPRESENTS ONE WINDBREAK

figure 7

figure of the percent of change in windbreak numbers for the time frame studied was derived in the inventorying process.

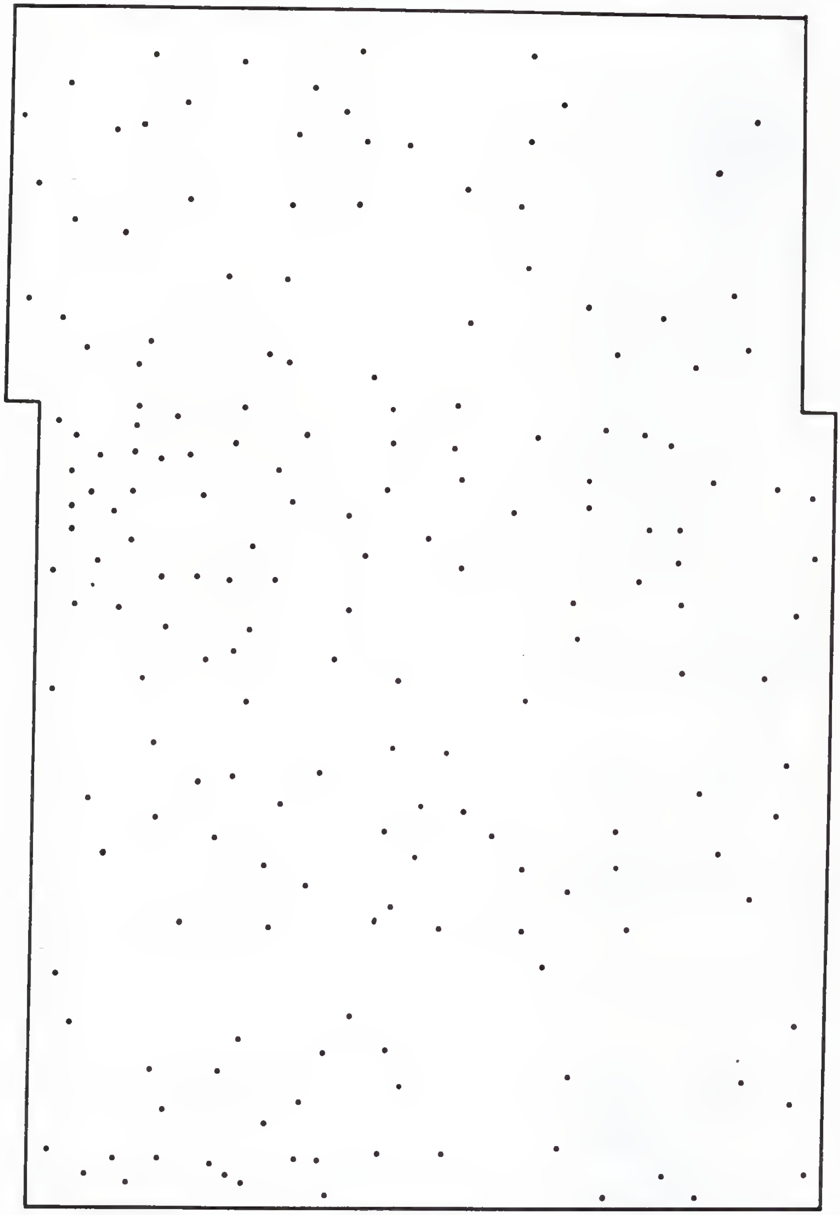
In examining the maps of Clark County, a substantial change was noted in the number of windbreaks occurring from 1960 to 1981. In 1960, there were 167 recorded windbreaks within the county, most of which were located in the southern and eastern portions of the county and tended to follow the drainage patterns found within the county. It is important to note that cultivated windbreaks can be distinguished from riparian woodland by examining the width of the tree line and observing the line of the growth pattern. Some remnant clusterings were also seen along railway lines that bisect the county. In 1981, the number of established field windbreaks had dropped to 116 for Clark, much of the reduction was noted to be in the southeastern portion of the county, near and in the Cimmarron drainage basin. This portion of the county is where much of the irrigation development for Clark County has occurred. These changes have resulted in a 31 percent loss in windbreak population over the study period in Clark County.

In reviewing the resulting windbreak maps of Gray County, the decline is even more extreme. In 1961, there were 191 noted windbreaks within the county boundaries. Although much more dispersed than those found in Clark, concentrations were noted within the mid portion of the county, especially along the Arkansas River Valley. Small concentrations were also noted in the southwest corner following Crooked Creek Basin, and again along many of the railway lines. By 1981, the number of windbreaks found in Gray County had fallen to 79.

As can be seen in Figure 9, the noticeable clustering found in Figure 8 no longer exists, although some remnants of this can be detected in the central portion along the Arkansas River. Again the drastic reduction in field windbreak numbers is assigned to irrigation development. It is interesting to note here that of the two counties, Gray has by far seen the greatest amount of irrigation development and also the highest rate of windbreak decline for the study area. This notion thus far supports the hypothesis of increased amounts of irrigation development resulting in decreased numbers of field windbreaks. The drop in numbers for Gray County amounted to a 59 percent loss in field windbreak numbers for the time frame studied.

In addition to mapping the windbreaks of the study area, an inventory of center pivot irrigation development was also carried out. This inventory was done in part to support the researchers hypothesis of an inverse relationship between center pivot irrigation units and field windbreaks, and to gain insight into the magnitude of irrigation development for the study area. According to the 1960 air-photo mosaic, there were no recorded instances of center pivot irrigation or CPI development in Clark County. As mentioned in the previous chapter, Clark County has one of the lowest rates of irrigation for all southwest Kansas, with much of its cropland being dryland farmed. Upon inventorying the 1981 mosaic, 14 CPI units were counted, all of which appeared in the eastern one-third of the county. This knowledge results in an interesting contrast when viewing Figures 6 and 7. Whereas most of the windbreaks mapped from the 1960 mosaic remain the same on the 1981 map for the western two-thirds of the county, a

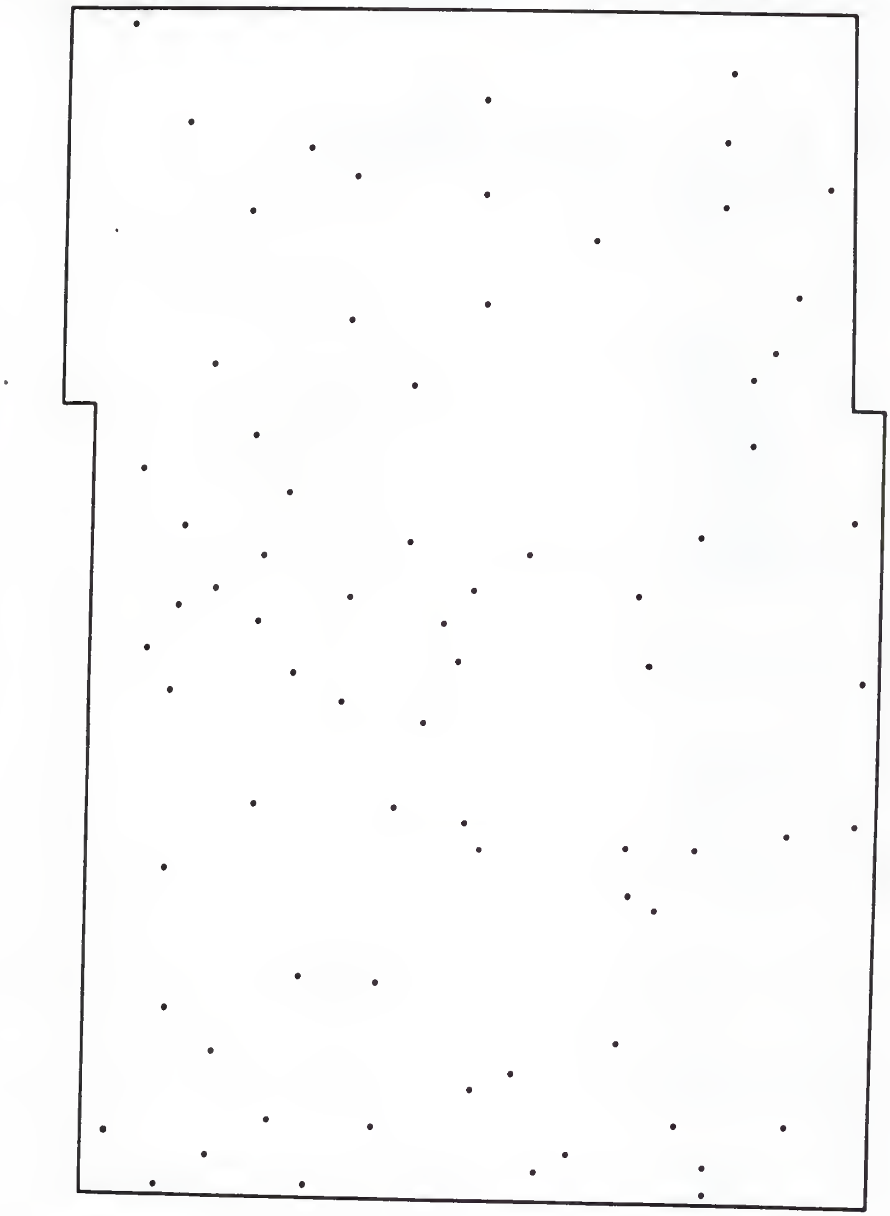
GRAY COUNTY 1961



EACH DOT REPRESENTS ONE WINDBREAK

figure 8

GRAY COUNTY 1981



EACH DOT REPRESENTS ONE WINDBREAK

figure 9

drastic decline in numbers for the eastern third is readily visible. Other areas of decline from 1960 to 1981 in Clark County occur in the southwestern corner as well as the northwest portion. A possible cause for this could be reduced flow in the intermittent streams of the area, and an apparent abandonment of cropland in the northwestern corner of the county. It is interesting to note that although much of the cropland in the northwest corner was no longer in production in 1981, the concentration of cropland migrated south to the central portion of the county, perhaps in an effort to take advantage of irrigation water from the same intermittent streams.

As for Clark County, the early air-photo mosaics of Gray County show no indications of CPI development. However, inventories of the 1981 mosaics indicate a boom in irrigation with 613 individual units being recorded, ranging in size from quarter section to full section pivots. Although the irrigation development appeared in great numbers all over the county, the heaviest development was found to be in the mid portion of the county following the Arkansas River flood plain. In viewing Figures 6 and 7, here again, the areas experiencing the highest amounts of CPI development show the greatest declines in windbreak numbers, i.e. the middle portion of the county which corresponds with the Arkansas River flood plain. The exception here for the two sets of figures seems to be where some areas of Clark County appeared to show little if no decline in windbreak numbers, a county wide decline appears on the Gray County maps. It should be taken into consideration when viewing these statistics that some limitations were imposed by the researcher in the inventorying and mapping process. For example, when testing the hypothesis of irrigation development vs. change in windbreak numbers, only center pivot irrigation units were taken into consideration, it was not tested to see whether other irrigation systems impacted the windbreak networks due to the difficulty of detecting other irrigation systems on the aerial photography.

As illustrated by the inventorying and mapping procedure, significant declines have occurred within the windbreak plantings of these two study counties for the time frame studied. It is the researchers opinion that these downward trends in windbreak numbers have been due in part to a change from the more traditional dryland farming methods to the use of center pivot irrigation systems. This type of irrigation method results in large scale coverage of the land area by the irrigation equipment which may not be compatible with long strips of wooded land.

The next portion of Chapter four includes analysis of data derived from mailed questionnaires sent to residents of Gray and Clark counties that currently or within the past twenty years have maintained windbreaks on their property. From these statistics and written comments, efforts were made to disclose additional reasons for the decline in windbreak numbers and to gain insight into residents present feelings of the field windbreak as a conservation tool.

Questionnaire Analysis and Results

In developing the questionnaire used in this portion of the research (Appendix A) special attention was given to the individual respondents statements as well as the statistically important aspects.

For example, tenure of owner/operator on the farm as well as age of owner/operator were felt to offer insight into whether or not age and years on the farm played a role in windbreak populations. Next, several questions were asked dealing with the individuals perceptions of the windbreak as a conservation tool, and how their presence may or may not effect growing crops. This was done in order to discern whether or not windbreaks were felt to have an impact on their surroundings. The respondents were also presented with two questions which asked them to rank in order the reasons they felt best described why removals and establishments had occurred in the windbreak populations for their area. Other questions asked dealt with the owner/operators knowledge of establishment incentive programs, and personal preferences concerning current and future establishment of windbreaks. The final sections of the survey were dedicated to irrigators. Here, questions were asked dealing with acreages irrigated, type of system(s) used, and whether or not any windbreak removal had been resultant from irrigation practices. And lastly, a question dealing with windbreak composition was asked to gain insight into what species are preferred in the area.

In selecting the individuals to be included for the questionnaire sample, aid was solicited from each counties Soil Conservation Service District Representative. After contacting Mr. Warren Conner of the Clark County SCS office, and Mr. Mike Kinsey from the Gray County office, names of individuals within each county which were known to have or once have windbreaks on their property within the last twenty years were collected using county records. Then using a county directory, the names and addresses of the owner/operators were matched, and the surveys sent to the appropriate individuals in the months of February and March of 1987. A sample size of 75 per county was chosen for two reasons. First, that was the maximum number of names that could be obtained for Clark County, and second it allowed for a manageable sample size for the mailing and computer processing. Upon receiving the returned responses, each set of data was transferred to a code sheet and then to the computer. A total of 80 individuals completed and returned their survey's with 42 of those responses being from Clark County while the remaining 38 were from Gray County.

Cross Tabulation Methodology and Analysis

The data presented in this section is arranged and tested by means of contingency tables in-which two nominal-scale variables were cross-classified (Blalock 1979). A series of tables were formed from the questionnaire which were felt to best explain reasons for windbreak change within the study area. For example, it was tested to see whether or not the age of the farm operator had any bearing on the feelings of that operator as to the use of windbreaks for a conservation practice. The results were organized into the following 3 x 4 contingency table.

Table 1. 3 x 4 Contingency Table

Age	Conservation Practice		
	Definite Value	Some Value	No Value
18-30	2 100.0 4.3	0 0 0	0 0 0
31-40	10 58.8 21.3	7 41.2 22.6	0 0 0
41-55	4 33.3 8.5	6 50.0 19.4	2 16.7 100.0
Over 55	31 63.3 66.0	18 36.7 58.1	0 0 0
Column Total	47 58.8	31 38.8	2 2.5

The frequencies were converted into percentages showing the difference between conservation practice values, and the age of the respondents. To further the analysis, the Chi-squared test was used to evaluate whether or not the differences were statistically significant. Through these means it was discovered whether or not the actual frequencies differed significantly from those expected under theoretical conditions. For the example offered above, the null hypothesis would assume that no differences exist between the age groups and their feelings towards windbreaks as a conservation practice. The value of this test is computed using the formula:

$$X^2 = \frac{(fo - fe)^2}{fe}$$

where fo refers to the observed frequency while fe makes reference to the expected frequency for each cell (Blalock 1979). Therefore, the square of the difference between the observed and expected frequencies was computed for each cell, and then divided by the expected number of cases for that cell. Also, all the non-negative values for all the cells were summed, resulting in the value of chi-squared. For the example given, chi-squared (X) equals 14.64 at six degrees of freedom. The degrees of freedom are determined by the number of cells in the table which can be computed using this formula:

$$\text{degrees of freedom} = (\text{row} - 1)\ (\text{column} - 1)$$
$$\text{d.f.} = (3 - 1)\ (4 - 1)$$
$$\text{d.f.} = 6$$

After determining 6 degrees of freedom for the 3 x 4 table, a probability level of .05 percent was selected for the level of significance. Using the .05 level with 6 degrees of freedom would result in a 95 percent probability that a difference exists. Therefore, if the chi-squared value offered for this example would exceed the chi-squared value which corresponds to the .05 probability at 6 degrees freedom, the null hypothesis would be rejected. For the example given, the computed chi-squared value is 14.64 at .02 probability with 6 degrees of freedom. However, (referring to Blalock 1979, p. 613), the corresponding table value is 12.59, thus rejecting the null hypothesis and stating that there clearly is a relationship between age of owner/operator and their belief in windbreaks as a conservation tool.

Because of the relatively small sample size, two basic problems resulted. First, the sampling distribution approximates the true distribution given for the chi-squared table only when a large sample is used (Blalock 1979). Although only a few categories showed significant correlations between variables, some individual frequencies showed high associations within the tables. It is possible that a larger sample size would have produced more significant results. Thus, a sample size that would be large enough to approximate the true distribution given in the chi-squared table would possibly indicate a greater significance among variables. Secondly, because of the small sample size, some of the expected frequencies in each cell fell below five, which as stated by Blalock is accepted as the minimum number of frequencies per cell. However, because of the importance placed on the individual variables, elimination of cells and consolidation of categories was not done although category consolidation would have increased the final statistical reliability. And finally, some corrections were made by the computer SPSS CROSSTABS program to increase the meaning of these chi-squared values.

Analysis Results

The frequencies shown in tables 3 through 8 indicate the relationships between differing variables associated with windbreaks and their role in the agricultural systems of Gray and Clark counties. Some tables showed no significant associations at the .05 probability level, but did at the .10 level while still others showed no association at all. Table 2 indicated the probability level offered for each individual table used in the study. The boxed values indicate the tables that showed significant correlation of the two variables at .05 probability. The values which are followed by an asterick show those tables which illustrate significant correlation at the .10 level. The remaining values indicate those tables which showed significance beyond the .10 level.

Table 2.

	Conservation Practice	Value	Economic Efficiency	Removal 1	Removal 2	Removal 3	Removal 4	Removal 5
Age	.02	.15	.86	.64	.66	.64	.48	.24
Age Cont.	Est. 1	Est. 2	Est. 3	Est. 4	Est. 5	Prog.	More	Add rec
	.99	.86	.26	.08*	.18	.74	.13	.35
Age Cont.	Remov.							
	.25							
	Value	Econ. Eff.						
Own/Op	.42	.49						
	Est. 1							
Economic Efficiency	.09*							
	Remov							
Nacreir	.40							
	Est. 1	Est. 2	Est. 3	Est. 4	Est. 5	Current		
More Wind Break	.19	.50	.14	.42	.11	.00		
	Irremo							
Hinder	.00							
	Nacreir	Irr. Sys.	Type Wind Brk.					
Remov.	.40	.38	.03					

** Abbreviation Key for Questionnaire:

Remov - Removed windbreaks
Hinder - Windbreaks a hindrance
Est. - Establishment
Ownop - Owner/operator
Econo eff - Economic effect
Prog - Program
Current - Windbreaks currently standing
Type Wind Brk - Type of Windbreak
Irrremo - Irrigation removals
More - More windbreaks
Nacreir - number of acres irrigated
Irr Sys - Irrigation system
Add rec - Added recently

Tables 3-1 through 3-17 consist of seventeen subtables that were developed from the questionnaire which examined relationships between the age of the owner/operator and various questions dealing with windbreaks. The first table offered looks at the effects of age in relationship to the perceived value of windbreaks as a conservation practice. The four age groups responding were those 18-30, 31-40, 41-55 and those over 55. The age group with the highest number of respondents was the over 55 category with 49 responses followed by the 31-40 age group with 17 responses and then the 41-55 and the 18-30 groups with 12 and 2 respondents, respectively. Of the available options, the majority of the respondents felt that windbreaks proved to be a definite value as a conservation practice, while a large percentage of the 31 and above group determined windbreaks to be of some value (Table 3-1). Only a small percentage, 16.7 percent felt that windbreaks were of no value as a conservation practice, all of whom fell into the 41 to 55 age group. The significance level for this table is .02 percent indicating with more than 95 percent confidence that a relationship exists between the respondents age and their beliefs in windbreaks as a conservation practice.

Table 3-1. Attitudes of Windbreaks Used as a Conservation Tool Relating to Land Impact

Land Impact	Age of Owner/Operator 18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
Conservation Practice				
definite value	100	58.8	33.3	63.3
some value	0	41.2	50.0	36.7
no value	0	0	16.7	0

In subtable 3-2, the relationship of age to the perceived value of mature field windbreaks on farmland value is examined. Here, the majority of all age groups felt some increase in value was seen, while a large number also felt that no effect on the value of farmland was offered by windbreaks. A relatively minor percentage indicated they felt sizable increases were seen in the value, and only 8.3 percent claimed windbreaks to be of no value to their land. The significance level for this table is .15, therefore, a definite relationship between the two variables cannot be accepted.

Table 3-2. Attitudes of Windbreaks Used as a Conservation Tool Relating to Farmland Value

Effects on Farmland Value	Age of Owner/Operator 18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
sizable increase	0	11.8	8.3	24.5
some increase	50.0	76.5	41.7	53.1
no effect	50.0	11.8	41.7	22.4
negative effect	0	0	8.3	0

In table 3-3, the effects of age and the net economic effect of establishing field windbreaks are cross-tabulated. Here again, the majority of the respondents in all age groups felt either no effects or some returns were seen. A small percentage felt some economic loss was involved while 6.3 percent indicated sizable returns and 2.1 percent registered sizable losses, both of which were listed in the over 55 age category. The significance level here is .86 percent, much too high to draw any significant correlations between the variables.

Table 3-3. Attitudes of Windbreaks Used as a Conservation Tool Relating to Economic Effects

	Age of Owner/Operator			
Economic Effect of Windbreaks of Farmland	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
sizable returns	0	0	0	6.3
some returns	50.0	52.9	41.7	33.3
no effects	50.0	29.4	25.0	41.7
some loss	0	17.6	33.3	16.7
sizable loss	0	0	0	2.1

For the next group of subtables, tables 3-4 through 3-8, the variable of age has been cross-tabulated with the respondents opinions on reasons for windbreak removals in their area. In these tables, the respondents were asked to rank in descending order from 1 to 5 reasons they felt most accurately determined current windbreak removals. Due to the ranking process, five different tables were generated illustrating the five reasons which were chosen with the most frequency. To enhance understanding of the results, this group of tables will be looked at collectively. The two top ranked reasons for all age groups were conflicts with irrigation practices (a notion that again supports the researchers hypothesis) and conflicts with farming practices (which suggest incompatibilities with planted fields and/or farm machinery). Other reasons offered with a high degree of frequency in the 31 to 55 age group were competition with crops, no economic value of land put into windbreaks, and age and condition of windbreaks, which also ranked high in the over 55 age group. The remaining options offered received only limited percentages throughout all age categories. Of the comments which could be interjected by the respondents, one individual wrote "In our area, CPI's don't work with windbreaks". Although the significance levels run .64, .66, .64, .48 and .24 respectively, it is felt by the researcher that the response percentages alone offer valuable information in discerning reasons for windbreak removals in the study counties.

Table 3.4. Attitudes of Windbreaks Used as a Conservation Tool Relating to Removals 1

	Age of Owner/Operator			
Reasons for Removal (1)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
age/cond. of windbreak	50.0	11.8	41.7	34.7
prep. for new windbreak	0	0	0	2.0
competition with crops	0	17.6	0	6.1
conflict with farming	50.0	5.9	8.3	20.4
no econ. value of land	0	0	8.3	6.1
conflict with irrigation	0	52.9	41.7	26.5
snow accumulation	0	5.9	0	2.0
add-on-farms	0	0	0	2.0
other	0	5.9	0	0

Table 3-5. Attitudes of Windbreaks Used a Conservation Tool Relating to Removals 2

	Age of Owner/Operator			
Reasons for Removal (2)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
age/cond. of windbreak	0	17.6	0	6.1
prep. for new windbreak	0	0	8.3	12.2
competition with crops	0	11.8	16.7	12.2
conflict with farming	50.0	41.2	50.0	26.5
no econ. value of land	0	11.8	0	4.1
conflict with irrigation	50.0	0	16.7	24.5
snow accumulation	0	5.9	8.3	8.2
add-on-farms	0	11.8	0	6.1
other	0	0	0	0

Table 3.6. Attitudes of Windbreaks Used as a Conservation Tool Relating to Removals 3

	Age of Owner/Operator			
Reasons for Removal (3)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
age/cond. of windbreak	0	17.6	8.3	12.2
prep. for new windbreak	50.0	11.8	0	4.1
competition with crops	0	23.5	33.3	26.5
conflict with farming	0	5.9	25.0	14.3
no econ. value of land	0	5.9	8.3	8.2
conflict with irrigation	50.0	17.6	8.3	20.4
snow accumulation	0	0	0	8.2
add-on-farms	0	17.6	16.7	4.1
other	0	0	0	2.0

Table 3.7. Attitudes of Windbreaks Used as a Conservation Tool Relating to Removals 4

	Age of Owner/Operator			
Reasons for Removal (4)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
age/cond. of windbreak	0	5.9	25.0	14.3
prep. for new windbreak	0	0	8.3	16.3
competition with crops	50.0	17.6	8.3	14.3
conflict with farming	0	29.4	16.7	16.3
no econ. value of land	0	5.9	8.3	12.2
conflict with irrigation	0	11.8	25.0	14.3
snow accumulation	0	17.6	8.3	8.2
add-on-farms	50.0	11.8	0	4.1
other	0	0	0	0

Table 3-8. Attitudes of Windbreaks Used as a Conservation Tool Relating to Removals 5

	Age of Owner/Operator			
Reasons for Removal (5)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
age/cond. of windbreak	0	29.4	16.7	14.3
prep. for new windbreak	0	5.9	8.3	12.2
competition with crops	0	11.8	8.3	14.3
conflict with farming	0	17.6	0	20.4
no econ. value of land	0	11.8	16.7	6.1
conflict with irrigation	0	5.9	8.3	2.0
snow accumulation	50.0	0	25.0	22.4
add-on-farms	0	0	8.3	8.2
other	50.0	17.6	8.3	0

Like the previous group, the next set of tables (tables 3-9 to 3-13) cross-tabulates age and variables in which the respondents were asked to rank in descending order from 1 to 5 reasons they felt best emulated establishment of windbreaks in their area. Although the tables were split to accommodate the ranking process, they will be reviewed as a collective unit. The respondents were not as consistent in their answers here as in the previous group of questions, although several ideas did stand out within given age groups. Soil conservation and cattle protection were answers prevalent for all age groups, but were especially evident in the 41 and over categories, possibly indicating a referral back to the dust bowl days of the 1930's and 1940's. Wildlife management, increased property value, and snow management made a strong showing in the 18 to 40 age groups suggesting this generations interest in the peripheral benefits associated with windbreaks. Of the remaining options offered, all received only limited acceptance, although it is interesting to note when given the opportunity to interject their own reasons for windbreak establishment, all seven respondents who did so indicated wind protection for farmsteads as one of their 5 reasons. These statements support the recurring theme found throughout the survey responses; that there is increased farmstead windbreak support rather than field windbreak support. The confidence levels for these tables were .99, .86, .26, and .08 (falling within the 90 percent confidence range), and .18 respectively.

Table 3-9. Attitudes of Windbreaks Used as a Conservation Tool Relating to Establishment 1

	Age of Owner/Operator			
Reasons for Est. (1)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
yield improvement	0	5.9	0	6.1
soil conservation	50.0	35.3	41.7	40.8
aesthetics	0	11.8	0	4.1
cattle protection	50.0	23.5	33.3	30.6
increase prop. value	0	0	0	4.1
snow management	0	11.8	16.7	6.1
wildlife hab.	0	5.9	8.3	4.1
wood source	0	0	0	2.0
other	0	5.9	0	2.0

Table 3-10. Attitudes of Windbreaks Used as a Conservation Tool Relating to Establishment 2

	Age of Owner/Operator			
Reasons for Est. (2)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
yield improvement	0	5.9	0	0
soil conservation	0	23.5	8.3	20.4
aesthetics	0	5.9	8.3	4.1
cattle protection	50.0	29.4	58.3	36.7
increase prop. value	0	5.9	0	10.2
snow management	50.0	5.9	8.3	16.3
wildlife hab.	0	17.6	16.7	10.2
wood source	0	5.9	0	2.0
other	0	0	0	0

Table 3-11. Attitudes of Windbreaks Used as a Conservation Tool Relating to Establishment 3

Reasons for Est. (3)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
	Age of Owner/Operator			
yield improvement	0	5.9	0	0
soil conservation	0	0	8.3	6.1
aesthetics	100	5.9	25.0	16.3
cattle protection	0	11.8	0	18.4
increase prop. value	0	29.4	8.3	8.2
snow management	0	11.8	25.0	22.4
wildlife hab.	0	29.4	25.0	22.4
wood source	0	5.9	8.3	6.1
other	0	0	0	0

Table 3-12. Attitudes of Windbreaks Used as a Conservation Tool Relating to Establishment 4

Reasons for Est. (4)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
	Age of Owner/Operator			
yield improvement	0	5.9	0	0
soil conservation	0	5.9	16.7	8.2
aesthetics	0	35.3	25.0	12.2
cattle protection	0	11.8	8.3	4.1
increase prop. value	50.0	23.5	16.7	2.0
snow management	0	11.8	16.7	30.6
wildlife hab.	50.0	5.9	16.7	34.7
wood source	0	0	0	8.2
other	0	0	0	0

Table 3-13. Attitudes of Windbreaks Used as a Conservation Tool Relating to Establishment 5

	Age of Owner/Operator			
Reasons for Est. (5)	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
yield improvement	50.0	5.9	0	10.2
soil conservation	50.0	17.6	16.7	12.2
aesthetics	0	11.8	8.3	24.5
cattle protection	0	17.6	0	6.1
increase prop. value	0	0	33.3	8.2
snow management	0	0	0	0
wildlife hab.	0	35.3	16.7	16.3
wood source	0	5.9	16.7	18.4
other	0	5.9	8.3	4.1

The next subtable (table 3-14) examines age in relation to the operators awareness of incentive programs for windbreak establishment. As shown, large percentages of the 18 to 40 age groups indicated an awareness of some sort of incentive program, although an even higher percentage knew of none. While a large percentage of the 41 and over age categories stated they knew of no windbreak incentive programs. The significance level for this table is .74, however, the individual percentages indicate a greater awareness among the younger rural age groups of these counties, and/or an inability of the governmental agencies to reach the older farmers, or rejection of these agencies by the older rural residents. Of the sixteen written responses concerning this question, nearly all responded with the Agriculture Stabilization and Conservation Service Conservation Reserve Program or the State Forestry subsidy, while three responded with programs that are no longer in existence.

Table 3-14. Attitudes of Windbreaks Used as a Conservation Tool Relating to Incentive Programs

	Age of Owner/Operator			
Landowner aware of any incentive program	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
yes	50.0	41.2	25.0	30.6
no	50.0	58.8	75.0	69.4

For the next subtable (table 3-15), the variables of age and the desire to see more windbreaks established in the residents area is explored. Here, high positive percentages are indicated in the 18 to 40 groups and over 55 group, while the 41 to 55 category indicated less of a desire to see more establishment. The significance level here is .13 falling just outside the 90 percent confidence range. Of the written responses offered four individuals indicated wildlife enhancement as their reasons for new establishment, and an additional three supported farmstead windbreak not field windbreak establishment. However, the remaining ten did not wish to see additional establishment of windbreaks largely because they felt the windbreaks reduced their yields.

Table 3-15. Attitudes of Windbreaks Used as a Conservation Tool Relating to the Desire to See More Windbreaks

Desire to see more windbreaks established	Age of Owner/Operator 18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
yes	100.0	70.6	33.3	54.2
no	0	29.4	66.7	45.8

The next subtable (table 3-16) cross-tabulated the variables of age and whether or not the landowner had recently added any windbreaks. Higher percentages in all age groups (with the exception of the 18-30 group which was split 50-50) indicated that they had not added any windbreaks. Again, the percentages show insight into the apathetic feelings of windbreak establishment by the respondents.

Table 3-16. Attitudes of Windbreaks Used as a Conservation Tool Relating to Recent Additions

Landowner added any windbreaks recently	Age of Owner/Operator 18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
yes	50.0	29.4	25.0	14.3
no	50.0	70.6	75.0	85.7

The final subtable (table 3-17) in this grouping looks at the relationship of age and whether the owner/operator has initiated any windbreak removals from his/her land. Although a high significance level is seen at .25, and the 18-30 year age group showed that no removals had occurred, small instances of removals had occurred in the

31-40 group. While the 41-55 group demonstrated the highest levels of removal, the 55 and over group showed moderate removals.

Table 3-17. Attitudes of Windbreaks Used as a Conservation Tool Relating to Removals

	Age of Owner/Operator			
Has owner removed any windbreaks from his land	18-30 n = 2	31-40 n = 17	41-55 n = 12	> 55 n = 49
yes	0	5.9	33.3	20.4
no	100.0	94.1	66.7	79.6

Table 4 looks at the tenure of the owner/operator in relation to questions covering owner/operator attitudes of field windbreaks relative to economic variables. Two cross-tabulations are contained within table 4. The first table looks at the variables of tenure of owner/operator on the farm and how the owner/operator perceives the presence of mature field windbreaks on farmland value. The heaviest concentrations of percentages fell into the "some increase in value" category which applied to all tenure groups. The next heaviest concentration of percentages, (again, in all tenure groups with the exception of over 16 years) responded with windbreak having "no effect on value". The remaining percentages were 26.3 for "sizable increase in value" in the over 16 years group, and 1.8 for "negative effect on value" in this same age category. The significance level for this table is .42 indicating limited if any relationship between variables.

Table 4-1. Tenure of Owner/Operator On Farm Relating to Attitudes Towards Windbreaks

Owner/Operator Attitudes	n = 5 1-5	n = 8 6-10	n = 10 11-15	n = 57 > 16
*Effects on Farmland Value				
sizable increase	0	0	0	26.3
some increase	80.0	75.0	60.0	50.9
no effect	20.0	25.0	40.0	21.1
negative effect	0	0	0	1.8

The second crosstab within the table looks at tenure of owner/operator and the perceived economic effects of establishing field windbreaks to protect cropland. Here again, the majority of responses for all tenure groups fell into the middle of the road categories of "some return" and "no effect". The exception here is shown to be the increase in the "some loss" category, especially in the 11-15 year tenure group. Again as in the previous crosstab, the greatest dispersal within a tenure group was the over sixteen year category. The significance level for this table is .49 (again indicating limited correlation between variables). However, it is interesting to note in both crosstabs that as tenure on farms increases so does the dispersal in viewing economic effects of windbreaks on the land.

Table 4-2. Tenure of Owner/Operator On Farm Relating to Economic Effects of Windbreak Establishment

Owner/Operator Attitudes	n = 5 1-5	n = 8 6-10	n = 10 11-15	n = 57 > 16
*Economic Effect on Farmland				
sizable returns	0	0	0	5.4
some returns	40.0	62.5	30.0	37.5
no effect	60.0	25.0	20.0	39.3
some loss	0	12.5	50.0	16.1
sizable loss	0	0	0	1.8

Table 5 shows the crosstabulation of the respondents reasons for windbreak establishment and the degree to which they feel windbreaks have economically impacted their cropland. One hundred percent of those who indicated sizable economic returns elected either yield improvement or soil conservation as their number one reason. Throughout the remainder of the table either soil conservation or cattle preparation was elected as the two leading reasons for windbreak establishment. The significance level for this table is .09*. Thus, when using the 90 percent confidence level, a relationship does exist between reasons for windbreak establishment and the degree of economic effect on cropland imposed by the windbreaks.

Table 5. Economic Effects of Windbreaks Relating to Establishment 1

Reasons for Establishment (1)	n = 3 sizable return	n = 31 some return	n = 29 no effect	n = 15 some loss	n = 1 sizable loss
yield improvement	66.7	6.5	0	0	0
soil conservation	33.3	48.4	41.4	20.0	100.0
aesthetics	0	9.7	0	6.7	0
cattle prep.	0	19.4	34.5	53.3	0
increase prop. value	0	0	3.4	0	0
snow management	0	9.7	10.3	6.7	0
wildlife Hab.	0	3.2	6.9	6.7	0
wood source	0	0	3.4	0	0
other	0	3.2	0	6.7	0

For table series 6, the desire to see more windbreak establishment has been crosstabulated with differing variables in order to gain insight into reasons that contribute to establishment. For the first five subtables, the respondents were asked to rank in descending order from one to five reasons they felt best approximated establishment of windbreaks. In the first two subtables, it is interesting to note that the same reasons which have high percentages in the "yes" category, also retain high percentages in the "no" category. Reasons for establishment which rate high in the "yes" column throughout all the subtables are soil conservation, cattle preparation, aesthetics and wildlife habitat. Whereas those reasons which rank high in the "no" category differ little from those in the "yes". The significance levels run, .19, .50, .14, .42 and .11 respectively, thus reducing the researcher's ability to draw significant correlations between the variables.

Table 6.1. Desire to See More Windbreaks Relating to Establishment 1

Reasons for Est. (1)	n = 44	n = 35
yield improvement	9.1	0
soil conservation	40.9	40.0
aesthetics	4.5	5.7
cattle preparation	29.5	31.4
increase property value	2.3	0
snow management	11.4	5.7
wildlife hab.	0	11.4
wood source	0	2.9
other	2.3	2.9

Table 6-2. Desire to See More Windbreaks Relating to Establishment 2

Reasons for Est. (2)	n = 44	n = 35
yield improvement	0	2.9
soil conservation	18.2	17.1
aesthetics	9.1	0
cattle preparation	36.4	42.9
increase property value	9.1	5.7
snow management	15.9	11.4
wildlife hab.	9.1	17.1
wood source	2.3	2.9
other	0	0

Table 6-3. Desire to See More Windbreaks Relating to Establishment 3

Reasons for Est. (3)	n = 44	n = 35
yield improvement	2.3	0
soil conservation	9.1	0
aesthetics	13.6	22.9
cattle preparation	18.2	8.6
increase property value	13.6	11.4
snow management	13.6	25.7
wildlife hab.	27.3	20.0
wood source	2.3	11.4
other	0	0

Table 6-4. Desire to See More Windbreaks Relating to Establishment 4

Reasons for Est. (4)	n = 44	n = 35
yield improvement	0	2.9
soil conservation	11.4	5.7
aesthetics	22.7	14.3
cattle preparation	2.3	11.4
increase property value	11.4	8.6
snow management	25.0	22.9
wildlife hab.	20.5	31.4
wood source	6.8	2.9
other	0	0

Table 6-5. Desire to See More Windbreaks Relating to Establishment 5

Reasons for Est. (5)	n = 44	n = 35
yield improvement	9.1	5.7
soil conservation	11.4	20.0
aesthetics	25.0	11.4
cattle preparation	11.4	2.9
increase property value	4.5	17.1
wildlife hab.	25.0	14.3
wood source	9.1	22.9
other	4.5	5.7

The last table in this series crosstabulates the respondents feelings towards windbreaks currently standing, and if they are felt to represent the best use of land they occupy and the desire to see establishment of more windbreaks. Here, 84.1 percent of those who indicated windbreaks represented the best use of land also indicated a desire to see more. While 54.3 percent who did not feel them to be of best land use also desired no future establishment. The significance level registered for this table is .00 suggesting the highest degree of correlation between the variables.

Table 6-6. Desire to See More Windbreaks Relating to Those Currently Standing

Windbreaks Currently Standing Represent Best Use of Land	n = 44	n = 35
yes	84.1	45.7
no	15.9	54.3

Throughout the next series of tables much of the data deals with irrigation effects and the response these effects have had on windbreaks. Table 7 crosstabs removal of windbreaks as a result of irrigation and windbreaks as a hindrance in relation to irrigation. Here, 90 percent of those who indicated windbreaks had been a hindrance had removed them as a result of irrigation. Whereas, 98.2 percent who contended windbreaks had not been a hindrance had not removed any. Further, 78.6 percent who said windbreaks had not been a hindrance also related that sometimes removals had occurred because of irrigation. Most comments interjected into the answer by the respondents indicated that removal of the trees was done to accommodate sprinkler systems. The significance level for this table .00 again suggesting the highest degree of correlation between the variables.

Table 7. Has Removal of Windbreaks Been Result of Irrigation Relating to Windbreaks as a Hinderance

Related to Irrigation Have windbreaks been a hindrance	n = 10 yes	n = 56 no	n = 14 sometimes
yes	90.0	1.8	21.4
no	10.0	98.2	78.6

For table 8-1, the first table in this final set, the variables of windbreak removals and the number of acres irrigated have been examined. The percentages in the table seem to suggest that for the lower irrigated acreages (those of 1 to 320) no significant removals have occurred. However, as the irrigated acreages increased so did indicated removals. This is true until the over 641 acre category is reached when the numbers level off and both categories approximate each other. The significance level for this subtable is .40 indicating no acceptable relationship between variables.

Table 8.1. Has Any Removal of Windbreaks Occurred on Your Land Relating to Acreage Irrigated

No. of Acres Irrigated	n = 14 yes	n = 42 no
1-160	28.6	31.0
161-320	14.3	31.0
321-640	35.7	16.7
641 & over	21.4	21.4

The next table in this set reveals the relationship between windbreak removals and the type of irrigation system used. For those respondents who employ center-pivot sprinklers, 92.9 percent indicated removal had occurred while 83.3 percent of the same had not removed any. For those who registered the gravity method of irrigation, 7.1 percent had initiated removals while 4.8 percent had not. Here the significance level is .38, suggesting no correlation between variables; although again, the individual percentages shed light on windbreak removals due to irrigation.

Table 8.2. Has Any Removal of Windbreaks Occurred on Your Land Relating to Irrigation System Used

Type of Irrigation System Used	n = 14 yes	n = 42 no
Centerpivot	92.9	83.3
Gravity	7.1	4.8
Other	0	11.9

In the final subtable, the composition of the windbreaks found on the respondents land is cross-tabulated with removals. Here, removals of both coniferous and deciduous windbreaks outweigh non-removals. But a change is seen in those who have a combination of the two. Here 78.1 percent indicate no removals opposed to 46.7 percent who do. The significance level for this subtable is .03, stating a high degree of correlation between variables. Examples of species listed which make-up windbreaks were Eastern Red cedar, Elm, Honeylocust, Pine, Russian Olive, Cottonwood, and Osage Orange, respectively. Approximately half of those individuals responding to the species list indicated their windbreaks were composed of both coniferous and deciduous varieties.

Table 8-3. Has Any Removal of Windbreaks Occurred on Your Land Relating to Type of Windbreak

Type of Windbreak Found on Land	n = 15 yes	n = 64 no
Coniferous	20.0	10.9
Deciduous	33.3	10.9
Combination	46.7	78.1

Throughout the analysis of the results of this survey, various themes became evident. It would appear that the notions of increased irrigation practices and decreased windbreak numbers along with conflicts in farming practices and an increasing appeal of farmstead windbreaks as opposed to field windbreaks are quite common. In light of the limited number of responses, the importance of sample size becomes very evident. The results surmised from both the air-photo interpretation analysis as well as the survey will be summarized in the next and final chapter of this thesis.

Chapter 6

SUMMARY AND CONCLUSION

The fate of the field windbreak lies in the hands of the people who utilize the agricultural lands of our country. Whether or not the number of windbreaks now standing will continue to serve their conservation purpose and be expanded upon or will fall prey to the repercussions of modernized methods of farming entirely, remains to be seen. However, it is hoped by the researcher that this study has been able to show current activity and shed light on future trends in the use of field windbreaks as a conservation tool. It should be noted that trends in the agricultural sector as with trends in any economic sector are changed and modified over the course of time. But, it is also felt that an unmeasureable importance is to be placed on the land managers and the State and Federal agencies in so far as their roles in continuing windbreak establishment and promoting their importance in the agricultural setting is concerned.

This study has examined Clark and Gray Counties of Southwestern Kansas. Each county varies widely in its topography and geological make-up, therefore, the mode of agriculture practices also range. This, in part, was purposefully chosen to demonstrate whether or not these differences had any bearing on possible windbreak changes. It is the researchers feelings that they did. Gray County, a county with deep even soils, much plowed land and high irrigation potential, initially saw the greatest windbreak development and subsequently the greatest declines. Where as, Clark County, a county high in rangeland

and low in arable soils and irrigation development, experienced limited windbreak establishment and moderate removals.

Through the air-photo index interpretation, the mapping procedure for each county for the two dates was completed showing a number of changes in the windbreak networks of the study counties. First, sizable reductions have occurred in both counties but especially in Gray, illustrating the importance of high irrigation development. In all instances, the greatest reductions were found in areas which correlated with heavy concentrations of center-pivot irrigation development. Secondly, interesting changes in plowed regions and hence windbreak populations were disclosed. In examining the mosaics of Clark County, quite a percentage of cultivated land appears to have shifted Southward to the central portions of the county from the Northwest. Efforts to take advantage of new irrigation sources seem to be the likely reason. Also supporting this is a marked decline in windbreaks for this new area as illustrated on the 1981 map.

Through analysis of the questionnaire, additional reasons for these declines were uncovered and various trends concerning windbreaks became apparent. First, irrigation, specifically center-pivot irrigation, was seen as the greatest detriment to planted field windbreaks and to the potential establishment of new ones. Along with this, as farmers reported greater acreages of land falling under irrigation, more indicated removals of field windbreaks on their land. High percentages responded with the feelings that field windbreaks resulted in no or little effect on the value and economic production of their land, while several registered losses in these areas. Yet another reason given for declining numbers of windbreaks was the respondents beliefs that windbreaks were responsible for yield decreases for the fields they were planted adjacent to (although this has proved unwarranted through research done by State Foresters). An interesting trend was seen concerning the present windbreaks of the area. Whereas a general reluctance was seen in the establishment of new windbreaks, a reluctance was also seen in the removal of the old established ones.

A third trend made evident by the survey is a distinct pattern seen in the composition of those windbreaks removed. Whereas strips composed entirely of coniferous trees experienced the greatest removals (apparently due to the tendency for that species to randomly spread), examples made-up of completely deciduous species also saw very high rates of removals. This trend was found to be due in part to limited longevity and insect pests which plague many hardwood species. The lowest rates of removal were seen in windbreaks of multiple species composition, suggesting the importance played in correct design and composition.

The final trend made evident by the survey, and uncalculated by the researcher is the increased interest shown in farmstead windbreaks as opposed to field windbreaks. The majority of the respondents offering written comments to this question indicate a high degree of interest in farmstead windbreaks for wind protection and energy conservation while much of the time exhibiting little interest in field protection. It is felt that this perhaps reflects on the concerns of living and energy costs while showing an indifference to land and crop protection. This could be a possible repercussion of government subsidy programs. A concern regarding government programs also arose through results of the survey. Of the responses given, a distinctly higher number of the younger age groups involved showed some awareness of the various government incentive programs available, while the majority of the older respondents claimed limited knowledge of such programs. This indicates perhaps an unwillingness of the older farmer to either associate with the government agencies or a hesitation to accept their help and ideas. And lastly, of the reasons given, a high percentage indicated removals to be due in part to the incompatibilities of windbreaks with modern day farming practices, to include larger more bulky equipment, larger field size, and again modernized methods of irrigation.

To say that the field windbreak is an endangered species, is perhaps too strong a tone. However, percentage rates of decline have far out weighed establishment rates over the past twenty years. And while the older, diseased and dying windbreaks fall into decay new vital one's are no longer replacing them. This is an alarming trend which should be checked before irretrievable losses are incurred upon the ecosystem.

The following recommendations are made based on the results of this study. First, by continuing and intensifying the roles of the county agents and state and federal agencies as well as strengthening their knowledge and skills in windbreak benefits, rural land managers may cease to view windbreaks as a detriment. Secondly, through strong government incentive programs, perhaps one specifically designed for windbreak establishment and improvement, land managers may realize quick monetary benefits. Thirdly, investigations into new methods of windbreak placement and composition which have seen some success on experimental levels should be researched further to provide the irrigator and large scale farmer viable alternatives to the long linear strips that may not be compatible with his method of farming. And finally, an intense U.S.D.A. educational campaign stressing the benefits of windbreaks to agricultural producers should be implemented, illustrating the positive influences windbreaks can have on the landscape.

The investigation into the problems that plague modern day windbreak establishment for the entire state, let alone the agricultural ecosystems of the midwest, are far beyond the scope of this study. It should be noted however, that if windbreak losses are to go unchecked in this study area, the possibility for moisture loss, crop failure, soil loss and the beginnings of desertification exists.

APPENDICES

Appendix A

SOUTHWEST KANSAS WINDBREAK SURVEY

Please circle choice unless otherwise indicated.

1. How long have you been owner/operator of the farm on which you work?

   A. Less than 1 year

   B. 1-5 years

   C. 6-10 years

   D. 11-15 years

   E. over 16 years

2. How do you perceive the value of windbreaks as a conservation practice?

   A. Definite value

   B. Some value

   C. No value

3. How do you perceive the presence of mature field windbreaks on farmland value?

   A. Sizable increase in value

   B. Some increase in value

   C. No effect on value

   D. Negative effect on value

4. How do you perceive the effects of mature field windbreaks on crop production yields in fields protected by windbreaks?

   A. Sizable yield increase

   B. Some yield increase

   C. No yield effect

   D. Some yield decrease

   E. Sizable yield decrease

5. Given your comments above concerning yield effects as well as consideration of farmland taken out of production by the presence of windbreaks, how do you perceive the net economic effect of establishing field windbreaks to protect cropland?

   A. Sizable economic returns

   B. Some additional returns

   C. No effect on economic returns

   D. Some economic loss

   E. Sizable economic loss

6. In your opinion, what are the reasons for windbreak removals in your particular area? Please rank top 5 in descending order (1-5) of importance.

   _____ A. Age and condition of windbreaks

   _____ B. Preparation for new windbreaks

   _____ C. Windbreak competing with crops

   _____ D. Conflict with farming practices

   _____ E. No economic value of land in windbreaks

   _____ F. Conflict with irrigation development

   _____ G. Caused excessive snow accumulation on road

   _____ H. Consolidation of added-on farms

   _____ I. Other (please specify) ______________________________

7. What do you feel are the most important reasons for field windbreak establishment in your area? Please rank top 5 in descending order (1-5) of importance.

   _____ A. Crop yield improvement

   _____ B. Soil conservation

   _____ C. Aesthetic (appearance) considerations

   _____ D. Cattle preparation during winter months

   _____ E. Increased value of property

_____ F. Snow management

_____ G. Provide wildlife habitat

_____ H. Source of firewood, posts, etc.

_____ I. Other (please specify) ______________________________

8. Are you aware of any economic incentive programs which encourage landowners to establish field windbreaks? (please circle one).

   A. Yes

   B. No

   If yes, what are they? ______________________________
   ____

9. In your opinion, for your area, do field windbreaks currently standing represent the best use for the land area occupied? (please circle one).

   A. Yes

   B. No

   Explain: ______________________________
   ____

10. Do you have a desire to see more field windbreaks being established in your county in the coming years? (please circle one).

   A. Yes

   B. No

   Explain: ______________________________
   ____

11. How many acres do you irrigate? (please circle one)

   A. 1 - 160

   B. 161 - 320

   C. 321 - 640

   D. 641 and over

12. What types of irrigation system do you use? (please circle one)

    A. Center pivot sprinkler

    B. Gravity

    C. Other, please specify ______________________________

13. Taking into consideration your irrigation system, have the field windbreaks on your land have been a hindrance? (please circle one)

    A. Yes

    B. No

    C. Sometimes

    Explain: ______________________________
    ____

14. Has any removal of field windbreaks on your land been the result of irrigation influences?

    A. Yes

    B. No

    Explain: ______________________________
    ____

15. Have you added any field windbreaks in recent years?

    A. Yes

    B. No

    Explain: ______________________________
    ____

16. What is your age?

    A. 18-30

    B. 31-40

    C. 41-55

    D. over 55

17. Have you removed windbreaks on your farm? Yes _____ No _____. If yes, then what are the reasons for the windbreak removal on your particular farm?

____

____

18. Are the existing windbreaks on your land composed primarily of (check one) coniferous trees _____, deciduous trees _____, a combination of the two _____. Please give examples of species.

____

____

Thank you for your cooperation.

Appendix B

January 30, 1987

Dear Farmer or Land Manager:

I am currently working on a research project in southwest Kansas pertaining to field windbreak dynamics. The most central role of this research effort is farmer input through completion of the enclosed questionnaire. Please complete this form and return it using the enclosed postage free envelope.

Your name has been selected as part of a sample of rural residents that presently, or at one time may have had field windbreaks on their farmstead. I do hope you will help in this effort by completing the questionnaire.

Thank you for your assistance.

Sincerely,

Roxanne Beard
Graduate Student in Geography
Kansas State University

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FACTORS INFLUENCING THE CHANGING PATTERN OF

FIELD WINDBREAKS IN SOUTHWESTERN KANSAS

BY

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AN ABSTRACT OF A THESIS

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requirements for the degree

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ABSTRACT

Windbreak plantings traditionally have been an important part of soil erosion control for much of the Great Plains. Research done in recent years by the Soil Conservation Service has shown that windbreak plantings cause no net reduction in cropland yields; yet within the past twenty years, a growing trend of windbreak removal has been sweeping the plains states, including much of western Kansas.

Gray and Clark Counties in southwestern Kansas are two such areas which have experienced notable changes within their windbreak networks. By use of low altitude, air-photographs, inventory maps of existing windbreaks for the pre-irrigation dates of 1960 to 1961, to the post-irrigation date of 1980, were made. It was found that notable declines in the windbreak networks had occurred in both counties, with Gray County seeing the larger rate of decline in conjunction with a higher rate of irrigation development.

In addition to the mapping procedure, statistical observations were made in an effort to disclose any additional reasons for the declines. Using data derived from mailed questionnaires sent to residents in the area that were known to have windbreaks on their land for the time frame studied, additional conclusions were made. Along with irrigation which was seen as a detriment to windbreaks, farmers reported little or no effect on land value and lessened economic production of their lands that contained windbreaks. Another reason for declining windbreak numbers was due to the attitude that decreased yields occurred for fields planted adjacent to windbreaks. The species composition of the windbreak also seemed to play a role in its removal. The windbreaks that contained entirely coniferous trees or entirely

deciduous species experienced the greatest amounts of removal, while lower removal rates were seen in those examples composed of both species. Lastly, whereas farmers showed a general reluctance towards field windbreaks, farmstead windbreaks offering protection to homes and barns were viewed in a much more positive light.