CORN PRODUCTION IN THE CENTRAL GREAT PLAINS 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. Corn is the major irrigated crop in the region and is very responsive to irrigation, both positively when sufficient and negatively when insufficient. This paper will discuss the nature of corn evapotranspiration rates and the effect of irrigation system capacity on corn production and economic profitability. Although the information presented here is based on information 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 corn production.

CORN EVAPOTRANSPIRATION RATES

Corn evapotranspiration (ET) rates vary throughout the summer reaching peak values during the months of July and August in the Central Great Plains. Long term (1972-2002) 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 0.266 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 2002 were 0.331 and 0.263 inches/day, respectively, representing an approximately 15% increase over 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.

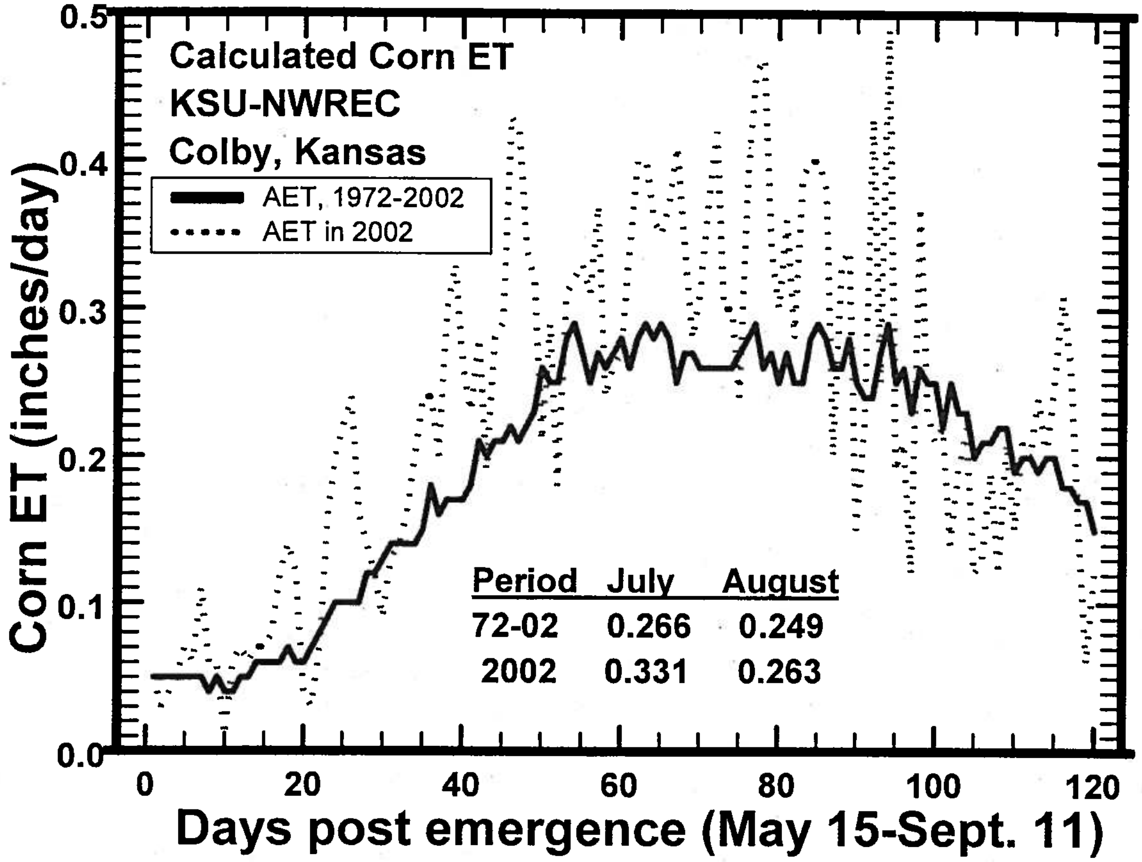

Figure 1. Long term corn evapotranspiration (ET) daily rates and ET rates for 2002 at the KSU Northwest Research-Extension Center, Colby Kansas. ET rates calculated using a modified Penman approach (Lamm et. al., 1987).

DESIGN IRRIGATION CAPACITIES

USDA-NRCS guidelines

The USDA-NRCS National Engineering Handbook (USDA-NRCS, 1997) and through its state supplements for Kansas (USDA-NRCS-KS, 2000, 2002) offer some suggested guidelines for center pivot sprinkler irrigation capacities. A complete description of the calculation procedures used to arrive at these guidelines lies beyond the scope of this paper. However, the minimum gross irrigation capacities in inches/day can briefly be summarized as the net irrigation requirement (NIR) for the July-August (62-day) period for 80 or 50% chance rainfall adjusted for the application efficiency divided by the 62-day period. A summary of this information and its resultant minimum gross irrigation capacities for corn at Colby, Kansas (Thomas county) is shown in Table 1.

Table 1. Summary of USDA-NRCS irrigation capacity guiding parameters and values for corn in Colby, Kansas (Thomas County). Adapted from USDA-NRCS-KS, 2000, 2002.

Parameter	Value	Tab. or Fig.	Source
Seasonal NIR, inches,			
80% chance rainfall	15.4	Table KS4-1	KS Guide, Feb 2000
50% chance rainfall	13.5	Table KS4-2	KS Guide, Feb 2000
Irrigation Zone for Colby, KS.	2	Figure KS4-1	KS Guide, Feb 2000
Irrigation Design Group for Keith silt loam, Colby, KS.	5	I D Group 5	KS Guide, Feb 2000
Monthly distribution of NIR, %			
July % with 80% chance rainfall	40.9%	Table KS4-3	KS Guide, Feb 2000
August % with 80% chance rainfall	32.5%	Table KS4-3	KS Guide, Feb 2000
July % with 50% chance rainfall	43.1%	Table KS4-4	KS Guide, Feb 2000
August% with 50% chance rainfall	33.9%	Table KS4-4	KS Guide, Feb 2000
Minimum center pivot sprinkler gross irrigation capacity, in/day, at stated application efficiency (Ea)			
85% Ea and 80% chance rainfall	0.21	Table KS4-10	KS Guide, Apr 2002
90% Ea and 80% chance rainfall	0.20	Table KS4-11	KS Guide, Apr 2002
85% Ea and 50% chance rainfall	0.20	Table KS4-10a	KS Guide, Apr 2002
90% Ea and 50% chance rainfall	0.19	Table KS4-11a	KS Guide, Apr 2002

The calculation of minimum gross irrigation capacities in this manner violates long standing irrigation design philosophies as is stated in the Irrigation Guide (USDA-NRCS-KS, 2002). However, the rationale is given that center pivot sprinklers in the region typically do not satisfy the peak crop ET without either (1) relying on major withdrawal of root zone soil water rationale for these guidelines or (2) allowing application rates to exceed soil intake rates thus producing excessive runoff. An argument can be made against this rationale in that irrigation runoff might best be handled through sprinkler package selection and the subsequent management of that package rather than through reducing irrigation system capacity.

The USDA-NRCS-KS 2002 guidelines do list the caveat that for dryer-than-average years this design criterion will likely result in plant water stress and reduced yields unless stored soil water reserves can buffer the irrigation system capacity deficiency. However, there might be another point of discussion about the procedure used to calculate the minimum gross irrigation capacity. The calculation procedure uses the July and August monthly distributions of seasonal NIR to determine minimum capacities. The monthly distribution tables also include planning values for the month of May of approximately 1.5 to 4% of NIR. These May planning values might be of good value for preseason planning, but may be detrimental to design of good irrigation management in July and August. Allocation of some monthly distribution to May would result in some reductions of irrigation distributions in June, July and August.

Simulation of corn irrigation schedules for Colby, Kansas

Irrigation schedules (water budgets) were simulated for the 1972-2002 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 for the location (Lamm, 2001) to give the actual corn ET. The irrigation season was limited to the 90 day period between June 5 and September 2 based on results from earlier simulations conducted by Lamm et. al., (1994). 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.

Using this procedure, the mean simulated net irrigation requirement (SNIR) for corn in the 31-year period was 14.6 inches (Table 2.). The maximum SNIR during the 31-year period was 21 inches in 1976, while the minimum was 5 inches in 1992. Monthly distributions of SNIR averaged 15.8, 38.4, 42.8, and 3% for June, July, August and September. However, it might be more appropriate to look at the SNIR in relation to probability. In this sense, SNIR values of 18 and 14.6 inches will not be exceeded in 80 and 50% of the years, respectively (Table 3). These are approximately 17 and 8% higher than the USDA-NRCS-KS guidelines expressed in Table 1, respectively. The minimum gross irrigation capacities (62-day July-August period) generated using the SNIR values are 0.277 and 0.225 inches/day (80% and 50% exceedance levels) for center pivot sprinklers operating at 85% Ea using the simulated monthly distributions (Table 3). These minimum capacities are about 32 and 13% higher than the corresponding values of USDA-NRCS-KS in Table 1.

Table 2. Simulated net irrigation requirements for corn and monthly distributions of irrigation requirements for Colby, Kansas, 1972-2002.

Year	Simulated Net Irrigation Requirement, inches. (SNIR)	June % of SNIR	July % of SNIR	Aug. % of SNIR	Sept. % of SNIR
1972	9	11.1%	44.4%	44.4%	0.0%
1973	15	20.0%	20.0%	53.3%	6.7%
1974	16	12.5%	56.3%	31.3%	0.0%
1975	13	0.0%	46.2%	46.2%	7.7%
1976	21	19.0%	38.1%	38.1%	4.8%
1977	15	20.0%	40.0%	33.3%	6.7%
1978	18	11.1%	44.4%	44.4%	0.0%
1979	8	12.5%	12.5%	62.5%	12.5%
1980	18	16.7%	38.9%	44.4%	0.0%
1981	15	20.0%	40.0%	33.3%	6.7%
1982	16	12.5%	43.8%	43.8%	0.0%
1983	20	10.0%	40.0%	50.0%	0.0%
1984	18	11.1%	55.6%	33.3%	0.0%
1985	15	13.3%	33.3%	46.7%	6.7%
1986	16	12.5%	43.8%	43.8%	0.0%
1987	15	6.7%	40.0%	53.3%	0.0%
1988	18	22.2%	38.9%	38.9%	0.0%
1989	14	7.1%	42.9%	42.9%	7.1%
1990	16	25.0%	37.5%	37.5%	0.0%
1991	15	6.7%	40.0%	53.3%	0.0%
1992	5	20.0%	20.0%	60.0%	0.0%
1993	8	50.0%	12.5%	37.5%	0.0%
1994	16	18.8%	25.0%	50.0%	6.3%
1995	15	6.7%	33.3%	60.0%	0.0%
1996	7	0.0%	42.9%	42.9%	14.3%
1997	13	15.4%	61.5%	15.4%	7.7%
1998	11	36.4%	18.2%	45.5%	0.0%
1999	9	11.1%	55.6%	33.3%	0.0%
2000	19	21.1%	36.8%	42.1%	0.0%
2001	20	20.0%	40.0%	35.0%	5.0%
2002	19	21.1%	47.4%	31.6%	0.0%
Mean	**14.6**	**15.8%**	**38.4%**	**42.8%**	**3.0%**
StDev	**4.1**	**9.8%**	**12.2%**	**10.0%**	**4.2%**
Min	**5.0**	**0.0%**	**12.5%**	**15.4%**	**0.0%**
Max	**21.0**	**50.0%**	**61.5%**	**62.5%**	**14.3%**

Table 3. Simulated net irrigation requirements (SNIR) of corn not exceeded in 80 and 50% of the years 1972-2002, associated monthly distributions and minimum irrigation capacities to meet July-August needs, Colby, KS.

Criteria	*SNIR*	*June SNIR*	*July SNIR*	*Aug. SNIR*	*Sept. SNIR*
SNIR value not exceeded in 80% of years	18 in.	15.8% 2.8 in.	38.4% 6.9 in.	42.8% 7.7 in.	3.0% 0.5 in
July-August capacity	0.236 inches/day				
Min. Gross capacity at 85% Ea	0.277 inches/day				
Min. Gross capacity at 90% Ea	0.262 inches/day				
Criteria	*SNIR*	*June SNIR*	*July SNIR*	*Aug. SNIR*	*Sept. SNIR*
SNIR value not exceeded in 50% of years	14.6 in.	15.8% 2.3 in.	38.4% 5.6 in.	42.8% 6.3 in.	3.0% 0.4 in
July-August capacity	0.191 inches/day				
Min. Gross capacity at 85% Ea	0.225 inches/day				
Min. Gross capacity at 90% Ea	0.213 inches/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 90 day season. *Thus, this procedure is markedly different from the procedure used in the USDA-NRCS-KS 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.

Equivalent irrigation capacities are shown in Table 4.

Table 4. 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 CORN YIELDS AND ECONOMIC RETURNS AS AFFECTED BY IRRIGATION CAPACITY

Model descriptions

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

Irrigated corn yields for the various irrigation capacities were simulated for the same 31 year period (1972-2002) 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 = -184 + (16.85 ET)

with yield expressed in bushels/ acre and ET in inches. Further application of the model reflects weighting factors for specific growth periods. These additional weighting factors are incorporated into the simulation to better estimate the effects of irrigation timing for the various systems and capacities. The weighting factors and their application to the model are discussed in detail by Stone et al. (1995).

Factors associated with the economic model are shown in Table 5.

Table 5. Economic variables and assumptions used in the model.

Revenue streams and field characteristics	
Total field area, acres	160
Center pivot sprinkler area, acres	125
Dryland area, acres	35
Corn harvest price, $/bushel	$2.35
Government payments, $/acre spread over all acres	$27.54
Net returns from dryland area, $/acre	$32.50
Total irrigation system depreciation costs, $/irrigated acre	$93.01
Costs and factors that change with corn yield and irrigation levels	
Corn seed emergence, %	95%
Nitrogen fertilizer, lb/bushel of yield	1.10
Nitrogen fertilizer, $/lb	$0.13
Phosphorus fertilizer, lb/bushel of yield	0.43
Phosphorus fertilizer, $/lb	$0.22
Harvest base charge, $/acre	$18.10
Yield level for extra harvest charge, bu/acre	51
Rate for extra harvest charge, $/bu	$0.135
Hauling charge, $/bu	$0.115
Fuel and oil for pumping, $/inch	$3.34
Irrigation maintenance and repairs, $/inch	$0.33
Interest rate, %	8%
Other variable costs	
Corn seed, $/acre	$34.80
Herbicide, $/acre	$30.48
Insecticide, $/acre	$38.54
Crop consulting, $/acre	$6.50
Crop insurance, $/acre	$10.00
Drying cost, $/acre	$0.00
Miscellaneous costs, $/acre	$10.00
Non-harvest field operations, $/acre	$42.15
Other non-fieldwork labor, $/acre	$5.00
Irrigation labor, $/acre	$5.00
Interest rate, %	8%
1/2 yr. interest for these other variable costs, $/acre	$7.30
Total other variable costs	$189.77

Yield results from simulation

Although corn grain yield is generally linearly related with corn ET from the point of the yield threshold up to the point of maximum yield, the relationship of corn grain yield to irrigation capacity is a polynomial. This difference is because ET and precipitation vary between years and sometimes not all the given irrigation capacity is required to generate the corn yield. In essence, the asymptote of maximum yield in combination with varying ET and precipitation cause the curvilinear relationship. When the simulated results are simulated over a number of years (e.g. 31-year period, 1972-2002) the curve becomes quite smooth (Figure 2.). Using the yield model, the 31 years of irrigation schedules and assuming a 95% application efficiency (Ea), the average maximum yield is approximately 201 bu/acre for the 0.25 inches/day (589 gpm/125 acres or 4.71 gpm/acre) irrigation capacity. The polynomial equations for yield at 95 and 85% application efficiencies are:

$$Y95 = 86 + 33\ Icap + 0.82\ Icap^2 - 0.572\ Icap^3 \qquad (1)$$

$$Y85 = 86 + 30\ Icap + 0.67\ Icap^2 - 0.434\ Icap^3 \qquad (2)$$

where Y95 and Y85 are yields in bu/acre at respective Ea values of 95 and 85% and Icap is the center pivot sprinkler flowrate in gpm/acre.

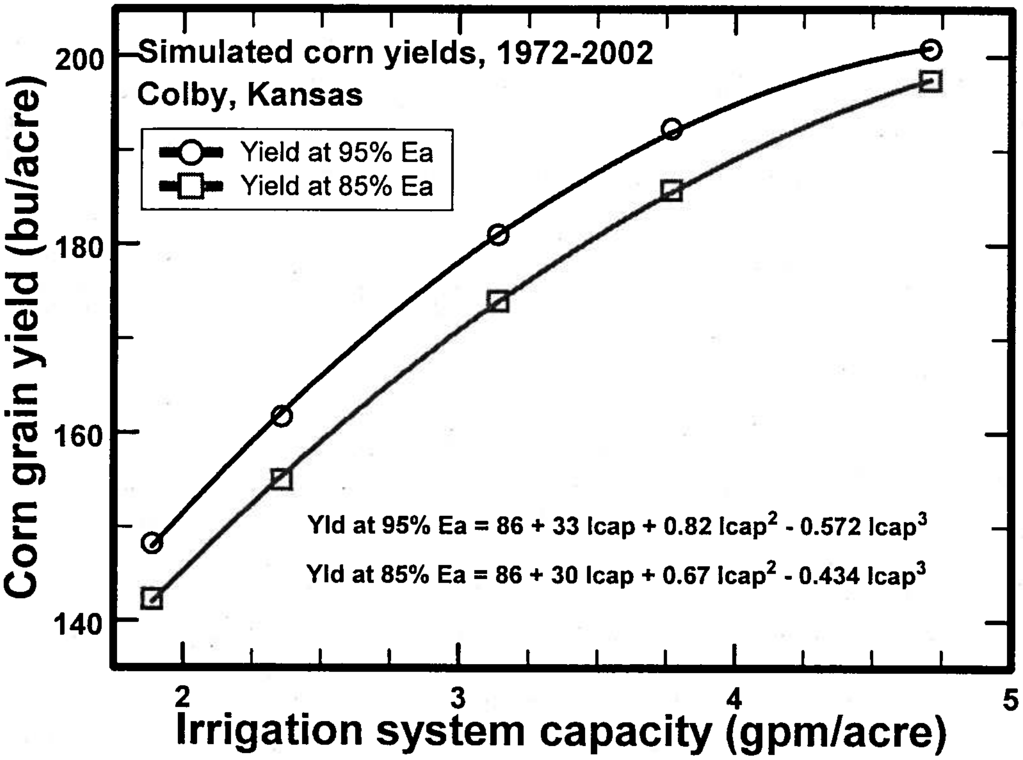

Figure 2. Simulated corn grain yields in relation to irrigation system capacity for the years 1972-2002, Colby, Kansas.

Economic results from simulation

Similarly, these yield results can be coupled with the economic model to generate the simulated net returns to land and management for the same 31 year period (Figure 3).

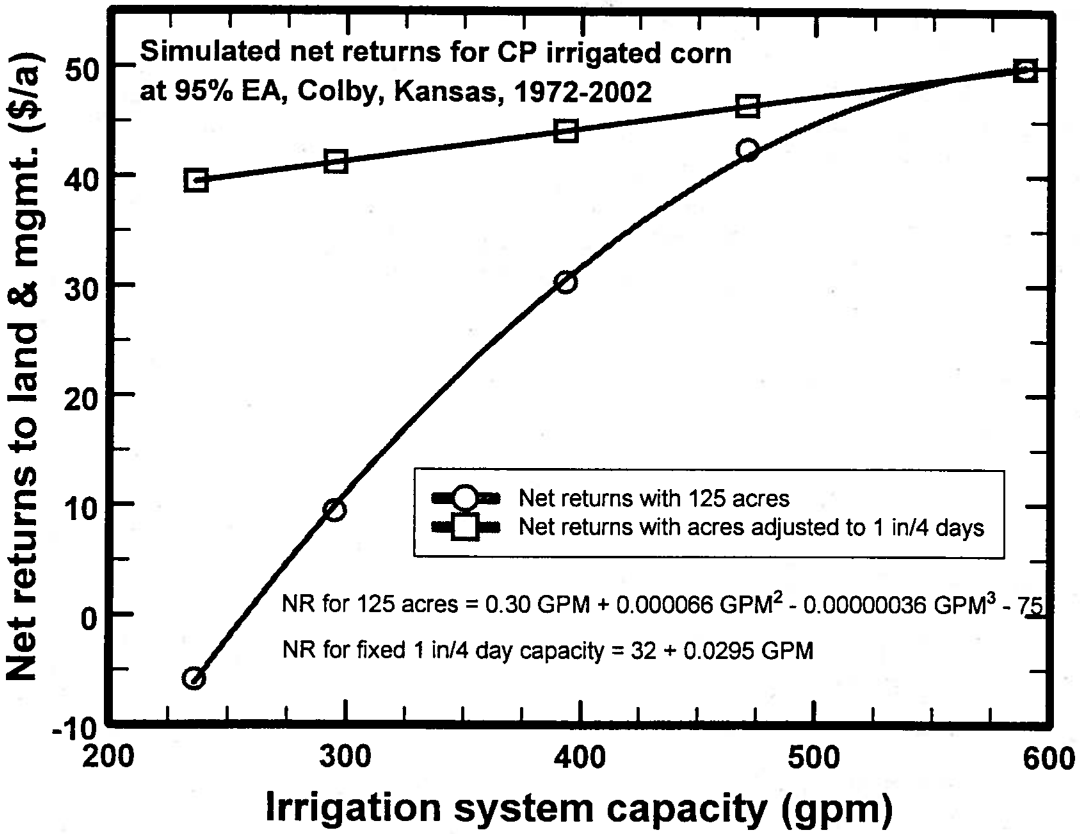

Figure 3. Simulated net returns to land and management for corn production in relation to irrigation system capacity for the years 1972-2002, Colby, Kansas.

Net returns maximized at approximately $50/acre at an irrigation capacity of 589 gpm/125 acres (0.25 inches/day or 4.71 gpm/acre) using the economic assumptions of the model. An alternative scenario where irrigation capacity is fixed at 0.25 inches/day (1 inch/4 days) and center pivot area is allowed to decrease is also shown in Figure 3. Net returns are highest when the gross irrigation capacity is held at the 0.25 inches/day level (1 in/4 days) and irrigated land area is allowed to decrease. It should be noted that fixed irrigation capacity scenarios such as this need to consider what the options are for the area coming out of corn production. In this model, the net returns for dryland production was used as estimated by dryland rent values. It would not be possible to substitute another summer irrigated crop on these acreage reductions because they would be competing for the same irrigation capacity. A winter-irrigated crop could be substituted providing there is sufficient water right available. *It also should be noted that these results are very different from simulations conducted in the mid 1990s where net returns were much higher. In those simulations (data not shown), net returns from the fixed 0.25 inch/day were less than for the full size 125 acre center pivot sprinkler until irrigation system capacity was reduced below 330 gpm/125 acres. This emphasizes how crucial economic assumptions and economic conditions are to the allocation of irrigation and land area.*

The equations for net returns to land and management for center pivot sprinkler irrigated corn are:

$$NR125 = 0.30\ GPM + 0.000066\ GPM^2 - 0.00000036\ GPM^3 - 75 \qquad (3)$$

$$NRFixed = 32 + 0.0295\ GPM \qquad (4)$$

where NR125 and NRFixed are the simulated net returns to land and management in $/acre for irrigated corn for a 125 acre center pivot sprinkler and for alternatively a fixed 0.25 inches/day irrigation capacity.

Yield and economic penalties for insufficient irrigation capacity

The penalties on yield and net returns for insufficient irrigation capacity at a 95% Ea can be calculated for various irrigation capacities (Table 6.)

Table 6. Penalties to corn grain yields and net returns to land and management for center pivot irrigated corn production at 95% Ea when irrigation capacity is below 0.25 inches/day (589 gpm/125 acres). Results are from simulations of irrigation scheduling and yield and economic modeling for the years 1972-2002, Colby, Kansas.

Various equivalent irrigation capacities				***Penalties to***	
Inches/day	GPM/acre	Days to apply 1 inch	GPM/125 acres	Yield, bu/a	Net returns to L & M, $/total 160 acre field
0.250	4.71	4	589	0	$0
0.200	3.77	5	471	8	$1,196
0.167	3.14	6	393	20	$3,122
0.143	2.69	7	337	30	$4,941
0.125	2.36	8	295	39	$6,506
0.111	2.10	9	262	47	$7,823
0.100	1.89	10	236	53	$8,831

Discussion of simulation models

The results of the simulations indicate both yields and net returns to land and management decrease when irrigation capacity was 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 (ET) of a fully irrigated corn crop really has not changed in the last 100 years. Total ET 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. It is possible that it should be further updated to reflect yield advancements. However, it is likely that yield improvements would just shift the curves upward in Figure 2. The effect on Figure 3 would be less clear. It is possible that yield advancements there might indeed shift the profitability of the fixed capacity (0.25 inches/day) line relative to the full 125 acre scenario (curve).

RECENT IRRIGATION CAPACITY STUDIES AT KSU-NWREC

Two different irrigation capacity studies 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., 2003). 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 varied widely. The years 1996-1999 canl 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 4.) 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.

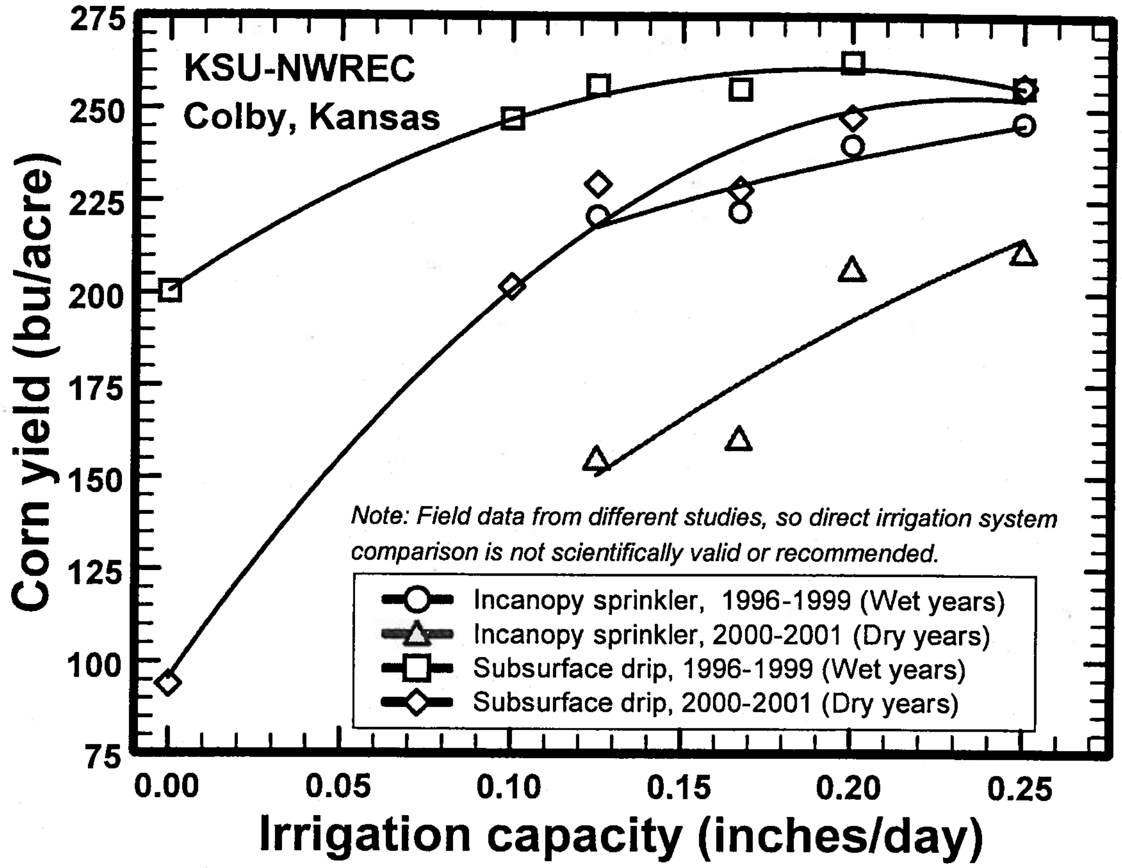

Figure 4. Corn grain yield as affected by irrigation capacity in wet years (1996-1999) and dry years (2000-2001) for two different studies at the KSU Northwest Research-Extension Center, Colby, Kansas.

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 4. 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 corn 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

CONCLUDING STATEMENTS

The question often arises, *"What is the minimum irrigation capacity for irrigated corn?"* 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. Corn can be grown at very low irrigation capacities and there is even dryland corn 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 dryer 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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Estimating Irrigation Pumping Plant Efficiency

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Introduction

Irrigated agriculture in Kansas uses groundwater as the primary water source. Much of the access to this water requires the use of deep wells but even in the more shallow alluvial aquifer systems, energy costs for pumping can be significant. Of course, an increase in energy cost, increase in pumping lift or increase in the total volume pumped causes a direct increase in pumping cost. Pumping costs also increase when changes in pumping conditions and regular wear and tear on pumping plant components result in a loss of pumping plant pumping efficiency.

Pumping Plant Efficiency

Any of the major components of a pumping plant, i.e. the pump, the gear head or drive, or the engine or motor, can be the cause of poor performance. Limited surveys of pumping plants in Kansas indicate the average unit uses about 40 percent more fuel then necessary for the given pumping conditions. In addition, many wells, due to age, initial construction techniques, screen incrustation, and declining water levels, have reduced specific yields. Some of this loss of capacity may be possible to recover with proper well maintenance. High well efficiency should be a concern whenever a replacement well is being considered, as new design and well construction techniques can help obtain good yield with the minimum drawdown during pumping.

Causes of poor pumping plant efficiency

Causes of poor pumping plant efficiency and subsequent excess fuel use include:

1. Poor pump selection.

Pumps are designed to best operate for a particular combination of head and discharge for a given operating speed. If the operating conditions were either not properly matched to a given pump or the conditions changed from the initial conditions, the pump efficiency will be poor.