Optimal Irrigation for Drought

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Wise and responsible water use requires both good management and good technologies.

*Management and technology go hand-in-hand and both can only be optimized in the presence of the other.*
Kansas irrigated corn yields have increased nearly 3 times faster than nonirrigated yields and with ≈ 40% less annual variation in yields.

Irrigated corn yields were ≈ 3.5 times greater than dryland in 2012.

“The predominate method of managing drought is irrigation.”

Dale Bucks, USDA-ARS Agricultural Engineer
Average daily corn ET (water use) at Colby, Kansas in 2012 was 16% greater than the long term average and on some days was nearly twice the average value.

Most regional irrigation systems are designed at less than 0.25 inches/day, and did not cope well at critical growth stages with such large increases in daily ET.
The severity of the high ET and low precipitation in 2012 was compounded considerably by the dry conditions that began in early August of 2010 in much of the western Great Plains. As a result, there was lower than normal overwinter replenishment of soil water reserves that usually help to buffer plant water stress during the growing season. Some Great Plains areas actually had drier conditions in 2011, but were only marginally better in 2012.

It should be noted that excessive temperatures in 2012 sometimes in 100 to 115°F range exacerbated drought effects and ruined crop pollination in some cases.
With seasonal ET nearly 16% greater than average and precipitation only 48% of the long term average, the cumulative difference between corn ET and precipitation was the greatest recorded value in the period 1972-2012.

The decreased precipitation and increased ET essentially means there was an approximately 10 inches greater than normal irrigation requirement in the year 2012.

An irrigation deficit of this size might reduce yields by 50% or greater and reduce gross income by $700/acre.
What’s happening on the ground.

Ideally, maybe we would like to see a uniformly green and healthy crop field like this.
What’s happening on the ground.

But often, we saw irrigated fields like this.

Or this.

Or even this!

Or this.

Or like this.
So, what can we do?

Let’s break the discussion into 3 parts:

- **Off Season Adjustments to the Drought**
- **In-Season Adjustments to the Drought**
- **Long-Term Adjustments to the Drought**
• Increase irrigation system efficiency and/or uniformity.

Each of these systems can be very efficient and uniform, but many producers find moving from left to right improves their own water management.
Center pivot sprinklers are the predominant irrigation system in Kansas. Although this technology is over 60 years old, we still find many operational, maintenance, and/or uniformity problems. The popular in-canopy drop nozzles have been oversold and are often misapplied.

K-State is assessing these problems and helping producers and industry improve sprinkler system performance.
Some of the earliest descriptions of in-canopy sprinkler irrigation (Lyle, 1992) discuss the importance of all crop plants having equal opportunity to water, yet irrigators, designers, and equipment manufacturers do not always follow this guideline.
In the extreme drought years of 2000 to 2003 that occurred in the U. S. Central Great Plains, even small amounts of surface water movement affected sprinkler-irrigated corn production. Large differences in corn plant height and ear size for in-canopy sprinkler application over a short 10-ft. distance (4 crop rows) as caused by small field microrelief differences and the resulting surface water movement during an extreme drought year, Colby, Kansas, 2002.
"Small field microrelief differences and the resulting surface water movement."

Hi falutin way of saying a puddle occurred
Solutions to Incanopy Sprinkler Uniformity Problems

- Use proper nozzle spacing
  (not more than twice corn row width)
- Use appropriate proper nozzle height
  (e.g., 2 or 7 ft, but not corn ear height)
- Use residue management
- Use circular rows

If runoff or uniformity problems continue, permanently raise nozzles above the crop canopy.
Subsurface drip irrigation (SDI) applies water below the soil surface to the crop root zone with small emission points (emitters) that are in a series of plastic lines typically spaced between alternate pairs of crop rows.
SDI can be used for small, frequent, just-in-time irrigation applications directly to crop root system. The primary ways that SDI could increase crop water productivity (WP), More crop per drop are:

- Reduction and/or elimination of deep drainage, irrigation runoff, and soil water evaporation
- Improved infiltration, storage, and use of precipitation
- Improved in-field uniformity and targeting of plant root zone
- Improved crop health, growth, yield, and quality
I believe there is growing evidence that subsurface drip irrigation (SDI) can stabilize yields at a greater level with less irrigation than in-canopy sprinklers.
Off-season adjustments to the drought.

- Increase irrigation efficiency and/or uniformity
- Adopt irrigation scheduling

Lots of good science-based methods are available now.

Monitoring available soil water

Water budget software

Infrared thermometers to monitor plant water stress

and more are on the way!!

We do need to improve adoption rates!!
Off-season adjustments to the drought.

- Increase irrigation efficiency and/or uniformity
- Adopt irrigation scheduling
- Improved management of precipitation and soil water through cultural practices

Great adoption of strip tillage

Reduction of tillage increases yields.

<table>
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<tr>
<th>Irrigation capacity (inches/day)</th>
<th>Corn grain yield (bu/a)</th>
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<tbody>
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<td>0.12</td>
<td>200</td>
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<tr>
<td>0.14</td>
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<td>0.22</td>
<td>250</td>
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<td>0.24</td>
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</tr>
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</table>

KSU-NWREC
Colby, Kansas
2004-2007

Increasing adoption of reduced or no tillage planting
Off-season adjustments to the drought.

- Increase irrigation efficiency and/or uniformity
- Adopt irrigation scheduling
- Improve management of precipitation and soil water through cultural practices
- Change crops or mixture of irrigated crops

Crops such as grain sorghum use less water and are more tolerant of water shortages.


K-State software that helps with decisions

Center pivot with multiple crops.
Off-season adjustments to the drought.

- Increase irrigation efficiency and/or uniformity
- Adopt irrigation scheduling
- Improve management of precipitation and soil water through cultural practices
- Change crops or mixture of irrigated crops
- **Reduce irrigated area**

Allowing some areas to lay fallow or using crops with different life cycles may be best means of increasing the irrigation capacity to mitigate drought.
In-season adjustments to the drought.

- Keep pumping, “Ride it out”, minimize any system down time, stay optimistic.
- Implement triage situation, abandoning some of the crop and concentrating water on most favorable crop portion.
- On multiple crops system, shift timing of irrigation events to most critical crop need. Good irrigation scheduling “tells” when.
- Timely address irrigation system uniformity problems.
- Manage drought-related pests (I will come back to this)

None of these are wrong, simplistic, or unrealistic!
Producer’s adjustments will depend on their perceptions of the drought severity and duration, crop stage and susceptibility, their own optimism and aversion to risk, and quite frankly the number of hours in the day.
Drumroll, please!

Spider mites.
These tiny pests thrive on hot and dry conditions and their tiny punctures into the plant for feeding basically destroy photosynthetic area.

Thus, even if the drought relents or is mitigated by irrigation, permanent crop yield-limiting damage has occurred.
Long-term adjustments to the drought. (i.e., drought continues, our climate is getting drier)

- Increase irrigation efficiency and/or uniformity
- Change crops or mixture of irrigated crops
- Adopt irrigation scheduling
- Improve management of precipitation and soil water through cultural practices

Do all of the above, but probably the long-term solution is:

REDUCE IRRIGATED AREA

As economically painful as this may seem, this has always been the design criteria for irrigation systems in arid regions.

Our semi-arid and more humid regions have just been able to successfully gamble on this criteria.
Wow!

That does sound economically painful!

- It will likely reduce income in years with ample rainfall.
- It may negatively affect land values if land is considered non-irrigated.
- It could reduce economic activity in the community as less inputs are bought and less outputs are sold.

Let’s explore this topic some more to see why we should still consider it.
Navigating the Drought Paradox

Crop water use, ETc usually increases during a drought while rainfall decreases.

Crop yield usually increases with crop water use, ETc.

Actually, yield is not directly “caused” by ETc. The correlation may be caused by greater ETc being related to good growing conditions.
Effect of Irrigation Capacity on Corn Yields

Corn yields were simulated for 42 years of weather data from Colby, KS. (1972-2013).

Well-watered corn ETc ranged from 17.6 to 27.1 inches with average of 23.1 inches.

Inseason precipitation ranged from 3.1 to 21.2 inches with average of 11.8 inches.

Full irrigation ranged from 6 to 22 inches with average of 15.7 inches.

The marginal WP (slope) is 17 bu/acre-in. (maybe $65 to $85/acre-in)

The yield threshold is at 10.9 inches of ETc.
When we decrease irrigation capacity to 1 inch/4 days, then we see small yield decreases in 10 of the 42 years.

Traditionally, at KSU, we have said that 1 inch/4 days is a reasonable design capacity for silt loam soils in NW Kansas.

Overall, the 1 inch/4 day irrigation capacity performs well except in the years with greatest ETc.
Effect of Irrigation Capacity on Corn Yields

When irrigation capacity dropped to 1 inch/6 days, (3.14 gpm/acre) corn yields were depressed in 80% of the 42 years.

Yield variability increased.

Average yield dropped 23 bu/acre and for the two greatest ETc years the yield reduction was nearly 45 bu/acre.
Yields continue to drop rapidly with further decrease in irrigation capacity to 1 inch/8 days.

The increased variability is due to amounts and timing of rainfall.

Average yield dropped 43 bu/acre and for the greater ETc years the yield reduction was 50 to 55 bu/acre.
As we further decrease capacity to 1 inch/10 days, the positive aspects of greater ETc \textit{(i.e., better growing conditions)} begin to disappear. Average irrigation is \approx 50\% of full irrigation.

Average yield dropped 57 bu/acre and for some years the yield reduction was \approx 70 bu/acre.
Under dryland conditions, corn yields typically decreased over the entire range of ETc experienced.

Average yield was only 38% of full irrigation and in one year the reduction was 200 bu/acre.
The simulations indicate the greatest yields are in the driest years, but they require greater irrigation capacities and amounts. The slope is nearly constant up through 1 inch/4 days capacity. ≈ 10 bushels/acre-in.

If pumping costs are $5/acre-inch and corn price is $4.00/bushel, the marginal benefit is $35/acre-in.
From previous slide

”...greatest yields are in the driest years, but they require greater irrigation capacities and amounts.”

Questions:

Are crop prices generally greater in dry years?

How important are these greater production years in terms of long term profitability?
Implications of Effect of Irrigation Capacity on Corn Yields

The variation in yields in the preceding graphs is primarily caused by variations in natural rainfall amounts and its timing as it is supplementing an insufficient irrigation capacity.

The variation increases as irrigation capacity decreases and the chances for sufficient yield for profitability also decreases.
Through reductions in irrigated land area, one can regain irrigation capacity (i.e., gpm/acre), increase crop yield, and reduce risk.

Short term marginal benefits to the individual producer should increase due to less input costs for nonirrigated acres.

*After consideration, the producer’s adjustments will depend on their own perceptions of the drought severity and duration, their own optimism and aversion to risk.*
It cannot be overemphasized that management and technology go hand-in-hand and both can only be optimized in the presence of the other.
List of K-State Research and Extension Irrigation-Related Websites:

Mobile Irrigation Lab
http://mobileirrigationlab.com/

General Irrigation Topics at K-State
http://www.ksre.ksu.edu/irrigate/

SDI in the Great Plains
http://www.ksre.ksu.edu/sdi/

The next Central Plains Irrigation Conference will be held in Burlington, Colorado, February 25-26, 2014.