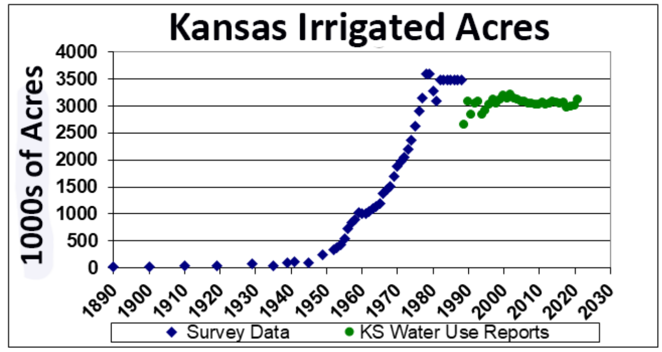
Kansas Irrigation Trends

The earliest irrigation in Kansas may have been from about 1650 to the early 1700s in a Taos Indian village in what is now Scott County State Park. The "modern" era of irrigation might be considered to date to the 1880s with the organization of irrigation ditch companies that began building diversion works and a canal system along the Arkansas River (*Erhart, 1969*). Rapid expansion of Kansas irrigation occurred following WWII for a variety of reasons including political/societal will, technology, and readily available energy (Figure 1). The 1945 water appropriation act, which provides the basis for Kansas water law today, was designed to encourage development of water resources. With improvements in irrigation well drilling and pumping equipment and the development of the Hugoton natural gas well field, irrigation acreage increased rapidly using groundwater from the Ogallala Aquifer.

The reported number of irrigated acres in Kansas has been relatively stable for several decades (Figure 1), but in actuality there has been a loss of irrigated acres in the west (Region 1) and an increase of irrigated acres in central (Region 2) and eastern (Region 3) Kansas, as shown in Figure 2 and Table 1. For the period of 1989 to 2021, the irrigated acres for Kansas had a slight increase of 3878 acres, but more than 230,000 acres dropped out of irrigated production in western Kansas. Within Region 1, Groundwater Management District (GMD) 3 had the largest loss, amounting to 175,257 acres, while GMD 1 had a reduction of 120,263 acres



Survey Data KS Water Use Reports

Figure 1: *Irrigated acreage trends for Kansas. Early estimates are based on various surveys. Since 1989, the irrigated acreage numbers are reported by irrigators on their annual water use reports submitted to the Kansas Department of Agriculture.*

Irrigated acreage and water use changes in GMD1 are even more dramatic than indicated by the 1989 to 2021 data, which show about a 40 percent reduction in irrigated acres. The peak authorized acres and authorized water use at the time of formation of GMD 1 in 1973 was around 425,000 acres and almost 700,000 acre-feet (ac-ft) of authorized water withdrawals (Figure 3), although not all authorized acres were ultimately developed (Personal communication, GMD 1).

Table 1: *Irrigated acres and change comparisons for 1989 and 2021. (KDA DWR Irrigation Water Use Reports).*

	1989	2021	Change in acres
Kansas	3,098,830	3,102,708	3,878
Region 1 (Western KS)	2,329,975	2,097,324	-232,651
Region 2 (Central KS)	716,480	896,719	180,239
Region 3 (Eastern KS)	52,375	108,665	56,290

Irrigated Acreage Shifts within Region 1

	1989	2021	Change in acres
GMD 1	291,574	171,311	-120,263
GMD 3	1,572,470	1,397,213	-175,257
GMD 4	359,016	410,340	51,324
Remainder of Region 1	106,915	118,460	11,545

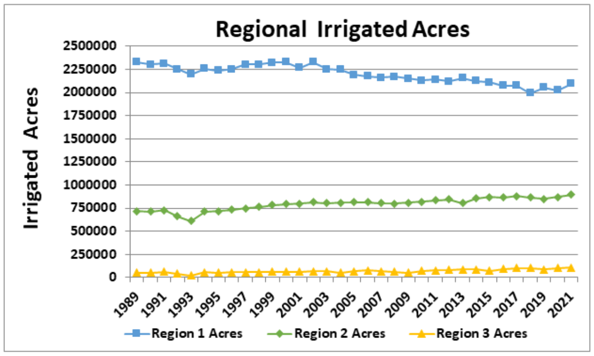


Figure 2: *Irrigated acreage trend in Kansas by regions, 1989 to 2021.*

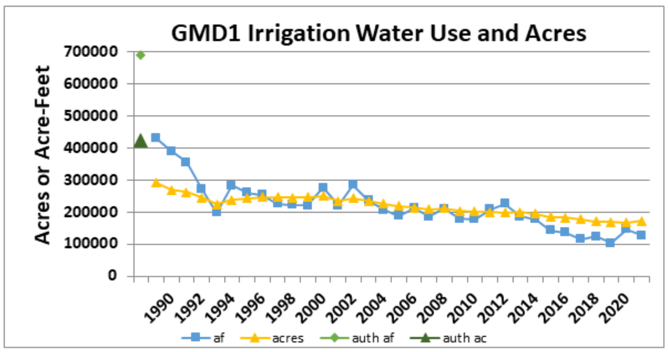


Figure 3: *Irrigated acreage trend in Western Kansas GMD 1, 1989 to 2021 and 1973 authorized acres and water withdrawals.*

System Type Acreage Trends

Irrigation system types have changed over time, switching from predominately surface flood irrigation to sprinkler irrigation, which is predominately center pivots (Figure 4). In 1970, about 18 percent of the 1.8 million irrigated acres were sprinkler irrigated. The volatility in the reported total irrigation acreage base until 1989 was due to the fact that irrigation data being reported in the annual water use report was based on authorized acres as opposed to acres actually irrigated. Nevertheless, much of the increase in the total irrigation acreage base during the 1970s was associated with the adoption of center pivot irrigation, with an increase of nearly an additional million acres irrigated by center pivots. In 1990, about one-half of all acres were center pivot irrigated. Since 1990, the total irrigated acreage base has remained relatively stable, but center pivot irrigation now irrigates nearly 94 percent of all irrigated land.

Subsurface drip irrigation (SDI) irrigated acres are also shown in Figure 4 but represent less than 1 percent of the irrigation base. SDI was not reported as a separate system type until 2004, so early SDI acreage estimates were based on contractor surveys and appear to have been over-estimating SDI development. In 2003, the estimated SDI acreage, based on a producer survey, indicated approximately 14,000 acres. The recent data is estimated from the annual water use reports but some systems are reported as a combination of systems. An example could be SDI irrigated corners of a center pivot system.

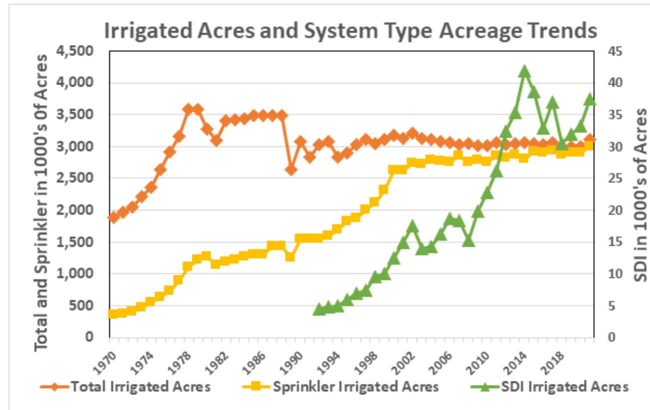


Figure 4: *Acreage trend of total irrigated acres, sprinkler system acres, and subsurface drip irrigation (SDI) acres in Kansas.*

Crop Acreage Trends

Irrigated corn production occurs on over one-half of all irrigated acres in Kansas, with the highest acreage peak occurring in 2019 (Figure 5a). Crop acreages are estimated since many irrigated fields are split between two or more crops.

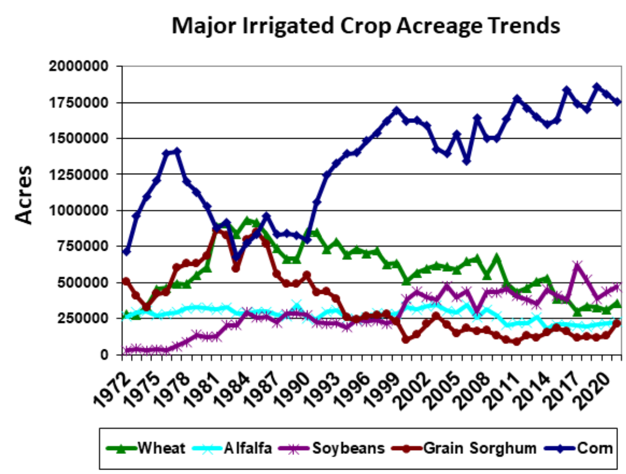


Figure 5a: *Irrigated acreage of the top five irrigated crops in Kansas.*

Even though the top five irrigated crops represent over 97 percent of the reported irrigated acreage base, there are a number of other irrigated crops in the state. Other cereal grain crops grown in the state are shown in Figure 5b. Triticale was first reported as an irrigated crop

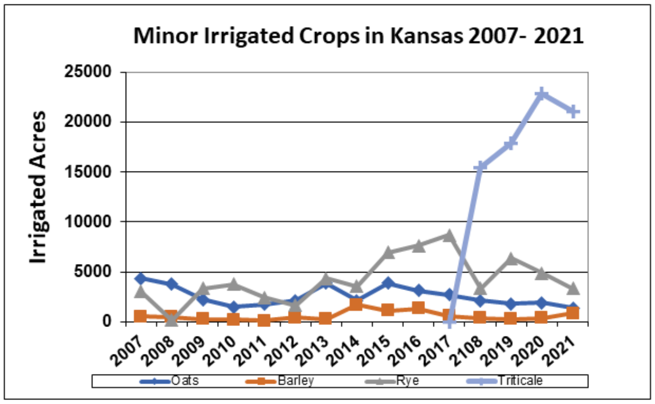


Figure 5b: *Irrigated acreage of other cereal grain crops in Kansas.*

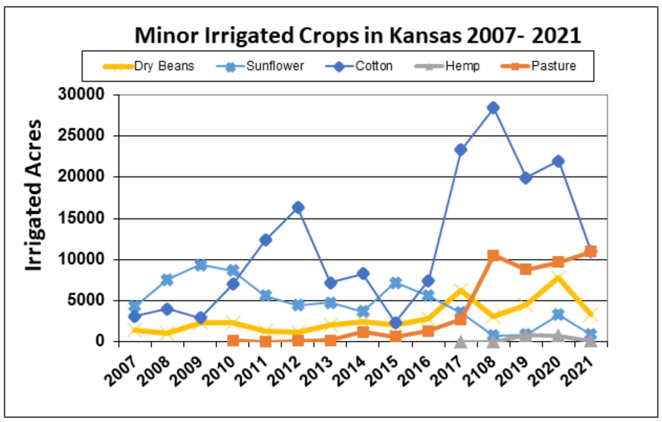


Figure 5c: *Irrigated acreage of other agricultural crops in Kansas.*

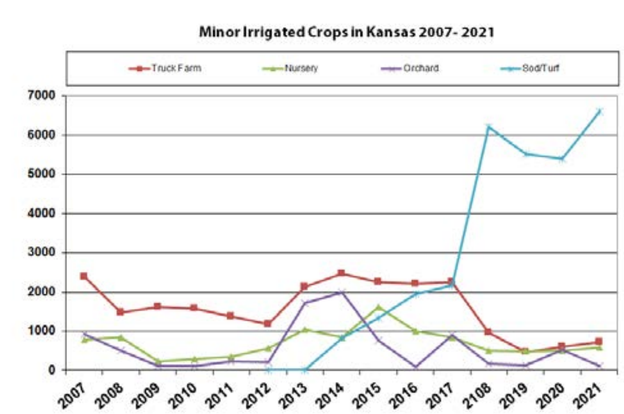


Figure 5d: *Irrigated acreage of other horticultural crops in Kansas.*

in 2018. Other agricultural crops are shown in Figure 5c. Irrigated cotton acreage trend has been variable with a large decrease in recent years since its peak in 2018. Irrigated pasture acreage is also included in this figure and has shown an increasing trend since the first reported acreage in 2010. Horticultural crops reported in the annual water use data include golf/sports fields, truck farms, orchards, sod/turf farms, nursery, and grapes as shown in Figure 5d. The reported acreage of golf courses/sports fields has remained relatively steady during this period of record. A recent trend has been an increase in sod farm acreage and a decrease in truck farm acreage. Irrigated grapes (not shown) have also been reported since 2009 but at less than 10 acres. The irrigated acreage of sports fields and horticultural crops are likely greater than indicated by the annual irrigated water use report since the irrigation of these crops could also occur under municipal and domestic water use.

Irrigation Water Diversion Trends

The total yearly amount of irrigation water diverted in Kansas is shown in Figure 6. A regression line through the reported pumping amount indicates a reduction in the total amount of water over the years, although the correlation is weak. The amount of precipitation that occurs during a given year also influences the annual diversion. In general terms, the 1990s were relatively wet years, while the 2000s were relatively dry. One of the highest rainfall years on record was 1993, while 2002 was one of the lowest, accounting for the corresponding valley and peak in water use, respectively. Note a secondary peak in water use during the nearly statewide drought years of 2011 and 2012. The conversion of flood irrigated land to center pivot irrigated land also continued during this time, increasing from roughly 50 percent to over 90 percent center pivot irrigated during those years. A center pivot system would generally have higher irrigation efficiency then a flood system.

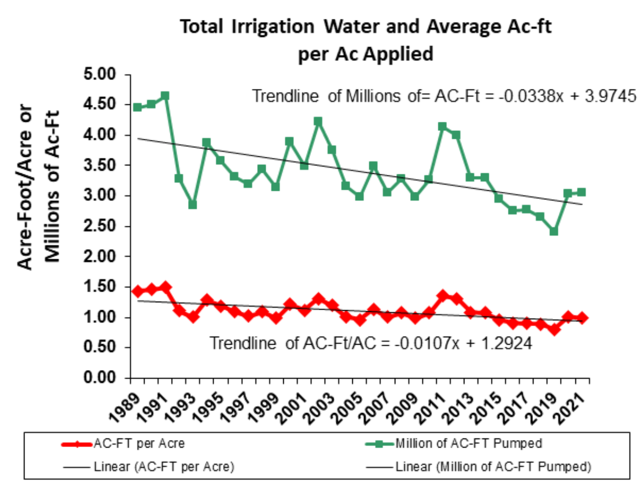


Figure 6: *Total irrigation water diverted and average application depth by year for Kansas.*

There are other factors that could contribute to reduced pumping over time. The continuing decline of water table levels and a subsequent decrease in well yield could also contribute to reduced total water diversion. Tillage practices have also shifted over time as well. Reduced and no-till tillage systems are dominant in irrigated agriculture. Flood systems relied on clean furrows to distribute irrigation water across the field. Since most fields are now sprinkler irrigated, the need to reduce the amount of surface residue to establish good furrows is eliminated. Reduced tillage also reduces soil water losses due to soil disturbance and enhances precipitation capture and stored soil water retention. Higher residues also reduce early season soil evaporation losses. Adoption of improved irrigation management practices, such as irrigation scheduling, increased pumping depths, and subsequent increase in irrigation pumping costs could also play a role in reducing application depths over time.

The application depth by regions is shown in Figure 7. Region 1 roughly represents the western one-third of Kansas; Region 2, the middle third; and Region 3, the eastern third. Most of the irrigated acres are in Region 1, which also has the largest net crop irrigation requirements, so Region 1 and the total for the state are very similar.

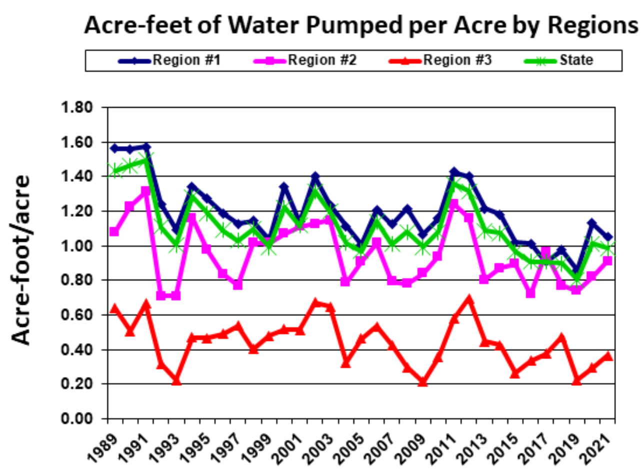


Figure 7: *Regional average irrigation application depths by year for Kansas*

Crop Yield Trends

The four major seed crops grown in Kansas have had upward trends in yield as shown in Figures 8 through 11 for corn, soybean, grain sorghum, and wheat. The Kansas corn yield trend has had the most dramatic increase for both irrigated and dryland production, with irrigated corn yield improvements of approximately 2.0 bushels per acre for the period of record, which is over twice the dryland rate of 0.91 bushels per acre. However, the yield increase for irrigated corn appears to be flattening in recent years. The increase in irrigated corn yield for the period of 1974 through 2005 was 2.58 bushels per acre, compared to a yield increase of 1.20 bushels per acre for the 2005 through 2018 period. One reason for this could be the increased number of acres of corn grown under limited irrigation conditions. The average irrigated yield increases for soybean and grain sorghum are 0.57 bu/ac and 0.54 bu/ac, respectively for the period of record when data was

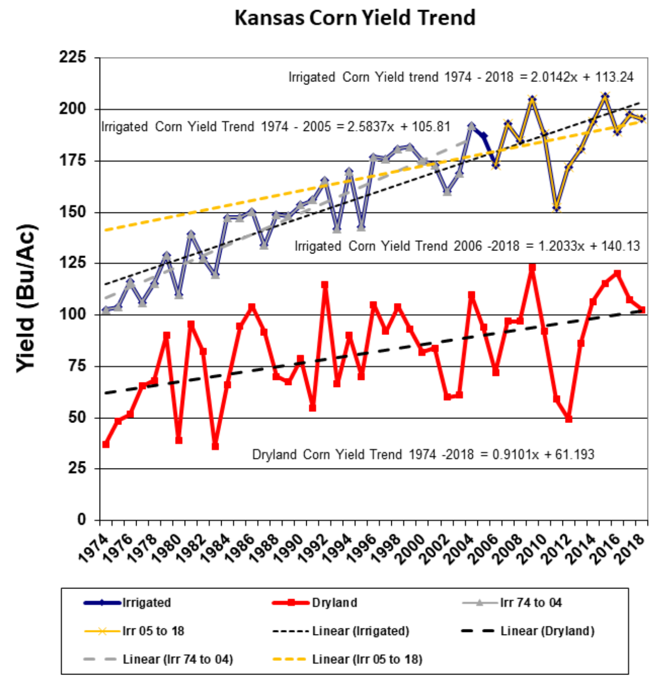


Figure 8: *Kansas Corn Yield Trends 1974 through 2018 (KDA Kansas Farm Facts).*

collected. Irrigated statewide estimates of soybean and grain sorghum ended in 2009. Irrigated wheat yield trend is 0.36 bu/ac.

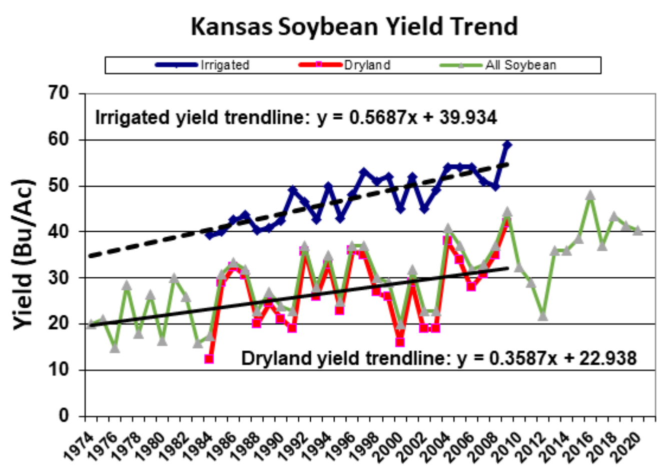


Figure 9: *Kansas Soybean Yield Trends, 1974 to 2020 (KDA Kansas Farm Facts).*

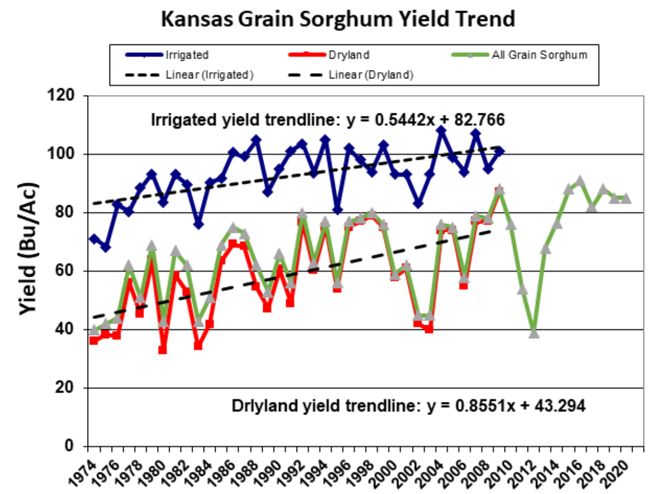


Figure 10: *Kansas Grain Sorghum Yield Trends 1974 to 2020 (KDA Kansas Farm Facts).*

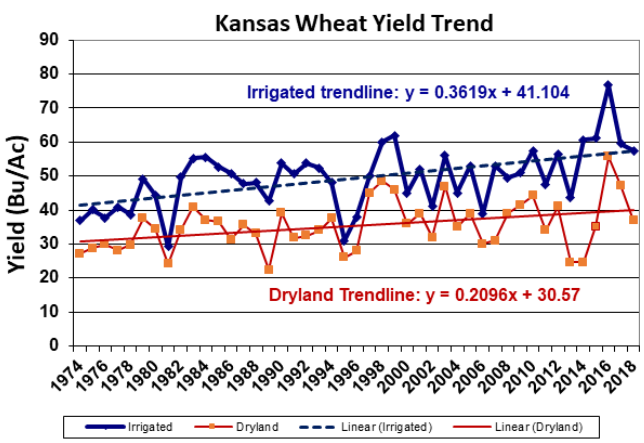


Figure 11: *Kansas Wheat Yield Trends since 1974; Dryland is the average of fallow and continuous dryland cropping. The irrigated and dryland yield survey ended in 2018 (KDA Kansas Farm Facts).*

Irrigation Water Use Efficiency

Irrigation water use efficiency (IWUE) is the yield of a crop divided by the amount of irrigation water applied. Since yield has increased over time (Figures 8 to 11) and the average application depth has been trending downward, IWUE should be increasing. Southwest Kansas yield, irrigation application, and IWUE for corn are shown in Figure 12. IWUE has increased over the period of record by a value of 0.14 bushels per inch per year, although the correlation is weak due to high year-to-year variability.

Seasonal variability is illustrated in Figure 13. This data was collected at the Southwest Kansas Research and Extension Center in Garden City, Kansas, and presented for illustrative purposes as it is well known that spa-

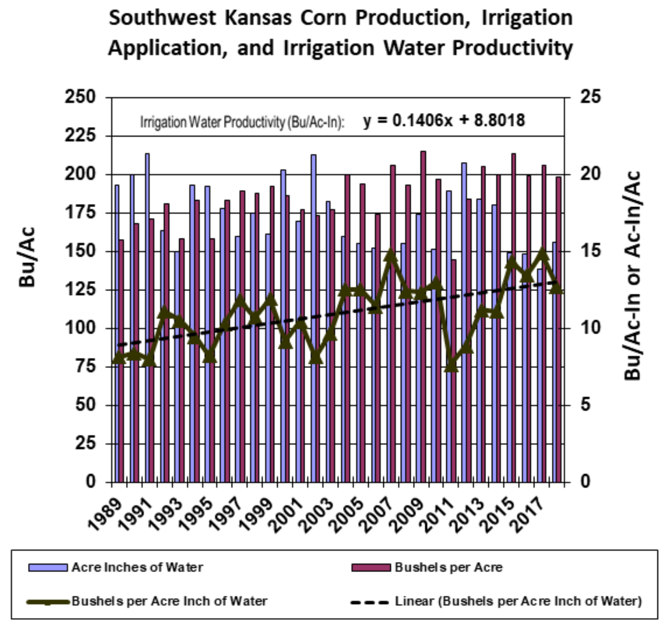


Figure 12: *Corn yield, irrigation application depth, and irrigation water use efficiency trends for southwest Kansas.*

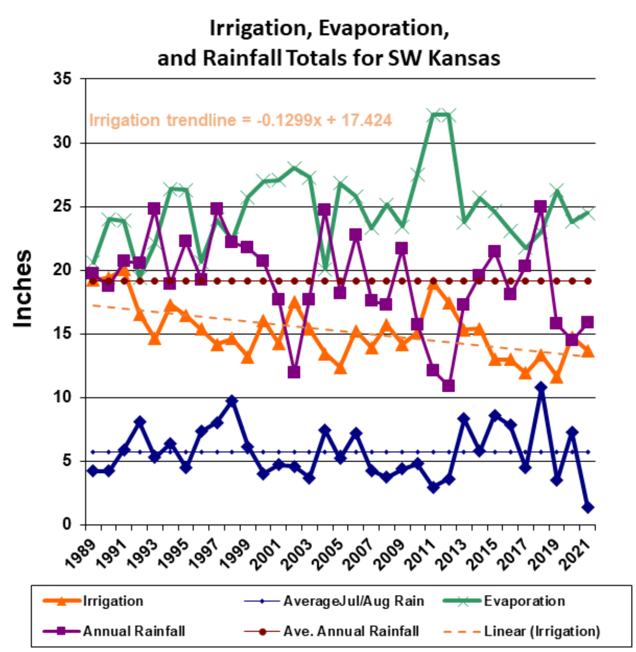


Figure 13: *Irrigation, pan evaporation, and rainfall values for the SWREC, Garden City, Kansas.*

tial variability of rainfall would exist across the region. The pan evaporation line is used as an indicator of crop water demand. More pan evaporation would correlate with sunny, warm, and windy days, which are the same conditions for high crop water use. Notice during the droughty 2000s years, the values were high. Annual rainfall and the in-season rainfall for July and August are also plotted. Annual rainfall during the 1990s was at or above normal as compared to several years below normal in the 2000s, especially 2002, which was about 6 inches below normal. Rainfall for the 2002 July/August period, however, was only slightly below normal. In addition, the in-season rainfall distribution is an important factor, the impact of which is not assessed with a simple seasonal or annual amount analysis.

The drought years of 2011 and 2012 showed low in-season rainfall and below normal annual rainfall amounts. The pan evaporation values were the highest recorded for the period. Applied irrigation in 2011 was the highest since 1991, but conditions were so extreme, irrigation corn yields were reduced as indicated by the low statewide yield value shown in Figure 8. Although yield can also be affected by heat, the loss of irrigation capacity over time likely also contributed to the loss of yield when combined with low precipitation and high crop water use need. The average application depth for the region for all crops and systems trended downward for the period of record, despite the wetter years being concentrated at the beginning of the period

Irrigation System Efficiency

An abundance of literature is available on irrigation system efficiency values. There are many definitions of irrigation efficiency. Different terms are used to describe various aspects of irrigation, but much confusion, misuse, and misunderstanding of the concept is still possible. The Kansas State University Research and Extension Bulletin MF2243, "Efficiencies and Water Losses of Irrigation Systems" (available at https://www.bookstore.ksre.ksu.edu/pubs/MF2243.pdf) reviews the topic.

The general perception in Kansas is that surface irrigation systems have low irrigation efficiency, while center pivot systems with modern nozzle packages have high irrigation efficiency. While surface irrigation is not universally inefficient, the typical gated pipe furrow irrigation system in Kansas was probably operating at about 65 percent irrigation efficiency. That means about 65 percent of the water diverted to the field ended up in the managed root zone of the crop. The major loss for these systems was deep percolation (water drained below the managed root zone) and tailwater (water running off the end of the field). Furrow irrigation systems are labor intensive, so to minimize operation labor, long runs and fixed set times (12- or 24-hour intervals) were used, which may not have matched well to field characteristics. The condition of the furrows, which change with irrigation and rainfall events, have a major influence on the advance of the water, and the irrigator would have to adjust accordingly. Correctly setting all gates to the proper discharge rate for the correct water advance rate down the furrow many times required as much art as science.

A four-year field demonstration project was conducted by the Northwest Kansas State University Research and Extension Center and the Northwest Kansas Groundwater Management District from 1978 through 1981. The results from this demonstration project are discussed to give some context to the changes that have occurred in irrigated agriculture and how irrigation water use has been affected. Field observations were made on a number of fields for the period, and records of average field yields and application depths were made. The data for the fields with corn production are shown in Figures 14 and 15.

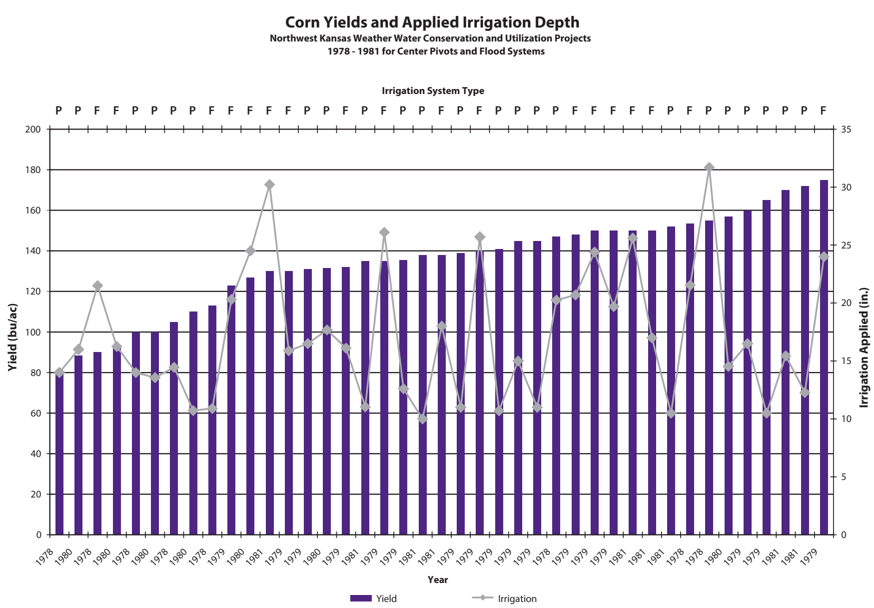


Figure 14: *Corn yield and irrigation application depth for various fields from the Northwest Kansas Water Conservation and Utilization Project arranged in order of yield.*

At the time, flood and center pivot irrigation were roughly equal in acres, and few wells were equipped with water meters. The short-term goal of the project at the time was to observe and record current practices by installing water meters and soil water monitoring stations in each demonstration field. This was a demonstration project, so results between fields cannot be statistically compared. It is nevertheless interesting to note that the average yield across years for the two system types were essentially equal at 134.9 bushels per acre for the center pivots and 134.8 bushels for the surface flood systems, which may be somewhat indicated by the Figure 14 when examining the listing of the system type across the top of the chart. The average water application depth for the center pivots was 14.34 inches as compared to 21.02 inches for the flood systems. In Figure 15, the system type associated with the application depth tends to have the higher amounts associated with flood systems, although the highest application depth observed was applied by a pivot irrigator. While this is anecdotal evidence of a difference in irrigation efficiency between system types, the results are consistent with research literature summarized in the bulletin cited previously.

The shift from flood to center pivot sprinkler irrigation also allows irrigators to improve management efficiency. This stems from the ability to apply smaller increments of water during a given event, the irrigation frequency interval is decreased, and the irrigation event is interruptible. These features allow the irrigator to be able to better match application amounts to root zone soil water holding capacity and maintain the root zone soil water to more consistent soil water levels; in short — be better able to employ improved irrigation scheduling techniques.

Corn Irrigation Efficiency

The corn yield trend indicates a steady improvement of yield over time for irrigated corn production. Yield increase can be attributed to several factors, such as improved corn genetics adapted to the climate and disease/insect pressures of the state, improved cultural practices allowing earlier planting, higher residues for improved precipitation management, and better weed and pest control. Yield increase is not necessarily directly associated with improvement in irrigation system efficiency since high production can occur with low irrigation application efficiency; however, the average applied irrigation amount was also shown to be trending downward.

The downward trend of irrigation application depth can be associated with a number of factors, as well, including: 1) reduced well capacities due to declining water tables, 2) improved use of off-season and in-season precipitation, 3) improved irrigation management, such as irrigation scheduling, and 4) improved irrigation system efficiency. The first factor would have a detrimental effect on yield potential, while the latter three would help maintain yield when deficit irrigation conditions developed or reduce irrigation water pumping for irrigation systems that still had sufficient capacity to meet crop water needs.

The database on applied irrigation water does not cover the period of time when flood irrigation systems were used extensively on corn and were of generally high irrigation capacity. However, personal observations and farm consultations prior to 1989 suggest that most flood irrigated corn fields were approaching or exceeding the standard water application permit or water right of western Kansas of 24 inches per acre. By 1989, about half of all irrigation systems were center pivots, and by 2005 about 90 percent were center pivots. Combining typical flood efficiency (65%) and center pivot efficiency (85%), in 1989, the average efficiency for the systems combined would be 75 percent. In 2005, this combined value would be 83 percent. If system type was proportional across corn production and using an average net irrigation requirement for corn for the time period (likely lower in the 1990's and higher in the 2000's based on the weather conditions), the increase in efficiency due to the shift of fields from flood to center pivot irrigation would account for about one-third of the reduction in the average application depth. For fields that have low efficiency systems that result in a low irrigation capacity and deficit irrigation conditions, an increase in efficiency would allow the deficit to be reduced. Once deficit irrigated conditions are eliminated, then increased efficiency could result in reduced water application amounts.

Adoption of conservation tillage practices leaving high residue levels on the soil surface has the advantages of 1) not causing soil water loss due to the tillage operation, 2) improved capture of precipitation, and 3) reduced soil

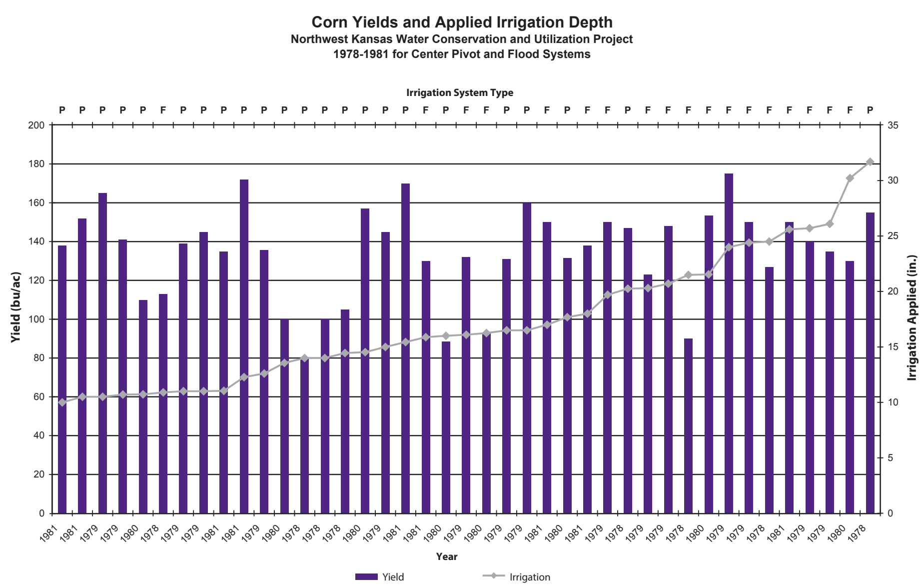


Figure 15: *Corn yield and irrigation application depth for various fields from the Northwest Kansas Water Conservation and Utilization Project arranged in order of irrigation application depth.*

water evaporation. The application of irrigation water is also more easily accomplished on a center pivot irrigated field since the soil (furrow) is not used as part of the conveyance system for water across a field. Each of the factors can impact the water budget by increasing the available water supply to a crop. In addition, the center pivot system application depth and irrigation interval can be much more easily matched to the available root-zone soil water storage conditions.

For example, a flood irrigation system may need to apply 3 to 4 inches of water per event in order to achieve uniform water distribution across the field as compared to a typical center pivot application depth of 1 inch. A flood system may take 10 to 14 days to complete an irrigation cycle as compared to 3 to 5 days for a center pivot. In order to prevent stress at the last watered part of the field, the irrigation event would need to start the number of days of the irrigation cycle in advance of the stress event at the end of the field. For the first irrigation, the root zone may still be small, so little soil water is available before stress begins. To prevent stress at the last irrigation zone, watering may have to begin in the first zone when little or no irrigation is needed. There may be less than 1 inch of root zone stage available when an irrigation of 3 or 4 inches must be started. With a reduced application amount and smaller irrigation cycle time, the likelihood of excess irrigation at the start of the irrigation cycle to prevent end of the cycle stress is minimal. A similar scenario occurs at the end of the season, when a full irrigation must be applied to satisfy a limited need to allow the crop to reach physiological maturity.

In conclusion, it would appear that the shift in irrigation system type from flood irrigation to center pivot irrigation has resulted in improved use of irrigation water in Kansas as indicated by the generally downward trend in application depth per acre. This is partially due to improved irrigation efficiency characteristics of the center pivot as compared to typical gated pipe furrow irrigation system in the state. This downward trend in application depths can also be partially associated with additional irrigation management and cultural practices that can be more easily adapted to sprinkler-irrigated fields. Since productivity in terms of yield appears to still be increasing, the improvements in irrigation and management efficiencies appear to still be offsetting productivity losses associated with loss of well capacities in many areas. Increase in corn productivity is also related to improvements in corn hybrid development that was better adapted to local conditions.

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MF2849 (Rev.) August 2023