SUMMER CROP PRODUCTION AS RELATED TO IRRIGATION CAPACITY

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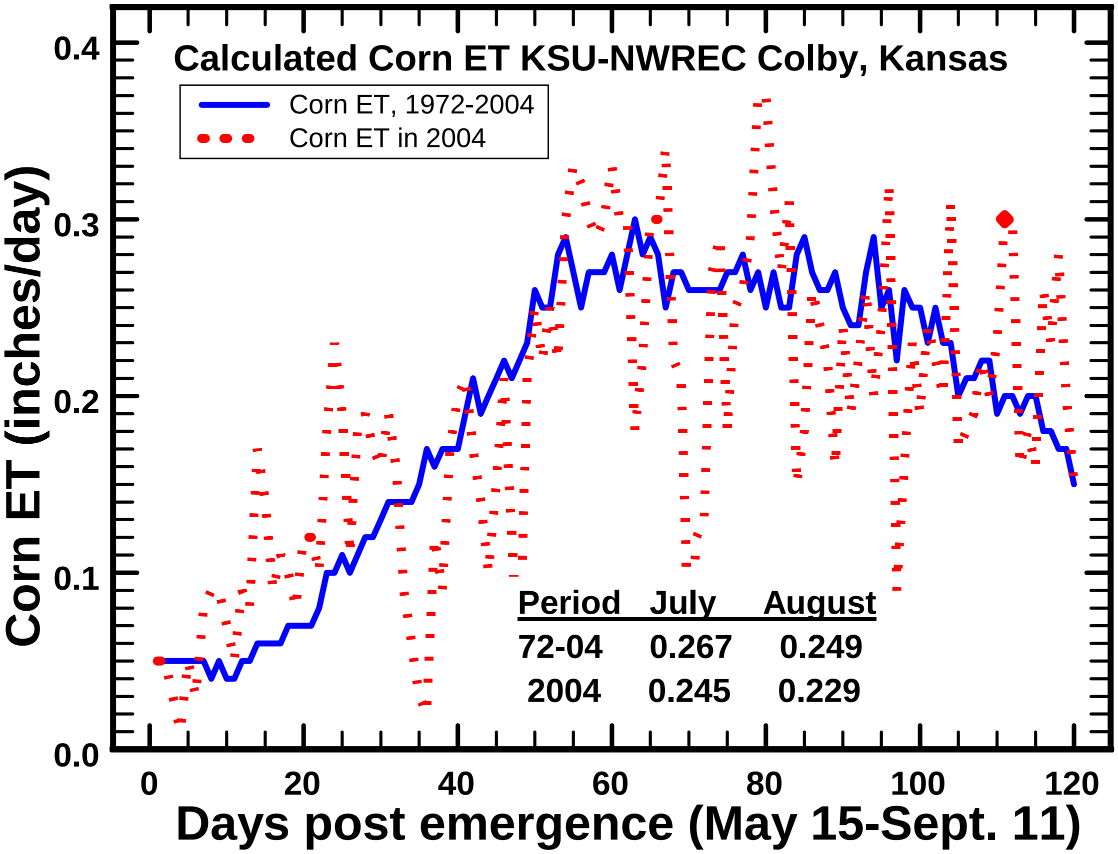
INTRODUCTION

In arid regions, it has been a design philosophy that irrigation system capacity be sufficient to meet the peak evapotranspiration needs of the crop to be grown. This philosophy has been modified for areas having deep silt loam soils in the semi-arid US Central Great Plains to allow peak evapotranspiration needs to be met by a combination of irrigation, precipitation and stored soil water reserves. The major irrigated summer crops in the region are corn, grain sorghum, soybean and sunflower. Corn is very responsive to irrigation, both positively when sufficient and negatively when insufficient. The other crops are less responsive to irrigation and are sometimes grown on more marginal capacity irrigation systems. This paper will discuss the nature of crop evapotranspiration rates and the effect of irrigation system capacity on summer crop production. Additional information will be provided on the effect of irrigation application efficiency on irrigation savings and corn yields. Although the results presented here are based on simulated irrigation schedules for 33 years of weather data from Colby, Kansas (Thomas County in Northwest Kansas) for deep silt loam soils, the concepts have broader application to other areas in showing the importance of irrigation capacity for summer crop production.

SUMMER CROP EVAPOTRANSPIRATION RATES

Crop evapotranspiration (ET) rates vary throughout the summer reaching peak values during the months of July and August in the Central Great Plains. Long term (1972-2004) July and August corn ET rates at the KSU Northwest Research Extension Center, Colby, Kansas have been calculated with a modified Penman equation (Lamm, et. al., 1987) to be 0.267 and 0.249 inches/day, respectively (Figure 1). However, it is not uncommon to observe short-term peak corn ET values in the 0.35 – 0.40 inches/day range. Occasionally, calculated peak corn ET rates may approach 0.5 inches/day in the Central Great Plains, but it remains a point of discussion whether the corn actually uses that much water on those extreme days or whether corn growth processes essentially shut down further water losses. Individual years are different and daily rates vary widely from the long term average corn ET rates (Figure 1). Corn ET rates for July and August of 2004 were 0.245 and 0.229 inches/day, respectively, representing an approximately 8% reduction from the long-term average rates. In contrast, the corn ET rates for July and August of 2003 were 15% greater than the long term average rates. Irrigation systems must supplement precipitation and soil water reserves to attempt matching average corn ET rates and also provide some level of design flexibility to attempt covering year-to-year variations in corn ET rates and precipitation.



Period	July	August
72-04	0.267	0.249
2004	0.245	0.229

Figure 1. Long term corn evapotranspiration (ET) daily rates and ET rates for 2004 at the KSU Northwest Research-Extension Center, Colby Kansas. ET rates calculated using a modified Penman approach (Lamm et. al., 1987).

DESIGN IRRIGATION CAPACITIES

Simulation of irrigation schedules for Colby, Kansas

Irrigation schedules (water budgets) for the major summer crops were simulated for the 1972-2004 period using climatic data from the KSU Northwest Research-Extension Center in Colby, Kansas. Reference evapotranspiration was calculated with a modified Penman equation (Lamm, et. al., 1987) and further modified with empirical crop coefficients (Figure 2) for the location to give the crop ET. Typical emergence, physiological maturity, and irrigation season dates were used in the simulation (Table 1). The 5-ft. soil profile was assumed to be at 85% of field capacity at corn emergence (May 15) in each year. Effective rainfall was allowed to be 88% of each event up to a maximum effective rainfall of 2.25 inches/event. The application efficiency, Ea, was initially set to 100% to calculate the simulated full net irrigation requirement, SNIR. Center pivot sprinkler irrigation events were scheduled if the calculated irrigation deficit exceeded 1 inch.

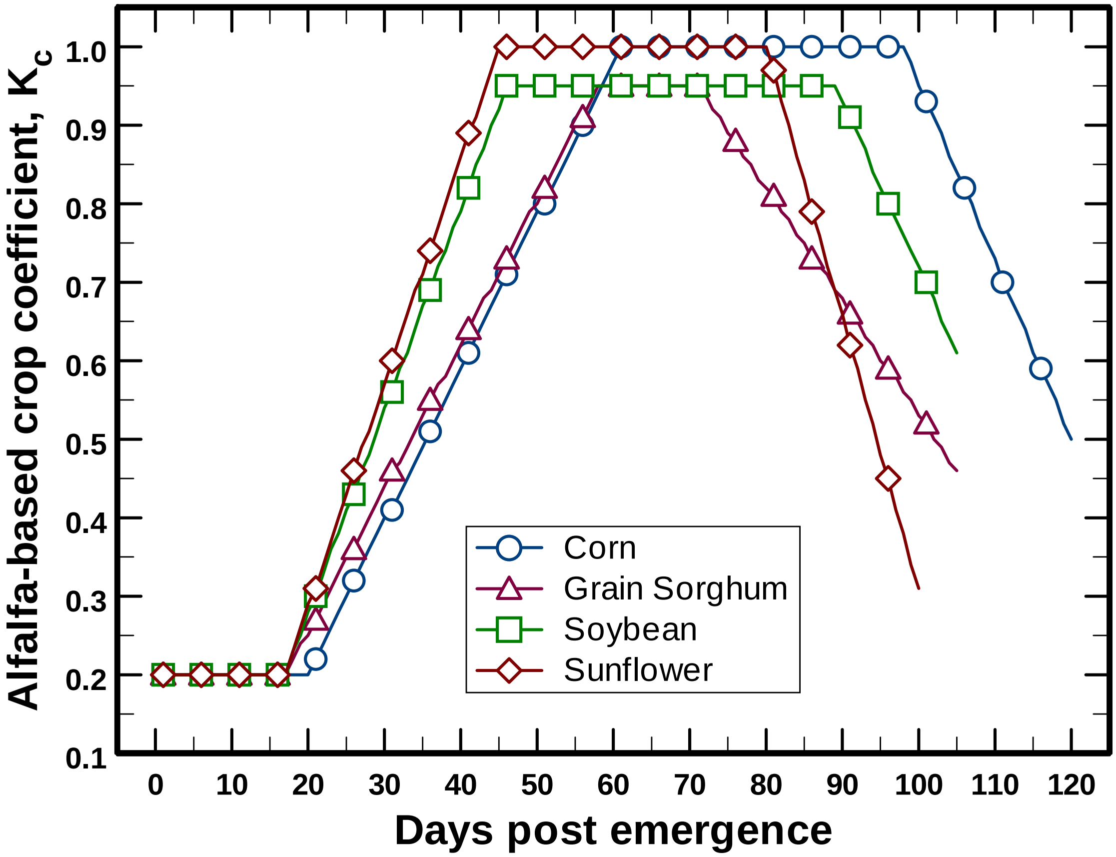


Figure 2. Alfalfa-based crop coefficients used in the simulated irrigation schedules and crop yield modeling.

Table 1. Parameters and factors used in the simulation of irrigation schedules and crop yield modeling.

Parameter	**Corn**	**Grain Sorghum**	**Soybean**	**Sunflower**
Emergence date	May 15	June 1	May 25	June 15
Physiological maturity date	September 11	September 13	September 16	September 11
Crop season, days	120	105	115	100
End of irrigation season	September 2	September 4	September 7	September 2
Irrigation season, days	110	95	105	90
Factors for crop yield model				
Vegetative period, days	66	54	38	53
Susceptibility factor (vegetative)	36.0	44.0	6.9	43.0
Flowering period, days	9	19	33	17
Susceptibility factor (flowering)	33.0	39.0	45.9	33.0
Seed formation period, days	27	22	44	23
Susceptibility factor (formation)	25.0	14.0	47.2	23.0
Ripening period, days	18	10	-	7
Susceptibility factor (ripening)	6.0	3.0	-	1.0
Slope on yield model	16.85	12.2	4.57	218.4
Intercept on yield model	-184	-84.7	-35.7	-1189

Using this procedure, the mean simulated net irrigation requirement (SNIR) for corn, grain sorghum, soybean and sunflower for the 33-year period was 14.85, 10.73, 14.52, and 12.24 inches respectively (Table 2.). The maximum SNIR for the crops was in 1976, ranging from 17 to 21 inches, while the minimum occurred in 1992, ranging from 3 to 5 inches. This emphasizes the tremendous year-to-year variance in irrigation requirements. Good irrigation management will require the irrigator to use effective and consistent irrigation scheduling.

July and August required the highest amounts of irrigation for all four summer crops with the two months averaging 84% of the total seasonal needs (Table 3). However, it might be more appropriate to look at the SNIR and seasonal distribution in relation to probability, similar to the probability tables from the USDA-NRCS irrigation guidebooks. In this sense, SNIR values will not be exceeded in 80 and 50% of the years, respectively (Table 4). The minimum gross irrigation capacities (62-day July-August period) generated using the SNIR values are 0.266, 0.188, 0.240, and 0.213 inches/day (50% exceedance levels) for corn, grain sorghum, soybean and sunflower, respectively, using center pivot sprinklers operating at 85% Ea (Table 4).

Table 2. Simulated net irrigation requirements for four major irrigated summer crops for Colby, Kansas, 1972-2004.

Year	Corn	Grain Sorghum	Soybean	Sunflower
1972	9	6	8	7
1973	15	11	15	12
1974	17	13	17	14
1975	13	10	14	12
1976	21	17	21	18
1977	10	7	10	8
1978	19	14	19	17
1979	8	5	8	8
1980	19	14	19	15
1981	15	11	14	11
1982	11	9	10	10
1983	21	16	21	19
1984	19	15	19	17
1985	16	10	14	10
1986	17	13	16	13
1987	16	12	16	14
1988	19	14	19	16
1989	14	10	14	11
1990	17	13	16	14
1991	16	12	16	14
1992	5	3	5	4
1993	8	5	8	5
1994	16	11	15	14
1995	16	12	16	15
1996	7	4	7	4
1997	13	8	12	9
1998	12	7	11	9
1999	10	7	11	9
2000	20	14	19	15
2001	20	15	19	16
2002	20	14	19	15
2003	18	13	18	16
2004	13	9	13	13
Maximum	21	17	21	19
Minimum	5	3	5	4
Mean	14.85	10.73	14.52	12.24
St. Dev.	4.41	3.68	4.35	3.99

Table 3. Average (33 year, 1972-2004) monthly distribution, %, of simulated net irrigation requirements for four major irrigated crops at Colby, Kansas.

Crop	June	July	August	September
Corn	13.71	42.29	42.38	1.62
Grain Sorghum	6.23	38.39	50.90	4.48
Soybean	10.08	42.90	40.87	6.15
Sunflower	2.37	25.16	53.71	18.77

Table 4. Simulated net irrigation requirements (SNIR) of 4 summer crops not exceeded in 80 and 50% of the 33 years 1972-2004, associated July through August distributions of SNIR, and minimum irrigation capacities to meet July through August irrigation needs, Colby, Kansas.

Criteria	***Corn***		***G. Sorghum***		***Soybean***		***Sunflower***	
	SNIR	***July-August***	***SNIR***	***July-August***	***SNIR***	***July-August***	***SNIR***	***July-August***
SNIR value not exceeded in 80% of the years	19 in.	93.8% 17.8 in	14 in.	100.0% 14.0 in.	19 in.	88.9% 16.9 in.	16 in.	84.2% 13.5 in.
July – August capacity requirement	0.287 in./day		0.226 in./day		0.272 in./day		0.217 in./day	
Minimum gross capacity at 85% application efficiency	0.338 in./day		0.266 in./day		0.320 in./day		0.256 in./day	
Minimum gross capacity at 95% application efficiency	0.302 in./day		0.238 in./day		0.287 in./day		0.229 in./day	
SNIR value not exceeded in 50% of the years	16 in.	87.5% 14.0 in.	11 in.	90.0% 9.9 in.	15 in.	84.2% 12.6 in.	14 in.	80.0% 11.2 in.
July – August capacity requirement	0.226 in./day		0.160 in./day		0.204 in./day		0.181 in./day	
Minimum gross capacity at 85% application efficiency	0.266 in./day		0.188 in./day		0.240 in./day		0.213 in./day	
Minimum gross capacity at 95% application efficiency	0.238 in./day		0.168 in./day		0.214 in./day		0.190 in./day	

It should be noted that this simulation procedure shifts nearly all of the soil water depletion to the end of the growing season after the irrigation season has ended and that it would not allow for the total capture of major rainfall amounts (greater than 1 inch) during the irrigation season. *Thus, this procedure is markedly different from the procedure used in the USDA-NRCS-Kansas guidelines (USDA-*

NRCS-KS, 2000, 2002). However, the additional inseason irrigation emphasis does follow the general philosophy expressed by Stone et. al., (1994), that concluded inseason irrigation is more efficient than offseason irrigation in corn production. It also follows the philosophy expressed by Lamm et. al., 1994, that irrigation scheduling with the purpose of planned seasonal soil water depletion is not justified from a water conservation standpoint, because of yield reductions occurring when soil water was significantly depleted. Nevertheless, it can be a legitimate point of discussion that the procedure used in these simulations would overestimate full net irrigation requirements because of not allowing large rainfall events to be potentially stored in the soil profile. In simulations where the irrigation capacity is restricted to levels significantly less than full irrigation, any problem in irrigating at a 1-inch deficit becomes moot, since the deficit often increases well above 1 inch as the season progresses.

There are many different equivalent ways of expressing irrigation capacity including depth/time, flowrate/system, flowrate/area, and time to apply given irrigation depth. Some of these equivalent irrigation capacities are shown in Table 5.

Table 5. Some common equivalent irrigation capacities.

Irrigation capacity, inches/day	*Irrigation capacity, gpm/125 acres*	*Irrigation capacity, gpm/acre*	*Irrigation capacity, days to apply 1 in.*
0.333	786	6.29	3
0.250	589	4.71	4
0.200	471	3.77	5
0.167	393	3.14	6
0.143	337	2.69	7
0.125	295	2.36	8
0.111	262	2.10	9
0.100	236	1.89	10

SIMULATION OF CROP YIELDS AS AFFECTED BY IRRIGATION CAPACITY

Model description

The irrigation scheduling model was coupled with a crop yield model to calculate crop grain yields as affected by irrigation capacity. In this case, the irrigation level is no longer full irrigation but was allowed to have various capacities (no irrigation and 1 inch every 3, 4, 5, 6, 8 or 10 days). Irrigation was scheduled according to climatic needs, but was limited to these capacities.

Crop yields for the various irrigation capacities were simulated for the same 33 year period (1972-2004) using the irrigation schedules and a yield production function developed by Stone et al. (1995). In its simplest form, the model results in the following equation,

Yield = Yldintercept + (YldSlope x ETc)

with yield expressed in bushels/acre, yield intercept and slope as shown in Table 1 and ETc in inches. As an example, the equation for corn would be,

Yield = -184 + (16.85 x ETc)

Further application of the model reflects crop susceptibility weighting factors for specific growth periods (Table 1). These additional weighting factors are incorporated into the simulation to better estimate the effects of irrigation timing for the various system capacities. The weighting factors and their application to the model are discussed in detail by Stone et al. (1995). Soybean weighting factors were developed by use of yield response factors of Doorenbos and Kassam (1979).

Yield results from simulation

Although crop grain and oilseed yields are generally linearly related with ETc from the point of the yield threshold up to the point of maximum yield, the relationship of crop yield to irrigation capacity is a polynomial. This difference is because ETc and precipitation vary between years and sometimes not all the given irrigation capacity is required to generate the crop yield. In essence, the asymptote of maximum yield in combination with varying ETc and precipitation cause the curvilinear relationship. When the results are simulated over a number of years the curve becomes quite smooth (Figure 3.). Using the yield model, the 33 years of irrigation schedules and assuming a 95% application efficiency (Ea), the average maximum yield is approximately 200 bu/a, 130 bu/a, 65 bu/a and 2800 lb/a for corn, grain sorghum, soybean and sunflower, respectively. Estimates of crop yields as affected by irrigation capacity at a 95% application efficiency can be calculated from the polynomial equations in Table 6.

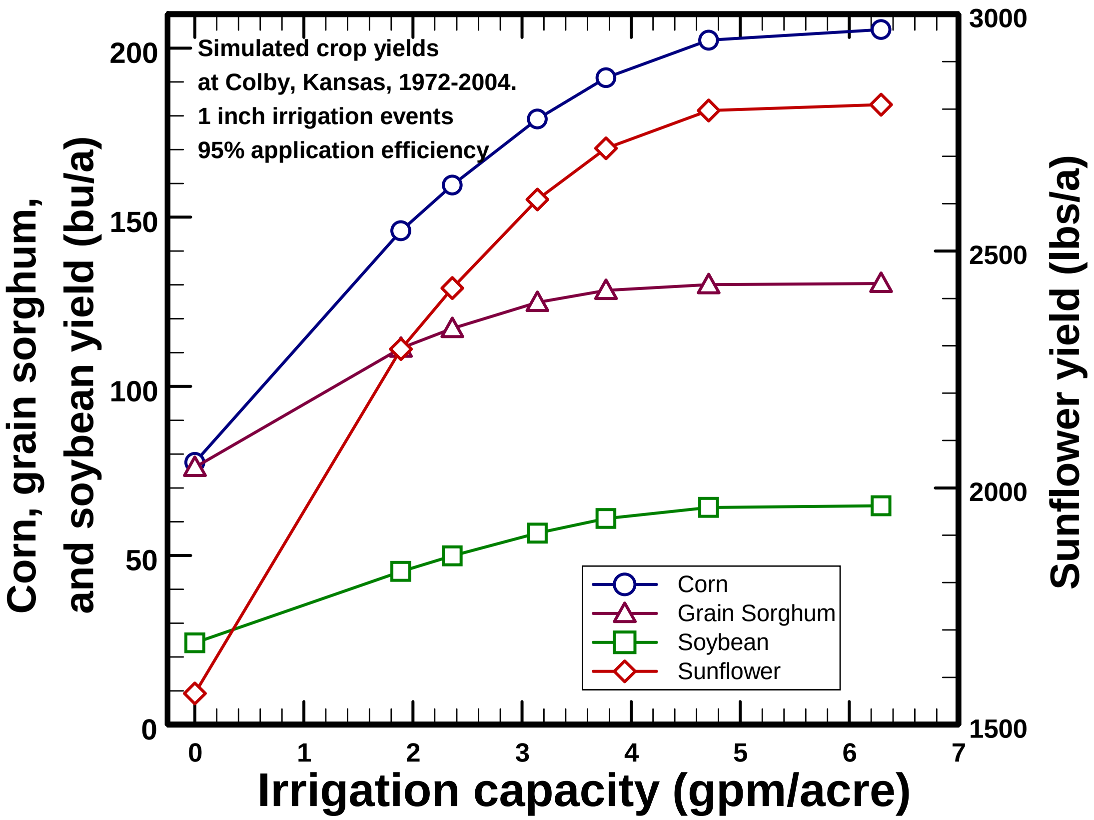


Figure 3. Simulated summer crop yields in relation to irrigation system capacity for the 33 years 1972-2004, Colby, Kansas.

Table 6. Relationship of crop yield to irrigation capacity for four summer crops at Colby, Kansas for 33 years (1972-2004) of simulation at a 95% application efficiency.

Crop	Crop yield relationship to irrigation capacity in gpm/a	R^2	Standard Error
Corn, bu/a	$Y = 77 + 42\ IC - 2.76\ IC^2 - 0.109\ IC^3$	0.9999	0.4
Grain Sorghum, bu/a	$Y = 76 + 25\ IC - 3.58\ IC^2 + 0.153\ IC^3$	0.9990	0.6
Soybean, bu/a	$Y = 24 + 12.4\ IC - 0.395\ IC^2 - 0.087\ IC^3$	0.9995	0.3
Sunflower, lb/a	$Y = 1565 + 474\ IC - 47.13\ IC^2 + 0.502\ IC^3$	0.9997	7.6

Crop yield penalty for insufficient irrigation capacity

The crop yield penalty for insufficient irrigation capacity at a 95% Ea can be calculated for various irrigation capacities by using the yield relationships in Table 6 and comparing these values to the maximum yield (Table 5). It can be seen that generally an irrigation capacity of 0.25 inches/day is sufficient for summer irrigated crop production. Lower capacities are possible for grain sorghum without much yield penalty.

Table 5. Penalty to crop yields for center pivot irrigated cron production at 95% application efficiency when irrigation capacity is below 0.33 inches/day (786 gpm/125 acres).   Results are from simulations of irrigation scheduling and yield for the 33 years 1972-2004, Colby, Kansas.

Equivalent irrigation capacities				***Penalties to crop yield***			
Inches /day	GPM /acre	Days to apply 1 inch	GPM/125 acres	Corn Yield, bu/a	G. Sorghum Yield, bu/a	Soybean Yield, bu/a	Sunflower yield, lb/a
0.333	6.29	3	786	0	0	0	0
0.250	4.71	4	589	3	0	0	2
0.200	3.77	5	471	15	2	4	98
0.167	3.14	6	393	27	6	8	202
0.125	2.36	8	295	46	13	15	380
0.100	1.89	10	236	59	18	19	512
No Irrigation				128	54	41	1242

Discussion of simulation models

The results of the simulations indicate yields decrease when irrigation capacity falls below 0.25 inches/day (589 gpm/125 acres). The argument is often heard that with today's high yielding corn hybrids it takes less water to produce corn. So, the argument continues, we can get by with less irrigation capacity. These two statements are misstatements. The actual water use (ETc) of a fully irrigated corn crop really has not changed appreciably in the last 100 years. Total ETc for corn is approximately 23 inches in this region. The correct statement is we can produce more corn grain for a given amount of water because yields have increased not because water demand is less. There is some evidence that modern corn hybrids can tolerate or better cope with water stress during pollination. However, once again this does not reduce total water needs. It just means more kernels are set on the ear, but they still need sufficient water to ensure grain fill. Insufficient capacities that may now with corn advancements allow adequate pollination still do not adequately supply the seasonal needs of the corn crop.

It should be noted that the yield model used in the simulations was published in 1995. The model may need updating to reflect yield advancements. However, it is likely that yield improvements would just shift the curves upward in Figure 3.

EFFECT OF APPLICATION EFFICIENCY ON IRRIGATION REQUIREMENTS AND CROP YIELDS

It has become popular in some water agencies to discount the potential of irrigation application efficiency improvements for saving water. The 33 years of simulated irrigation schedules were used to check the validity of this belief for corn using various irrigation capacities and application efficiencies. The results indicate that irrigation water savings will occur by improving application efficiency for capacities ranging from a very limited 1 inch every 10 days to full irrigation when averaged over the 33 year period (Table 6). Application efficiency improvements from 85 to 95% for a capacity of 1 inch every 3 days were 1.76 inches (11.4% savings) while the same improvements for a capacity of 1 inch every 8 days was only 0.12 inches (1.3% savings). The probability of needing to apply a given amount of irrigation or more for three selected capacities and application efficiencies is shown in Figure 4. In the case where the applied irrigation amount would only be exceeded in 25% of the years, the improvement in application efficiency from 85 to 95% would save 0.9, 0.32 and 0.11 inches (5.3, 2.5 or 1.1 %) for the irrigation capacities of 1 inch every 4, 6 or 8 days, respectively. Water savings were greatest for higher capacity systems when the irrigation requirements were greatest (hot and dry years). However, there is little or no opportunity to ultimately save irrigation water in extreme drought years such as 2000 through 2003 for marginal capacity systems. Any potential application efficiency improvements are readily used to help increase crop yields. The results suggest that it may be more important for water agencies to concentrate efforts at assuring that proper irrigation scheduling is utilized so that the potential irrigation system improvements can be fully realized.

The major advantage of irrigation system improvements that increase application efficiency is in the improvement in crop yields for lower capacity systems (Table 7). Corn yield increases of 15 to 20 bu/acre were obtained for lower capacity systems when the application efficiency was increased from 70 to 95%. The value of yield improvements due to higher application efficiency may well justify irrigation system improvements. This is probably one of the major reasons there has been a large conversion of furrow irrigation systems with lower application efficiency to center pivot sprinklers in the Great Plains region (Obrien et.al., 2000, 2001). Kansas Water Law requires that water diversion be used beneficially. The increased production from irrigation system improvements increases this benefit substantially for lower capacity systems. The U. S. and state economies benefit long term for these improvements and thus present federal and state cost-sharing programs for irrigation system improvements appear justified. In the cases where irrigation capacity is sufficient, there was little or no improvement in crop yields for higher application efficiency.

Table 6. Effect of improvements in application efficiency, E_a, on gross irrigation requirements (inches) for corn under various irrigation capacities at Colby, Kansas. Results are from simulated climatic-based irrigation schedules using 33 years (1972-2004) of weather data.

Statistic	**100% Ea**	**95% Ea**	**85% Ea**	**70% Ea**
Full Irrigation, irrigate as needed.				
Maximum of 33 yr.	21.00	22.00	25.00	31.00
Minimum of 33 yr.	5.00	6.00	6.00	8.00
Mean of 33 yr.	14.85	15.79	17.76	21.91
Limited to 1 inch/3 days, irrigate as needed				
Maximum of 33 yr.	21.00	22.00	25.00	30.00
Minimum of 33 yr.	5.00	6.00	6.00	8.00
Mean of 33 yr.	14.73	15.48	17.24	21.15
Limited to 1 inch/4 days, irrigate as needed.				
Maximum of 33 yr.	20.00	20.00	21.00	22.00
Minimum of 33 yr.	5.00	6.00	6.00	8.00
Mean of 33 yr.	14.06	14.55	15.39	16.79
Limited to 1 inch/5 days, irrigate as needed				
Maximum of 33 yr.	17.00	17.00	18.00	19.00
Minimum of 33 yr.	5.00	6.00	6.00	8.00
Mean of 33 yr.	12.61	12.88	13.42	14.24
Limited to 1 inch/6 days, irrigate as needed				
Maximum of 33 yr.	15.00	15.00	16.00	17.00
Minimum of 33 yr.	5.00	6.00	6.00	7.00
Mean of 33 yr.	11.18	11.39	11.70	12.33
Limited to 1 inch/8 days, irrigate as needed.				
Maximum of 33 yr.	12.00	12.00	13.00	13.00
Minimum of 33 yr.	4.00	5.00	6.00	6.00
Mean of 33 yr.	8.91	9.09	9.21	9.61
Limited to 1 inch/10 days, irrigate as needed.				
Maximum of 33 yr.	10.00	10.00	10.00	11.00
Minimum of 33 yr.	4.00	4.00	4.00	5.00
Mean of 33 yr.	7.45	7.55	7.61	8.06

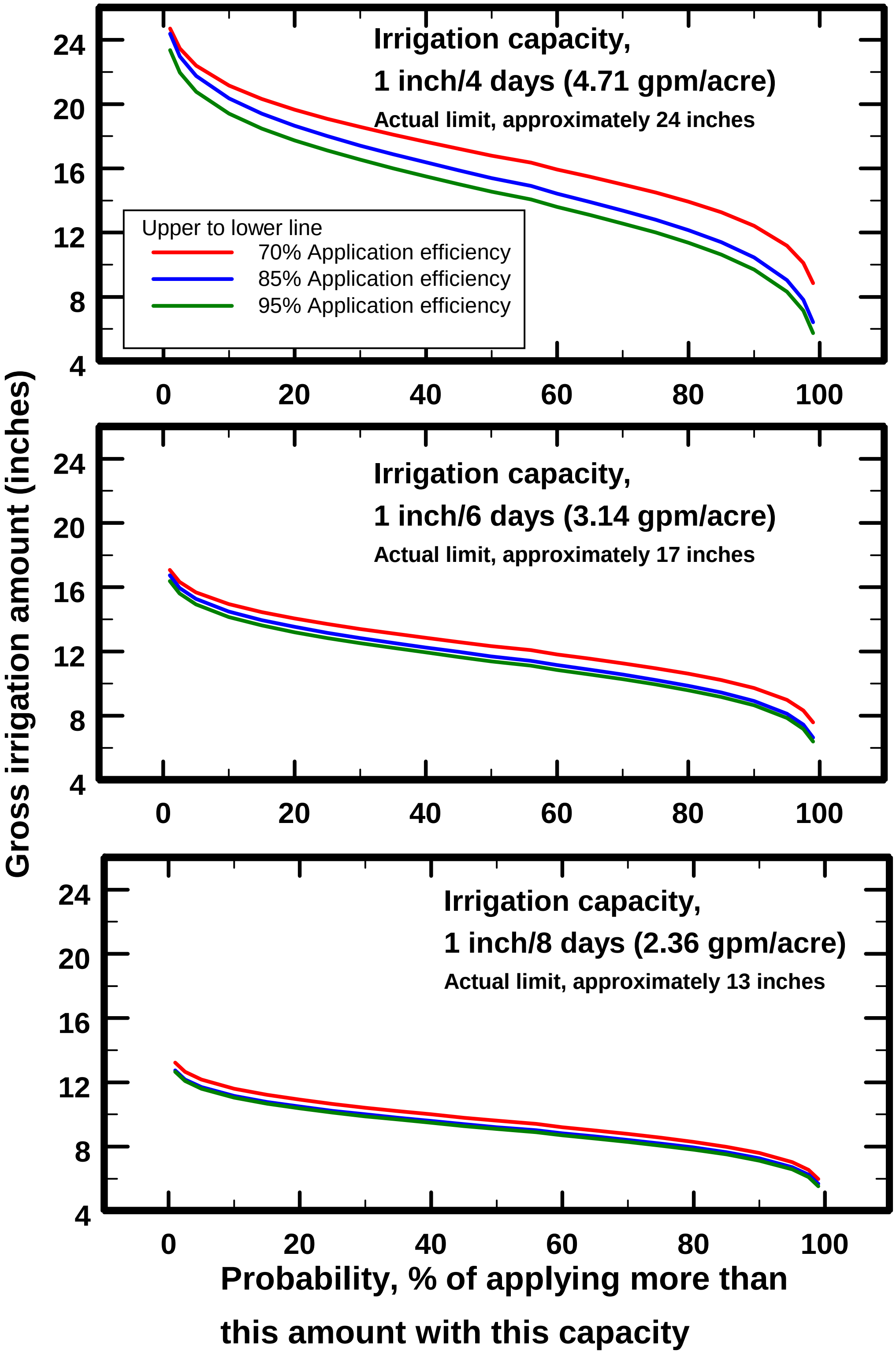


Figure 4. Gross irrigation amounts for corn as related to the probability of needing to apply that amount or more for three selected capacities and three selected application efficiencies assuming a normal distribution. Results from 33 years (1972-2004) of simulated irrigation schedules at Colby, Kansas.

Table 7. Effect of improvements in application efficiency, E_a, on corn grain yields (bu/acre) under various irrigation capacities at Colby, Kansas. Results are from simulated climatic-based irrigation schedules using 33 years (1972-2004) of weather data.

Statistic	**100% Ea**	**95% Ea**	**85% Ea**	**70% Ea**
Full Irrigation, irrigate as needed.				
Maximum of 33 yr.	273	273	273	273
Minimum of 33 yr.	112	112	112	112
Mean of 33 yr.	205	205	205	205
Limited to 1 inch/3 days, irrigate as needed				
Maximum of 33 yr.	273	273	273	273
Minimum of 33 yr.	112	112	112	112
Mean of 33 yr.	205	205	205	205
Limited to 1 inch/4 days, irrigate as needed.				
Maximum of 33 yr.	266	261	258	236
Minimum of 33 yr.	112	112	112	112
Mean of 33 yr.	204	202	198	186
Limited to 1 inch/5 days, irrigate as needed				
Maximum of 33 yr.	252	245	228	205
Minimum of 33 yr.	112	112	112	110
Mean of 33 yr.	194	191	184	171
Limited to 1 inch/6 days, irrigate as needed				
Maximum of 33 yr.	225	217	208	198
Minimum of 33 yr.	112	112	109	102
Mean of 33 yr.	182	179	172	159
Limited to 1 inch/8 days, irrigate as needed.				
Maximum of 33 yr.	200	198	192	188
Minimum of 33 yr.	105	103	98	91
Mean of 33 yr.	163	160	152	141
Limited to 1 inch/10 days, irrigate as needed.				
Maximum of 33 yr.	190	188	184	178
Minimum of 33 yr.	96	94	90	82
Mean of 33 yr.	149	146	140	130

RECENT IRRIGATION CAPACITY STUDIES AT KSU-NWREC

Two different irrigation capacity studies for corn production were conducted at the KSU Northwest Research-Extension Center at Colby, Kansas during the period 1996-2001. One study was an examination of center pivot sprinkler irrigation performance for widely-spaced (10 ft) incanopy sprinklers at heights of 2, 4 and 7 ft. It should be noted that research has indicated the 10-ft. nozzle spacing is too wide for corn production (Yonts, et. al., 2005). Discussion of the center pivot sprinkler irrigation study (CP) will be limited to the 2-ft. height. The second study was with subsurface drip irrigation (SDI) evaluating the effect of plant population at various irrigation capacities. Only the data from the highest plant population (range of 30,000-35,000 over the 6 years) will be discussed here.

The weather conditions over the 6 year period varied widely. The years 1996-1999 can be characterized as wet years and the years 2000-2001 can be characterized as extremely dry years. Corn yield response to irrigation capacity varied greatly between the wet years and the dry years (Figure 5.) In wet years, there was better opportunity for good corn yields at lower irrigation capacities, but in dry years it was important to have irrigation capacities at 0.25 inches/day or greater.

Maximum corn yields from both these studies were indeed higher than those obtained in the modeling exercises in the previous section. This may lend more credibility to the discussion that the yield model needs to be updated to reflect recent yield advancement. However, the yields are plateauing at the same general level of irrigation capacity, approximately 0.25 inches/day.

It should be noted that it is not scientifically valid or recommended that direct comparisons of the two irrigation system types be made based on Figure 5. The studies had different objectives and constraints.

OPPORTUNITIES TO INCREASE
DEFICIENT IRRIGATION CAPACITIES

There are many center pivot sprinkler systems in the region that this paper would suggest have deficient irrigation capacities. There are some practical ways irrigators might use to effectively increase irrigation capacities for crop production:

- Plant a portion of the field to a winter irrigated crop.
- Remove end guns or extra overhangs to reduce system irrigated area
- Clean well to see if irrigation capacity has declined due to encrustation
- Determine if pump in well is really appropriate for the center pivot design
- Replace, rework or repair worn pump

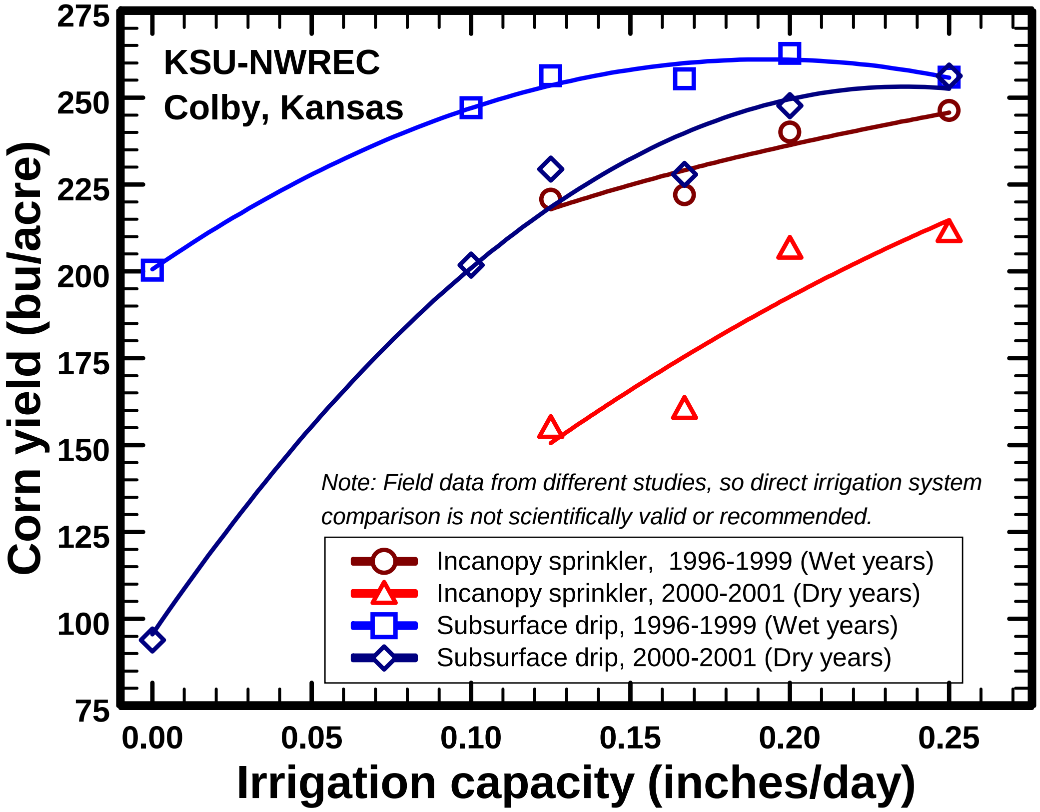


Figure 5. Corn grain yield as affected by irrigation capacity in wet years (1996-1999) and dry years (2000-2001) at the KSU Northwest Research-Extension Center, Colby, Kansas.

CONCLUDING STATEMENTS

The question often arises, *"What is the minimum irrigation capacity for an irrigated crop?"* This is a very difficult question to answer because it greatly depends on the weather, your yield goal and the economic conditions necessary for profitability. These crops can be grown at very low irrigation capacities and these crops are grown on dryland in this region, but often the grain yields and economics suffer. Considerable evidence is presented in this paper that would suggest that it may be wise to design and operate center pivot sprinkler irrigation systems in the region with irrigation capacities in the range of 0.25 inches/day (589 gpm/125 acres). In wetter years, lower irrigation capacities can perform adequately, but not so in drier years. It should be noted that the entire analysis in this paper is based on irrigation systems running 7 days a week, 24 hours a day during the typical 90 day irrigation season if the irrigation schedule (water budget) demands it. So, it should be recognized that system maintenance and unexpected repairs will reduce these irrigation capacities further.

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