DETERMINATION OF IRRIGATION PUMPAGE
IN PARTS OF KEARNY AND FINNEY COUNTIES,
SOUTHWESTERN KANSAS

By Richard J. Lindgren

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 82-4011

Prepared in cooperation with the

KANSAS STATE BOARD OF AGRICULTURE,

DIVISION OF WATER RESOURCES

Lawrence, Kansas
1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For further information write to:

U.S. Geological Survey
1950 Avenue A - Campus West
University of Kansas
Lawrence, Kansas 66044-3897
[Telephone: (913) 864-4321]

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CONVERSION FACTORS

To aid those readers who are interested in the International System (SI) of Units, the factors for converting from inch-pound units used in this report to SI units are given below:

Multiply inch-pound unit	By	To obtain SI unit
inch	2.54	centimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
acre	0.4047	square hectometer
acre-foot	1,233	cubic meter
acre-foot per year	1,233	cubic meter per year
cubic foot per second	28.32	liter per second
degree Fahrenheit (°F)	(1)	degree Celsius (°C)

[1] °C = (°F - 32)/1.8.

DETERMINATION OF IRRIGATION PUMPAGE IN PARTS OF KEARNY AND FINNEY COUNTIES, SOUTHWESTERN KANSAS

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ABSTRACT

Irrigation pumpage was determined for parts of Kearny and Finney Counties in southwestern Kansas using crop-acreage data and consumptive-irrigation requirements. Irrigated acreages for 1974-80 were compiled for wheat, grain sorghum, corn, and alfalfa using records from the U.S. Agricultural Stabilization and Conservation Service. Consumptive-irrigation requirements were computed using a soil-moisture model. The model tabulated monthly soil-moisture and crop-water demand for various crops and computed the volume of irrigation water needed to maintain the available soil moisture at 50 percent for loamy soils or at 60 percent for sandy soils. The consumptive-irrigation requirements determined by the soil-moisture model were increased by factors of 1.4 for flood irrigation and 1.3 for sprinkler irrigation to account for nonproductive losses of applied water (irrigation-application losses). Annual irrigation pumpage for each crop was computed as the product of the crop acreage times the consumptive-irrigation requirement, plus irrigation-application losses.

Irrigated acres in the study area increased from 265,000 acres during 1974 to 321,000 acres during 1980. Irrigation pumpage increased from 584,000 acre-feet during 1974 to 738,000 acre-feet during 1980. Decreased consumptive-irrigation requirements during 1979 resulted in a comparatively small irrigation-pumpage estimate of 458,000 acre-feet.

INTRODUCTION

Severe decreases in flow of the Arkansas River and declines in ground-water levels pose a serious threat to the economy of southwestern Kansas. A study was made by the U.S. Geological Survey, in cooperation with the Kansas State Board of Agriculture, Division of Water Resources, to determine the effects of irrigation pumping in parts of Kearny and Finney Counties. The objectives of the study included the construction and application of a digital ground-water flow model. The digital model was used to simulate the effects of pumping from the unconsolidated Ogallala aquifer on flow of the Arkansas River and on ground-water levels in the study area. Irrigation pumpage was estimated in most of Kearny and Finney Counties for use in the digital ground-water flow model of the area (fig. 1).

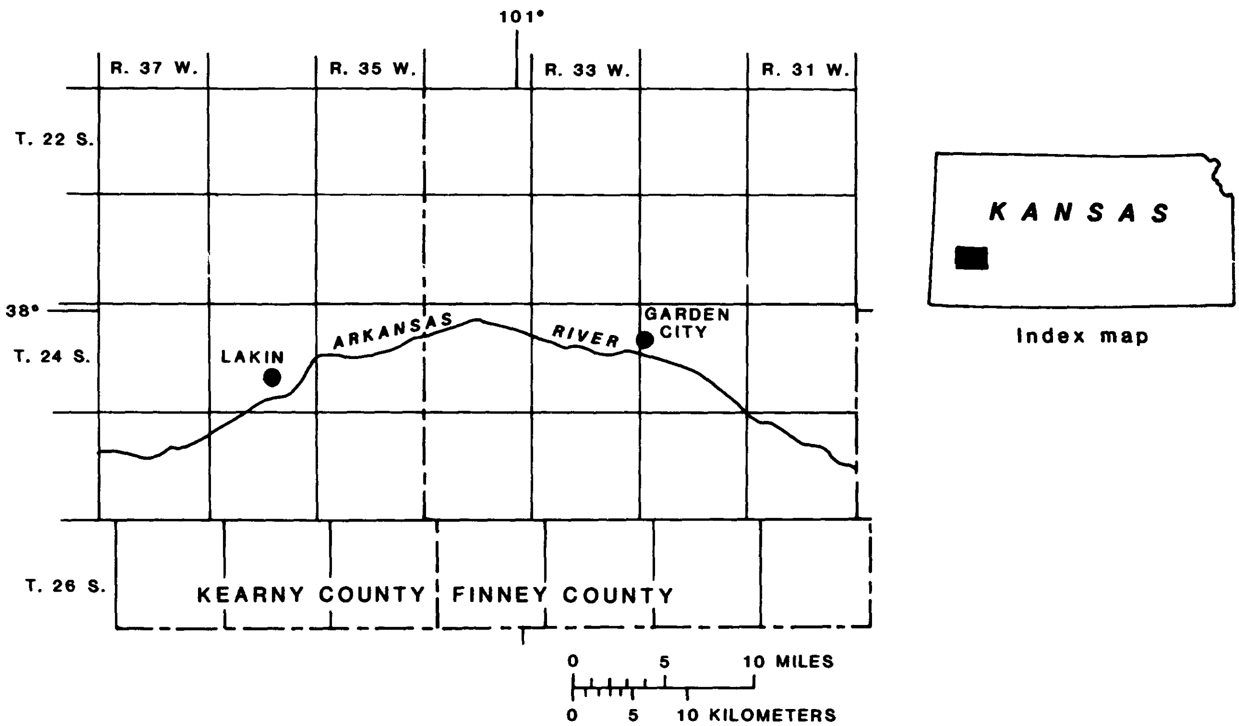


Figure 1.--Area for which irrigation pumpage was estimated.

The purpose of this report is to describe the method used to estimate irrigation pumpage. Seasonal irrigation withdrawal was estimated using irrigated-crop acreages and consumptive-irrigation requirements. Irrigated-crop acreages were obtained from records of the U.S. Agricultural Stabilization and Conservation Service. Requirements for consumptive irrigation were calculated using a soil-moisture model. Irrigation pumpage is the product of irrigated acreage times the consumptive-irrigation requirement, or that part of the crop-water demand that must be met by irrigation water, plus irrigation-application losses. The method described in this paper would be useful in similar cases when appropriate pumpage data are not available and need to be estimated.

CROP ACREAGES

Collection of Crop-Acreage Data

The determination of irrigated-crop acreages for each township was prerequisite to the computation of irrigation pumpage and provided a spatial distribution of relative pumpage intensities in the study area. Irrigated-crop acreages during 1974-80 for wheat, grain sorghum, corn, and alfalfa were compiled for each township in the study area using farm records from the U.S. Agricultural Stabilization and Conservation Service. About 90 percent of the farmers in the area reported their crop acreages, according to Gordon O'Dell of the U.S. Agricultural Stabilization and Conservation Service (oral commun., 1981). Farm records consisted of individual cards listing the owner(s), the legal description (location) of the land, and the irrigated and dryland acres of wheat, grain sorghum, and corn planted for specified years.

Additional crop records (by county), available from the Kansas State Board of Agriculture, Crop and Livestock Reporting Service, were used for determining alfalfa acreage. In Finney County, alfalfa acreage was reported to the U.S. Agricultural Stabilization and Conservation Service for the majority of farms during 1977, but only infrequently for other years. In Kearny County, alfalfa acreage rarely was reported in any year.

Missing Data

Three major problems occurring in the use of farm records were missing data for the entire period, 1974-80, unreported data for one or more isolated years, and individual cards containing acreage that was combined with acreage in another township or county. Missing data, which represent farm acreages for which no data could be found in records of the U.S. Agricultural Stabilization and Conservation Service for 1974-80, resulted from three main causes: (1) Farm acreages located in Kearny and Finney County may have been included on a card recorded in a different county office (therefore, the card and data were not readily available); (2) cards may have been missing from the files; or (3) about 10 percent of the farmers in the area may not have reported acreages of crops planted during any year from 1974 to 1980.

The acreage not accounted for due to the three causes listed above was determined to be 10,800 acres in Kearny County (345,600 total acres) and 19,300 acres in Finney County (460,800 total acres). Calculated as a percentage of the total acres in each county included in the study area, these acreages represent 3.1 percent for Kearny County and 4.2 percent for Finney County. The total acreage unaccounted for within the entire study area was 30,100 acres, or 3.7 percent of the total area. The above percentages incorporate the total acres unaccounted for, both dryland and irrigated. From 1974 to 1980, irrigated acres comprised from 33 percent (1974) to 40 percent (1980) of the total acres in the study area. Therefore, the irrigated acreage unaccounted for probably was less than 1.5 percent of the total acres in the study area. No estimate was made for this acreage in terms of crops planted.

Unreported Data

Unreported data for crop acreages by individual farms during part of 1974 to 1980 constituted a major problem. Unreported data were of two types: (1) intermittent unreported data and (2) data not reported before 1977.

In many cases, crop acreages were reported for all but 1 or 2 isolated years. In Kearny County, few data were reported for 1975 and 1976. Many of the values for unreported data for 1 or 2 intermittent years could be estimated from the farm records. When similar values of crop acreage were reported during the preceding and following years, a similar value was estimated for the unreported year. When an increasing or decreasing trend was evident in the crop acreages, a value that followed the perceived trend was estimated for the unreported year. When crop acreages fluctuated from year to year with no consistent pattern, an estimate of acreages for unreported years was not possible.

A relatively small number of very large farms in the sandhills south of the Arkansas River accounted for most of the unreported data prior to 1977. Because large acreages were involved, a method was devised to estimate the unreported acreages from 1974-76. The method used the number and location of irrigation wells and the year of application (to the Kansas State Board of Agriculture, Division of Water Resources) for those wells. Farmers are required to obtain an appropriation right from the Division of Water Resources to use the water from a well. The year of application for the appropriation and the first year of water use were assumed to coincide. In the sandhills south of the Arkansas River, where center-pivot-sprinkler systems predominate, it was further assumed that each well irrigated 136 acres (the acreage commonly irrigated by center-pivot systems). In a few areas north of the Arkansas River, where flood irrigation predominates, a single well was assumed to irrigate 320 acres (one-half of a square-mile section).

The number of wells existing from 1974 to 1976 on a farm not reporting prior to 1977 was determined from application dates. The acreage watered for a given year was estimated using 136 or 320 acres per well. The acreage reported for each farm during 1977 was used as an upper limit in estimating the crop acreages from 1974 to 1976. In most parts of the sandhills, corn was the only crop in the immediate area. In areas north of the Arkansas River, where grain sorghum and wheat also were grown, the estimated acreage was proportioned between crops in the same percentages that existed during 1977.

Irrigated crop acreages for wheat, grain sorghum, and corn in Kearny and Finney Counties from 1974-80 are shown in figures 2-4. Annual percentages of farms for which an acreage value was reported or estimated for each crop also are shown.

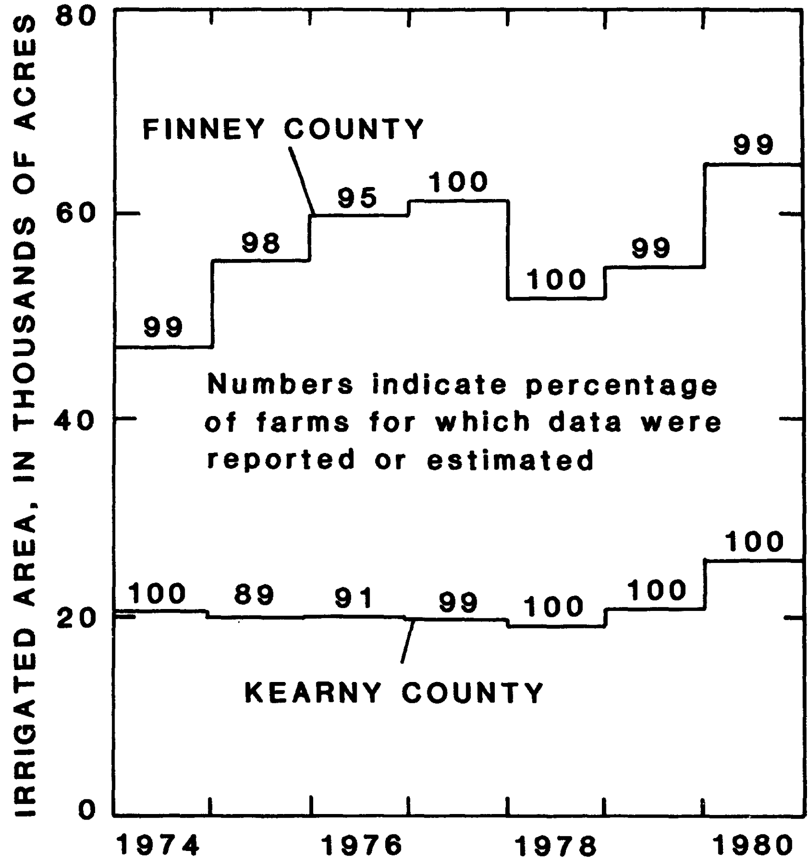


Figure 2.--Irrigated wheat acreage in Kearny and Finney Counties, 1974-80.

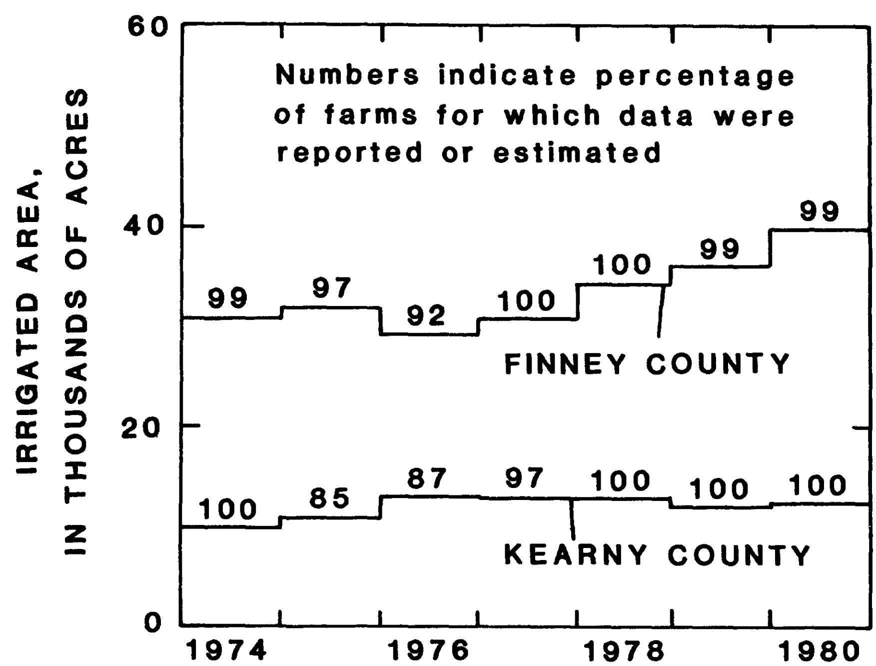


Figure 3.--Irrigated grain-sorghum acreage in Kearny and Finney Counties, 1974-80.

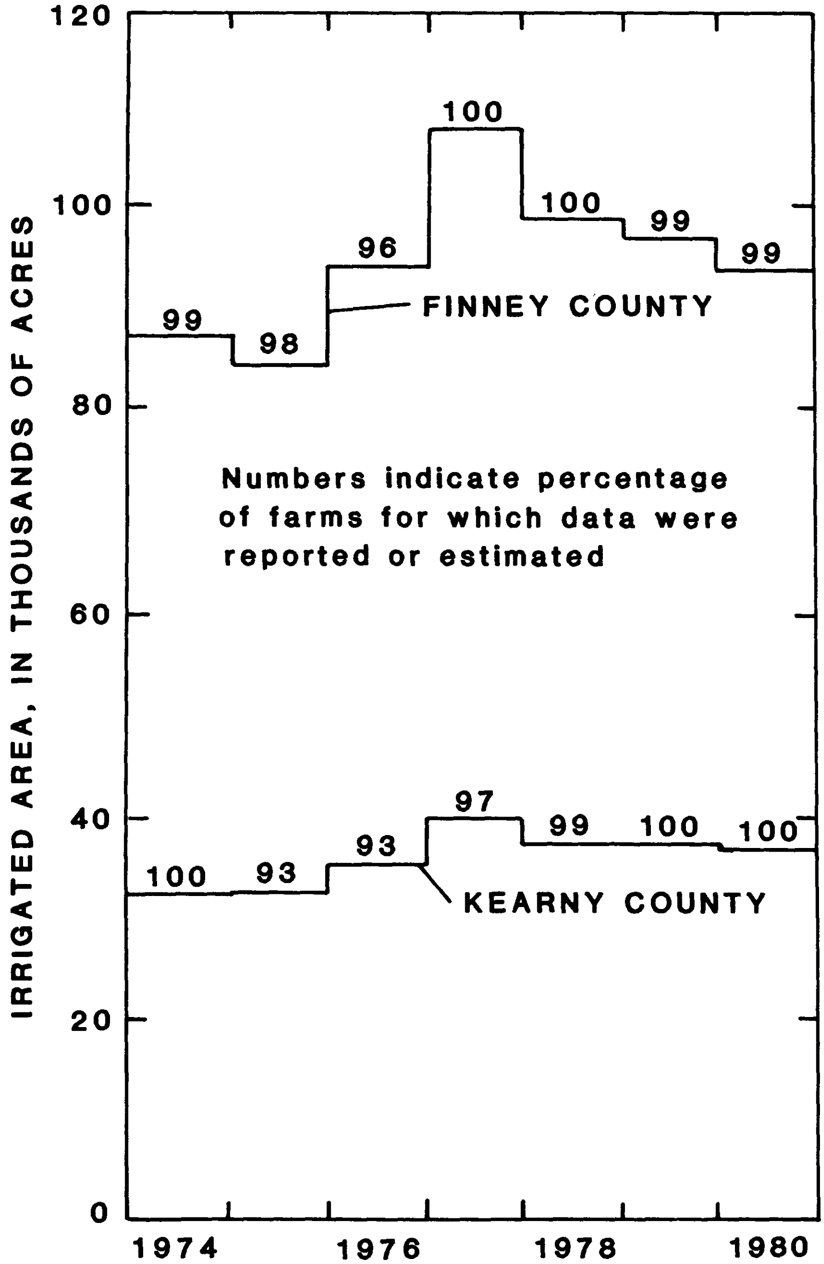


Figure 4.--Irrigated corn acreage in Kearny and Finney Counties, 1974-80.

Combined Acreages

Distribution of irrigated-crop acreages was approximated when individual farms composed of land from more than one township or including land from another county were reported as single irrigated-acreage values for each crop. In cases where acreages of greater than 200 acres were included, the method involving the number, location, and year of application for appropriation right was used, as previously described. The number of wells existing during a given year was determined, and the probable acres irrigated by each well were estimated. For farms spanning more than one township, the total irrigated acres attributable to each township were determined by the number of wells present in each township. For farms spanning more than one county, the estimated crop acreages attributable to another county (other than Finney or Kearny County) were subtracted from the total reported acreages on the farm card.

The problem of combined acreages was further complicated when changes occurred in the ownership of parts of an individual farm involving more than one township. Sometimes it was not possible to determine a reasonable partitioning of crop acreages between two townships occurring on the same farm card; in such cases, the entire acreages were credited to only one township.

Alfalfa Acreage

Another problem occurring in the use of farm records was the limited reporting of alfalfa acreage for all years in Kearny County and for all years except 1977 in Finney County. During 1977, 74 percent of farms in Finney County reported alfalfa acreage The alfalfa acreage for each township in the study area was estimated using the Kansas Crop and Livestock Reporting Service figures for 1974 to 1980. In Finney County, 1977 was used as a base year to determine the percentage of the total reported alfalfa acreage that should be allocated to each township. The alfalfa acreages reported by the Kansas Crop and Livestock Reporting Service for each year from 1974-80 were multipled by the percentage determined for each township in 1977. The product obtained equaled the yearly estimated alfalfa acreage for each township. In equation form:

$$T_{ij} = \frac{R_i}{A} \times K_j \quad , \qquad (1)$$

where

T_{ij} = alfalfa acreage for township i during year j;

R_i = reported alfalfa acreage for township i during 1977;

A = total reported alfalfa acreage for Finney County study area during 1977; and

K_j = alfalfa acreage reported by the Kansas Crop and Livestock Reporting Service during year j for Finney County.

In Kearny County a somewhat different method was used because reporting by farms was insufficient for all years. The alfalfa acreage for each township again was estimated using Kansas Crop and Livestock Reporting Service figures. The multiplication factor used for each township was equal to the percentage of total irrigated crop acres in Kearny County for 1974-80. In equation form:

$$T_{ij} = \frac{T_i}{C} \times K_j \tag{2}$$

where

T_{ij} = alfalfa acreage for township i during year j;

T_i = total irrigated-crop acres for township i during 1974-80;

C = total irrigated-crop acres for Kearny County study area during 1974-80; and

K_j = alfalfa acreage reported by the Kansas Crop and Livestock Reporting Service during year j for Kearny County.

Onsite inspection indicated that only minor quantities of alfalfa are grown in townships T. 25 S., R. 35 W.; T. 26 S., R. 35 W.; T. 26 S., R. 36 W.; and T. 26 S., R. 37 W. Therefore, these townships were not included in the calculations. Alfalfa acreages for Kearny and Finney Counties for 1974-80 are shown in figure 5. All alfalfa was assumed to be irrigated.

Comparison of Reported Acreages

The Kansas Crop and Livestock Reporting Service determines crop acreages by county from a combination of sources. The sources include a State census of farms and a survey of acreage and production. The crop acreages reported by the Kansas Crop and Livestock Reporting Service are designed to provide production totals and may indicate fewer than the total acres planted. Also, the lack of farm-by-farm reporting makes the determination of data shortcomings very speculative. Crop acreages compiled from records of the U.S. Agricultural Stabilization and Conservation Service do not represent all of Kearny and Finney Counties, but they do include most of the irrigated cropland in both counties.

In Kearny County, crop acreages reported in records of the Kansas Crop and Livestock Reporting Service were consistently less than the acreages determined from records of the U.S. Agricultural Stabilization and Conservation Service due to differences in the method used to obtain the data. In Finney County, the crop acreages given for corn and grain sorghum by the Kansas Crop and Livestock Reporting Service were again less, but wheat acreages were inconsistent.

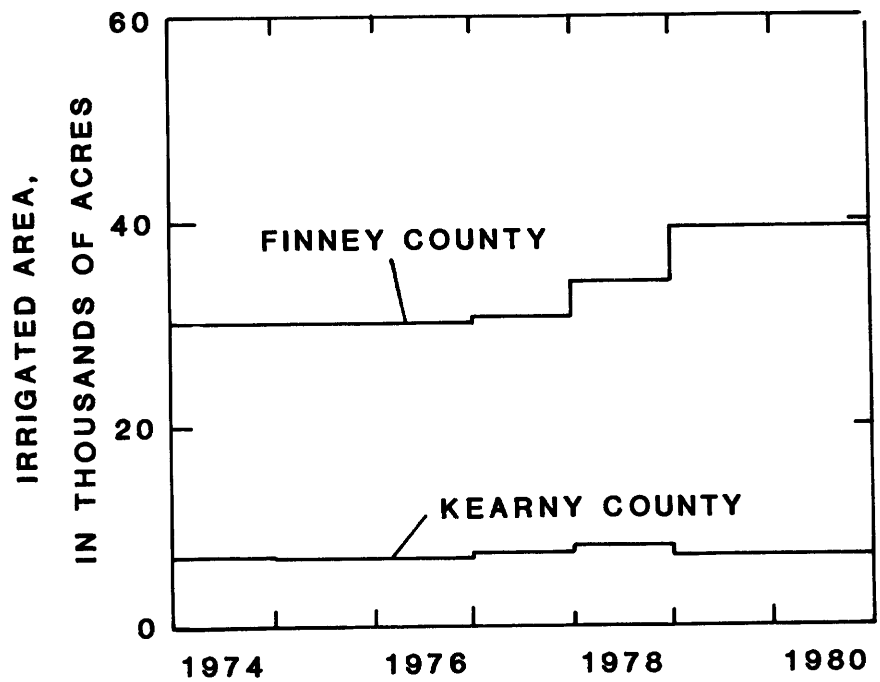


Figure 5.--Irrigated alfalfa acreage in Kearny and Finney Counties, 1974-80.

Irrigated Acres

Total irrigated acres in the study area from 1974 to 1980 are shown in figure 6. The land irrigated increased by 56,000 acres, from 265,000 acres during 1974 to 321,000 acres during 1980.

Total irrigated acres for 1980 and the change in irrigated acres since 1974 for each township are shown in figure 7. The recent agricultural development that has taken place in the sandhills south of the Arkansas River is indicated by the comparatively large increases in irrigated acres in Tps. 25 and 26 S., Rs. 31 through 37 W.

CONSUMPTIVE-IRRIGATION REQUIREMENT

Irrigation pumpage was computed as the crop acreage times a consumptive-irrigation requirement for each crop, plus irrigation-application losses. The consumptive-irrigation requirement was calculated using a potential-evapotranspiration model and a soil-moisture model (Lappala, 1978). The models have been used successfully in southwestern Kansas (Dunlap, Kume, and Thomas, 1980).

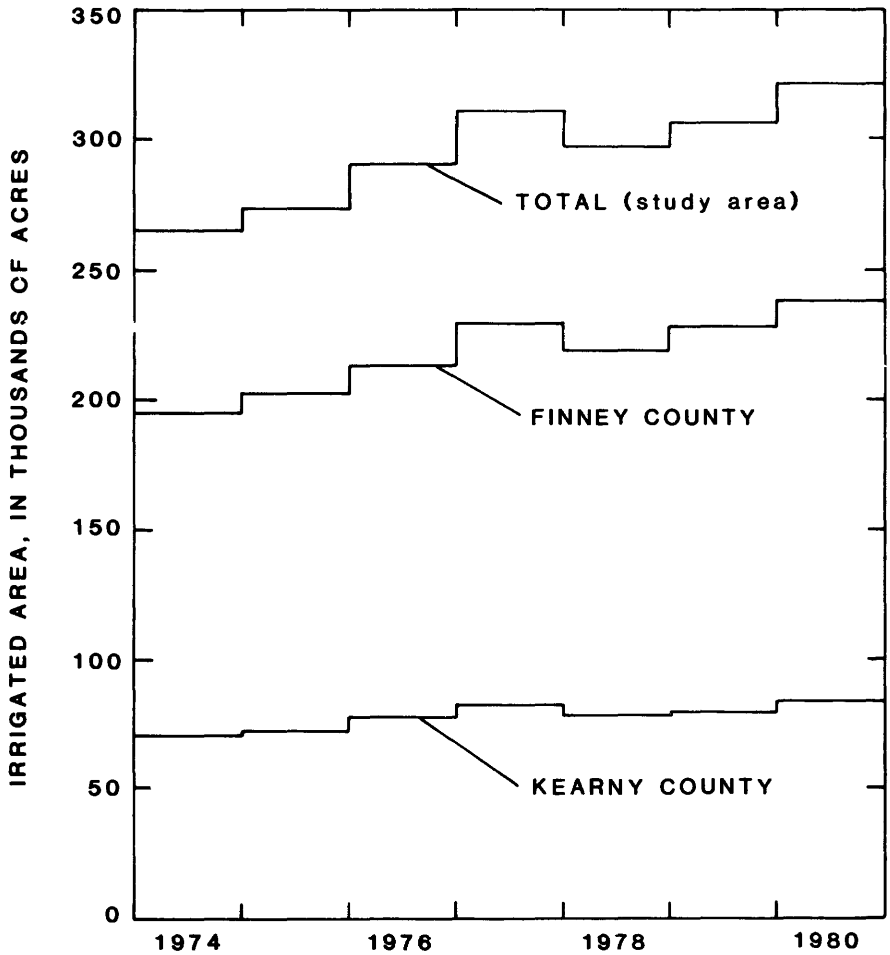
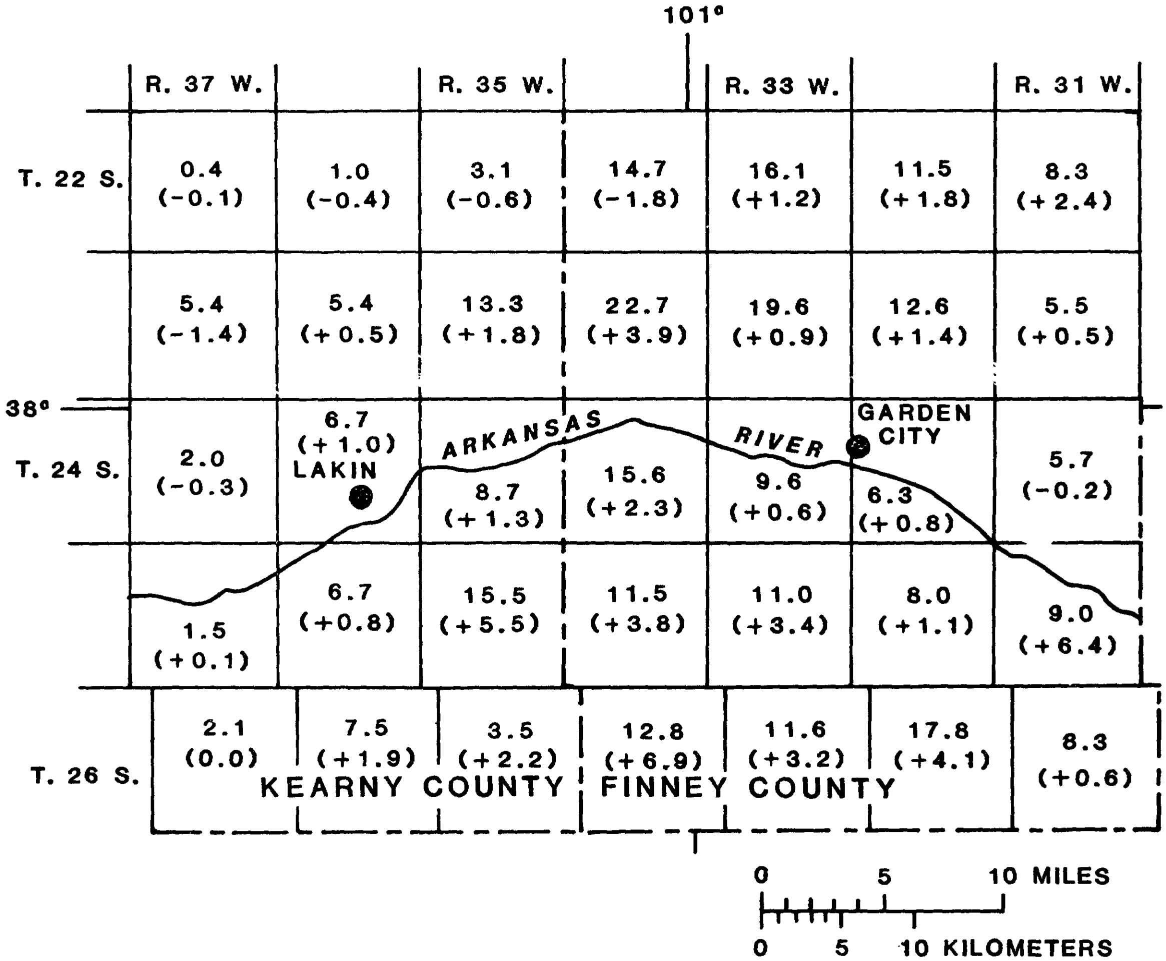


Figure 6.--Total irrigated acres for Kearny County, Finney County, and for study area, 1974-80.

Potential-Evapotranspiration Model

Data needed for the potential-evapotranspiration model consist of monthly mean maximum solar radiation on cloudless days, monthly precipitation, mean daily air temperature, percentage of possible sunshine, and mean maximum and minimum daily air temperatures during the warmest month. Values of monthly mean maximum solar radiation on cloudless days were the same as those used by Dunlap, Kume, and Thomas (1980) in west-central Kansas. The weather stations used for monthly precipitation, mean daily air temperature, and mean maximum and minimum daily air temperatures during the warmest month were Lakin for Kearny County and Garden City for Finney County. Dodge City, Kans., 50 miles east of Garden City, was the closest reporting station for which a percentage of possible sunshine was available. The monthly potential evapotranspiration was computed from this model by the Jensen and Haise method (Jensen and Haise, 1963) and then used as data for the soil-moisture model.



EXPLANATION

13.3 IRRIGATED ACRES DURING 1980, IN THOUSANDS OF ACRES

(±0.6) INCREASE (+) OR DECREASE (-) IN IRRIGATED ACRES SINCE 1974, IN THOUSANDS OF ACRES

Figure 7.--Total irrigated acres for 1980 and change in irrigated acres since 1974 by township.

The annual potential evapotranspiration for Kearny County (Lakin) and for Finney County (Garden City) is shown in figure 8. In both Kearny and Finney Counties, the lowest value occurred during 1979, and the highest value occurred during 1980. An examination of temperature and precipitation records from Garden City indicates that the lowest average of mean daily air temperatures during the summer (the average of June, July, and August mean daily air temperatures) from 1974-80 was recorded during 1979, and the highest during 1980, as shown in figure 9. Also, the greatest volume of summer growing-season precipitation at Garden City occurred during 1979 and a comparatively small volume during 1980 (fig. 10).

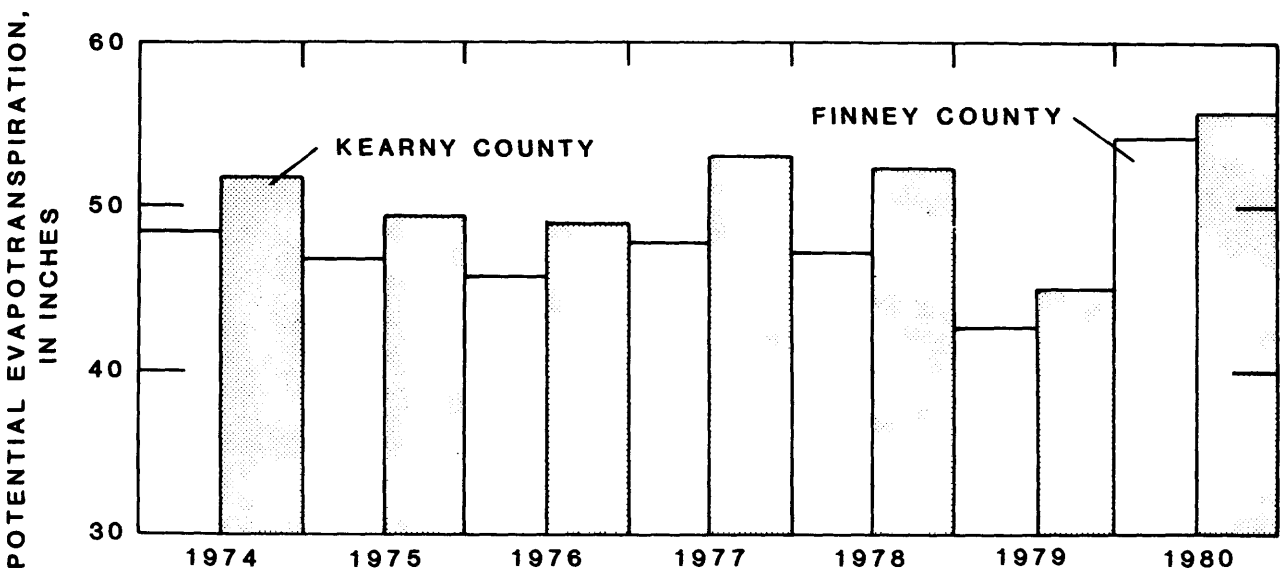


Figure 8.--Annual potential evapotranspiration for Kearny and Finney Counties, 1974-80.

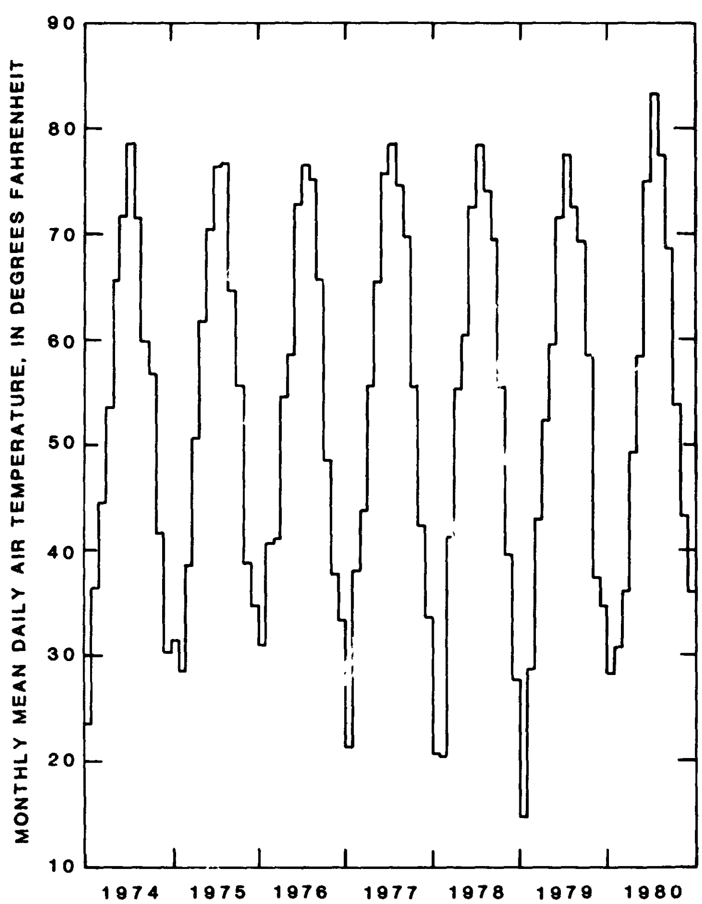


Figure 9.--Monthly mean daily air temperature at Garden City, 1974-80.

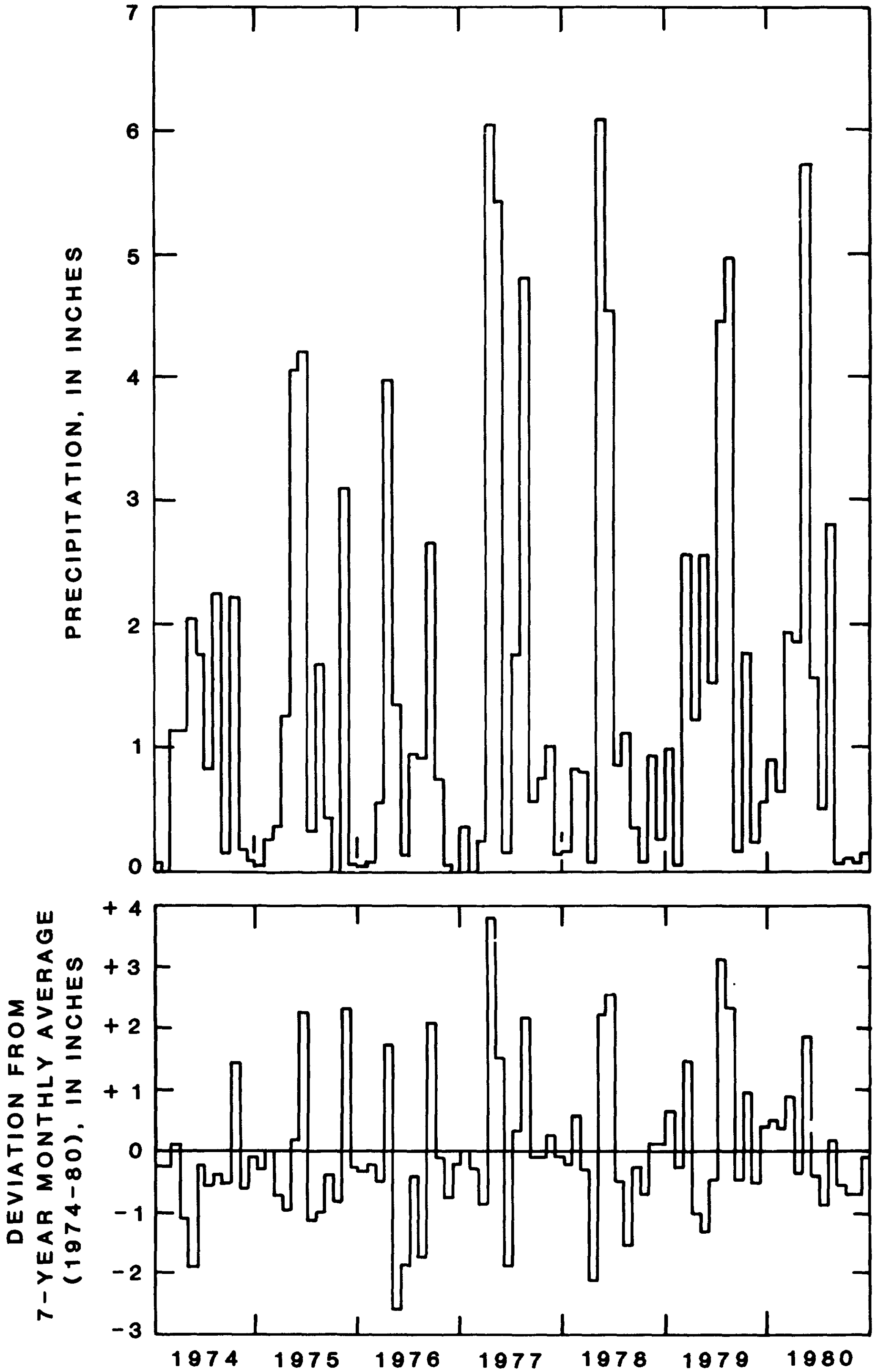


Figure 10.--Monthly precipitation at Garden City and deviations from the 7-year monthly averages, 1974-80.

Temperature and precipitation records for Lakin were very similar to those for Garden City and followed the same pattern. Decreased air temperatures and increased precipitation result in a lesser potential-evapotranspiration value; conversely, increased air temperatures and decreased precipitation result in a greater value. The monthly potential evapotranspiration for Finney County at Garden City is shown in figure 11.

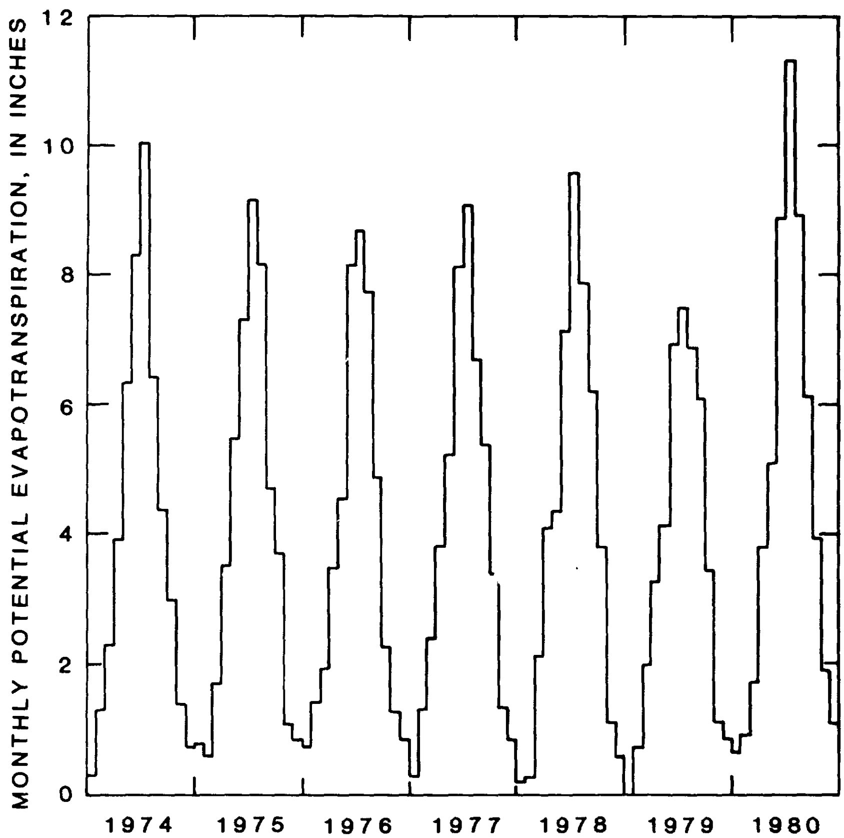


Figure 11.--Monthly potential evapotranspiration at Garden City, 1974-80.

Soil-Moisture Model

The soil-moisture model tabulates monthly soil moisture and crop-water demand for various crops and soil types and computes the irrigation water needed to maintain the available soil moisture at 50 percent. A figure of 60 percent of available moisture was used for sandy soils south of the Arkansas River, as recommended by James G. Thomas, Kansas State Extension (oral commun., 1981). Data needed for the model include monthly precipitation, mean monthly temperature, potential evapotranspiration determined from the potential-evapotranspiration model, and soil characteristics. The soil-moisture model computes and tabulates:

1. Monthly infiltration,
2. Monthly actual evapotranspiration,
3. Monthly deep percolation,
4. End-of-month soil moisture, and
5. Monthly consumptive-irrigation requirements during the growing season.

The model uses curves dependent on soil type, topography, and crop type to determine monthly infiltration based on the given monthly precipitation. The curves were derived from empirical monthly rainfall-runoff curves by the Agricultural Research Service at Rosemount, Nebr. (Lappala, 1978). Surface runoff, if any, is the difference between precipitation and infiltration. Precipitation data from Lakin were used for Kearny County, and data from Garden City were used for Finney County.

The model also computes monthly actual evapotranspiration. A monthly ratio of actual to potential evapotranspiration dependent on crop type and growth stage is used (Lappala, 1978).

Deep percolation is the infiltration in excess of the moisture-holding capacity of the soil, which is determined by its field capacity. Field capacity may be defined as the upper limit of soil water held after gravity drainage is complete.

End-of-month soil moisture is computed as:

$$S_i = S_{i-1} + [I-DP-ET], \tag{3}$$

where

S_i = soil moisture at end of current month, in inches;

S_{i-1} = soil moisture at end of previous month, in inches;

I = monthly infiltration, in inches;

DP = monthly deep percolation, in inches; and

ET = monthly actual evapotranspiration, in inches.

Infiltration and deep percolation are dependent on both the crop type and the soil type. Actual evapotranspiration is dependent on the crop type and growth stage.

The soil characteristics required for the soil-moisture model are field capacity, wilting point, available moisture, and soil type. The field capacity, wilting point, and available moisture determine the moisture-holding properties of the soil. Field capacity is the quantity of water held by the soil against the pull of gravity. The wilting point is the soil-moisture content at which plants are no longer able to extract water from the soil. Available moisture is a measure of the ability of a soil to hold water for use by plants and is the difference between field capacity and wilting point. Information on the types of soils occurring in the study area and their distribution was obtained from publications of the U.S. Department of Agriculture, Soil Conservation Service (1963; 1965). Four major soil types were identified in the study area: (1) Richfield-Ulysses silt loams, (2) Tivoli-Vona loamy fine sands, (3) Manter-Keith loams, and (4) Las-Las Animas clay loams. The distribution of these soils by township is shown in figure 12. The predominant type of irrigation system in each township also is shown. Each township was assigned a soil type on the basis of which type of soil was most extensive in the township.

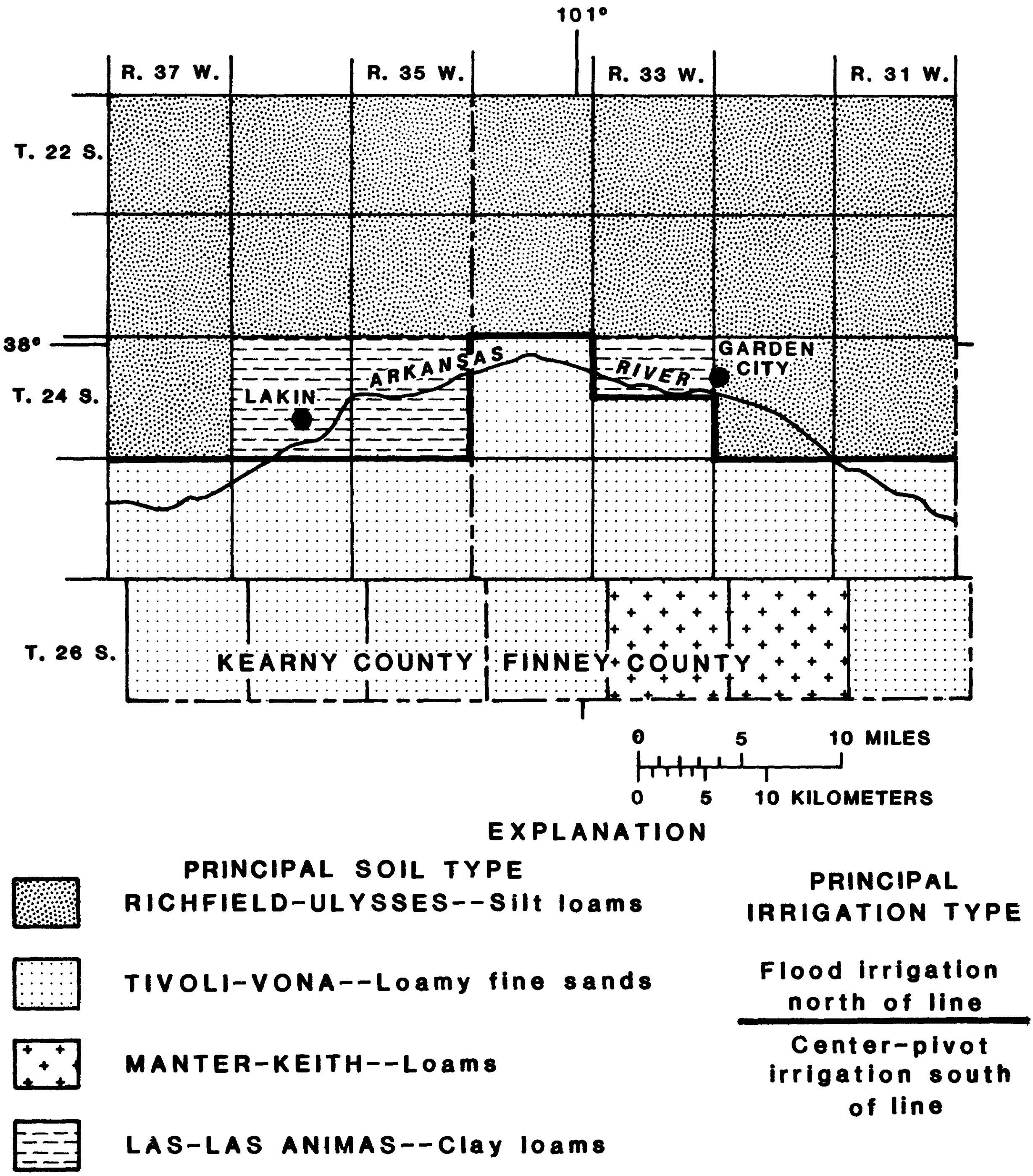


Figure 12.--Distribution of principal soil and irrigation types in study area.

Values for the field capacity and the wilting point of various soils generally were not available. However, experimentally determined figures were available for the Richfield-Ulysses silt loams in southwestern Kansas. The field capacity is 0.28 inch per inch, and the wilting point is 0.14 inch per inch (William S. Powers, Agronomy Department, Kansas State University, Manhattan, Kans., oral commun., 1979). Field capacities and wilting points were determined for the other soil associations on the basis of soil texture (Brady, 1974, p. 196, fig. 7:23). Also, available water-capacity values (available-moisture values), equivalent to the difference between field capacity and wilting point, are published by the U.S. Department of Agriculture, Soil Conservation Service, in county soil surveys (1963; 1965).

Different simulations of the soil-moisture model were made in which field-capacity and wilting-point values varied, but the difference between the values remained constant. Model results indicate greater sensitivity to changes in values for available moisture than to variations in the values used for field capacity and wilting point. The values used for field capacities and wilting points conform to the available water-capacity values given in the Kearny and Finney County soil surveys. The moisture-holding properties of the soils used in the model for this study are listed in table 1.

Table 1.--Field-capacity, wilting-point, and available-moisture values for soil types used in soil-moisture model

Soil type	Field capacity (inch per inch)	Wilting point (inch per inch)	Available moisture (inch per inch)
Richfield-Ulysses, silt loams	0.28	0.14	0.14
Tivoli-Vona, loamy fine sands	.15	.08	.07
Manter-Keith, loams	.26	.13	.13
Las-Las Animas, clay loams	.33	.20	.13

The soil-moisture model subsequently computes a consumptive-irrigation requirement, if necessary, during the specified growing season. The consumptive-irrigation requirement is the volume of irrigation water needed to maintain the available soil moisture at 50 percent in clay and silt loams, or at 60 percent for the sandy soils south of the river. The percentage is greater for sandy soils because soil moisture is depleted sooner as a result of faster water movement through the soil profile. Therefore, more frequent irrigation is required to maintain the soil moisture at a sufficient level for optimum plant growth.

The soil-moisture model calculates the soil moisture at the end of the current month (S_i) and then compares this soil moisture to a soil moisture equal to 50 percent (or 60 percent for sandy soils) of the available moisture. If the soil-moisture value (S_i) is greater than or equal to 50 (or 60) percent of the available soil moisture, no application of irrigation water is required.

In equation form:

$$CIR = [0.5\ RD\ (FC-WP) + (WP)\ (RD)\ ] - S_i \quad , \tag{4}$$

or

$$CIR = [0.5\ RD\ (AM) + (WP)\ (RD)] - S_i \quad , \tag{5}$$

where

CIR = monthly consumptive irrigation requirement, in inches;

RD = root-zone depth, in inches;

FC = field capacity, in inches;

WP = wilting point, in inches;

S_i = soil moisture at end of current month, in inches; and

AM = available soil moisture, in inches.

Root-zone depth is assumed to be 60 inches for all crops and soils in the model and does not vary according to the stage of plant growth. As used in the soil-moisture model, root-zone depth is a function of the soil type, not the crop type. Although root-zone depth does not vary in equations (4) and (5), plant-growth stage is a factor in determining actual evapotranspiration and the soil moisture (S_i). The monthly consumptive-irrigation requirement calculated by the soil-moisture model depends on crop type, growth stage, and soil type.

The monthly consumptive-irrigation requirements were summed to give a total growing-season requirement. Growing-season, consumptive-irrigation requirements during 1980 using climatological data for Garden City are listed in table 2. The growing-season, consumptive-irrigation requirement depends on both crop type and soil type. Therefore, each combination of crop type and soil type has an associated requirment for consumptive irrigation that is different from the values for other combinations, as illustrated in table 2. Alfalfa had the greatest consumptive-irrigation requirement among the four crop types, and Tivoli-Vona soil had the greatest requirement among the four soil types.

Table 2.--Growing-season,consumptive-irrigation requirements (in feet) for crop and soil types occurring in the study area, calculated using temperature and precipitation data for Garden City during 1980

Crop type	Soil type			
	RU[1]	TV[2]	MK[3]	LL[4]
Wheat	0.98	1.28	0.45	0.96
Grain sorghum	2.09	2.39	1.82	2.07
Corn	2.09	2.39	1.82	2.07
Alfalfa	2.49	2.80	2.36	2.47

[1] Richfield-Ulysses, silt loams.
[2] Tivoli-Vona, loamy fine sands.
[3] Manter-Keith, loams.
[4] Las-Las Animas, clay loams.

The requirements for consumptive irrigation computed by the model were increased by a factor of 1.4 for flood irrigation and 1.3 for sprinkler irrigation to account for irrigation-application losses, as recommended by James G. Thomas, Kansas State Extension Office (oral commun., 1981). Center-pivot irrigation predominates in the part of the study area south of the Arkansas River, while flood irrigation predominates north of the river (fig. 12). Irrigation-application losses may result from runoff of applied water and from application of more water than is needed to maintain the soil moisture at optimum levels, resulting in greater evaporation losses.

To determine the volume of water used for irrigation in the study area, growing-season, consumptive-irrigation requirements were calculated for wheat, grain sorghum, corn, and alfalfa for 1974-80. The growing season for wheat is September to May. The growing season for grain sorghum, corn, and alfalfa is May to October.

IRRIGATION PUMPAGE

Annual irrigation pumpage was calculated for each crop and township as the product of the irrigated-crop acres times the consumptive-irrigation requirement, which depends on the crop and soil types that are present in each township, plus irrigation-application losses. In equation form:

$$\text{Irrigation Pumpage} = \text{Crop Acreage} \times (\text{Consumptive-Irrigation Requirement} + \text{Irrigation-Application Losses}). \qquad (6)$$

In T. 24 S., R. 33 W., where more than one soil type is indicated (fig. 12), all corn acreage was assumed to occur on the Tivoli-Vona loamy fine sands, and all wheat, grain-sorghum, and alfalfa acreage was assumed to occur on the Las-Las Animas clay loams. The total annual irrigation pumpage for each township is the sum of the pumpage for the four crops.

Annual irrigation pumpages for Kearny and Finney Counties and for the study area as a whole are shown in figure 13. Irrigation pumpage in the study area as a whole increased from 584,000 acre-feet during 1974 to 738,000 acre-feet during 1980. The magnitude of irrigation pumpage reflects both the irrigated acres and the consumptive-irrigation requirement. The increase in irrigation pumpage from 1974 to 1980 reflects the general increase in irrigated acres during the same period. The relatively small irrigation pumpage during 1979 (458,000 acre-feet) reflects the decreased consumptive-irrigation requirement for that year. The cooler summer growing season and greater precipitation resulted in a decreased potential evapotranspiration. The decreased potential evapotranspiration and greater precipitation meant less irrigation water was needed to meet the crop-water demand. The relationships among precipitation, air temperature, potential evapotranspiration, irrigated acres, and irrigation pumpage in the study area are shown in figure 14.

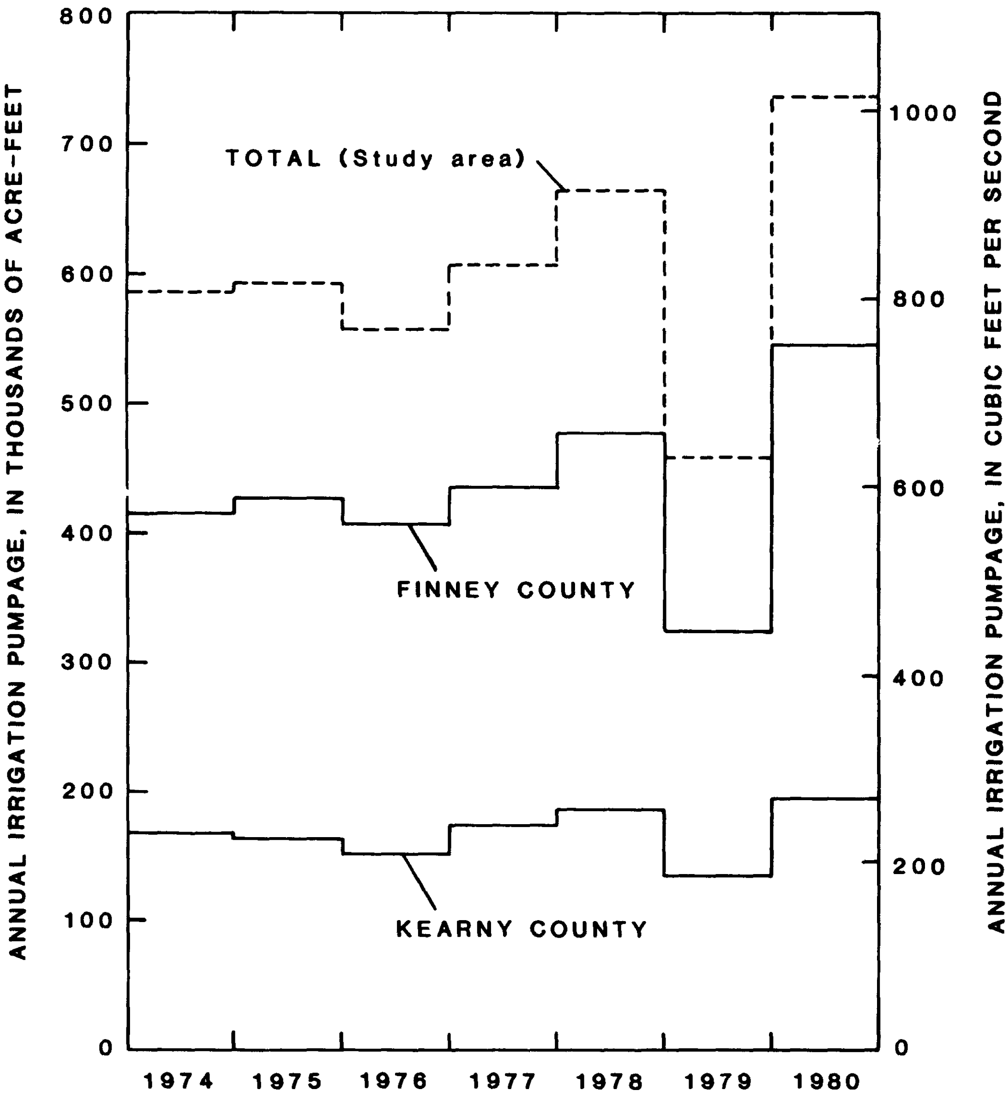


Figure 13.--Annual irrigation pumpages for Kearny County, Finney County, and for study area, 1974-80.

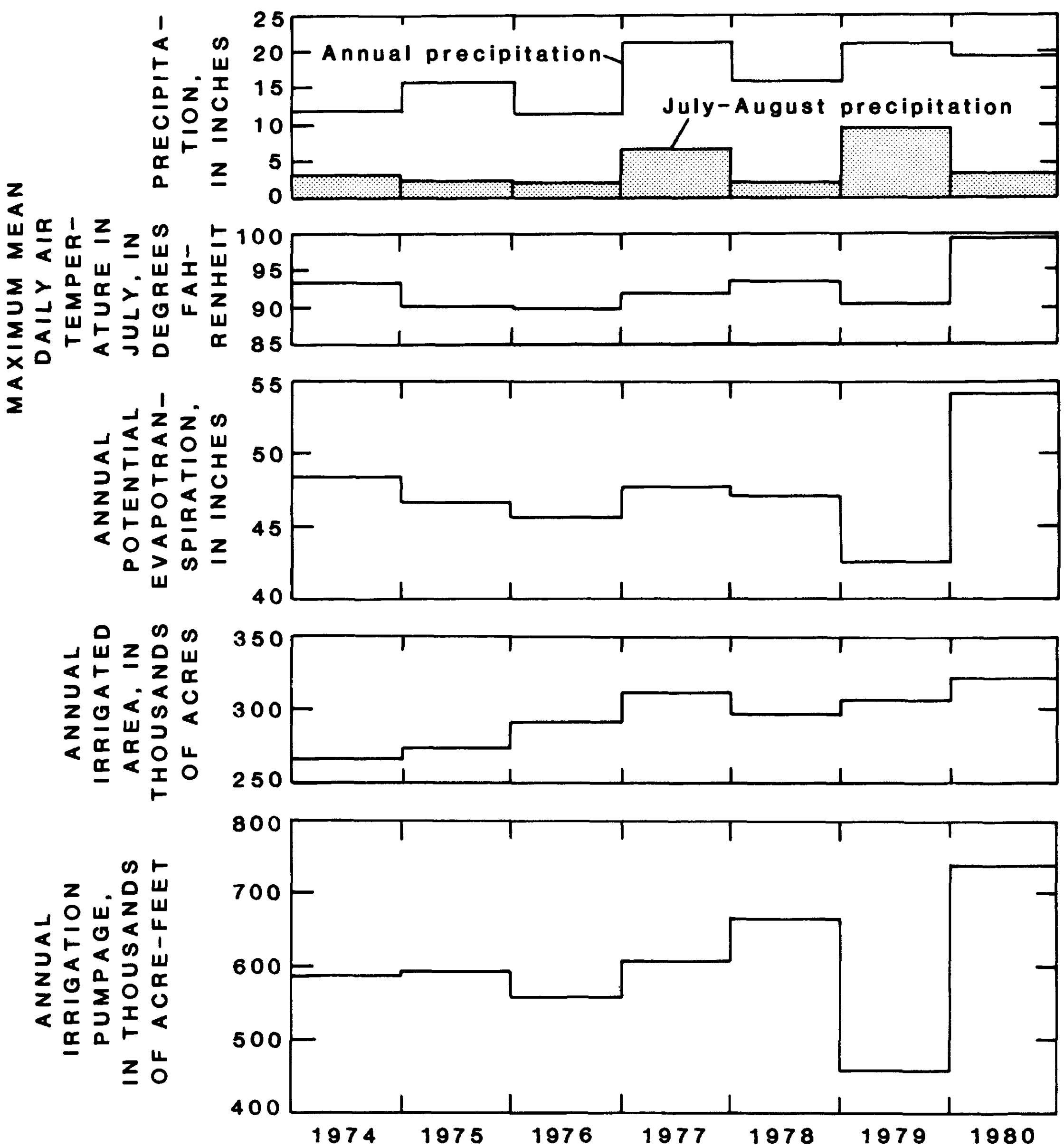


Figure 14.--Relationships among precipitation, air temperature, potential evapotranspiration, irrigated acres, and irrigation pumpage in study area, 1974-80.

SUMMARY AND CONCLUSIONS

In many cases, complete and reliable pumpage data may be lacking for an area where such data are needed. The method described in this paper is a useful and reliable way to obtain estimates of irrigation pumpage. Annual irrigation requirements were estimated using irrigated-crop acreages and consumptive-irrigation requirements plus irrigation-application losses. Irrigated acres in the study area increased from 265,000 acres during 1974 to 321,000 acres during 1980. Requirements for consumptive irrigation varied according to crop type but, for a given crop type, were least during 1979 and greatest during 1980. Environmental factors affecting consumptive-irrigation requirements include potential evapotranspiration and precipitation.

Irrigation pumpage increased from 584,000 acre-feet during 1974 to 738,000 acre-feet during 1980, reflecting the increase in irrigated acres. During 1979, however, relatively lesser potential evapotranspiration and greater precipitation during the summer growing season resulted in decreased consumptive-irrigation requirements. The result was a comparatively small irrigation-pumpage estimate of 458,000 acre-feet.

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