MANAGEMENT STRATEGIES FOR A LIMITED WATER SUPPLY

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INTRODUCTION

The Ogallala Aquifer is the major water supply for irrigation in the Central Great Plains. However, in many parts of the Ogallala Aquifer, groundwater levels are declining due to withdrawals greater than the recharge. Many regions face a future without irrigation water supplied by the Ogallala Aquifer. Trends in irrigated and non-irrigated cropland use in Texas from 1964 to 1982 showed that as groundwater supplies became inadequate, irrigated cropland reverted to dryland (Crosswhite et al. 1990). To deter this potential change in agriculture, some regions within the Central Plains have instituted regulations that restrict the amount of pumping. As groundwater declines occur, areas that previously had good producing wells have seen declines in their output. With these changes in well output or regulations, management practices for irrigation must change.

WHAT IS LIMITED IRRIGATION?

When water supplies are restricted in some way, so that full evapotranspiration demands cannot be met, limited irrigation results. Reasons that producer's may be limited on the amount of water that they can apply include:

1) Limited capacity of the irrigation well – In regions with limited saturated depth of the aquifer, well yields can be marginal and not sufficient to meet the needs of the crop.
2) Restricted allocation upon pumping – In some regions that have experienced declining groundwater levels, restrictions have been implemented to decrease the amount of pumping by producers. In some instances, the allocations are less than what is required to fully irrigate the crops grown.
3) Reduced surface water storage – In regions that rely upon surface water to supply irrigation needs, droughts can have a

major impact upon the amount of water accumulations that are available to producers for irrigation.

When producers cannot apply water to meet the ET of the crop, they must realize that with typical management practices, yields and returns from the irrigated crop will be reduced as compared to a fully irrigated crop. To properly manage the water for the greatest return, producers must have an understanding of how crops respond to water, how crop rotations can enhance irrigation management, and how changes in agronomic practices can influence water needs.

There are several important "pieces to the puzzle" that help to facilitate limited irrigation strategies. Many of these principles come from dryland water conservation management. They include: the relationships between grain yield and water use (evapotranspiration), crop residue management for water conservation, plant population management, crop rotations to balance water use, and irrigation timing. These factors will be discussed separately and then combined in actual demonstration/case studies of limited irrigation.

YIELD AND EVAPOTRANSPIRATION

Evapotranspiration is the amount of water that is used by the crop and is the driving force behind crop yields. Water from precipitation or irrigation enters the soil where it can then be used by the crop. Crop yields are a linear relationship to the amount of water that is used by the crop (Figure 1). Crops such as corn, respond with more yield for every inch of water that the crop consumes as compared to winter wheat or soybeans. However, crops such as corn require more water for development or maintenance and can be determined by where the yield-et line intersects the X-axis. Corn requires approximately 10 inches of ET as compared to 4.5 and 7.5 inches of ET for wheat and soybeans. These crops also require less ET for maximum production.

Irrigation is important to increasing ET and grain yields. Irrigation is used to supplement rainfall in periods when ET is greater than precipitation. However, not all of the water applied by irrigation can be used for ET. Inefficiencies in applications by the system result in losses. As ET is maximized, more losses occur since the soil is nearer to field capacity and more prone to losses such as deep percolation (Figure 2). When producers are limited on the amount of water that they can apply by either allocations or low capacity wells, wise use of water is important for maximizing the return from water.

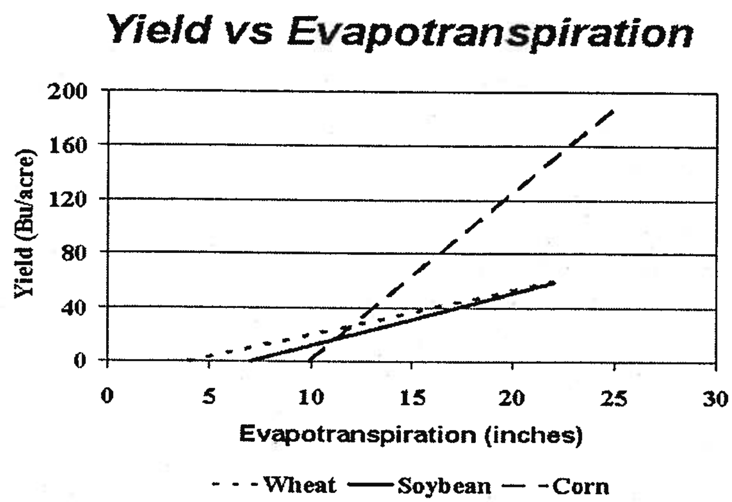

Figure 1. Grain yield vs ET relationship for corn, soybeans and winter wheat from North Platte, NE. (Schneekloth et al. 1991)

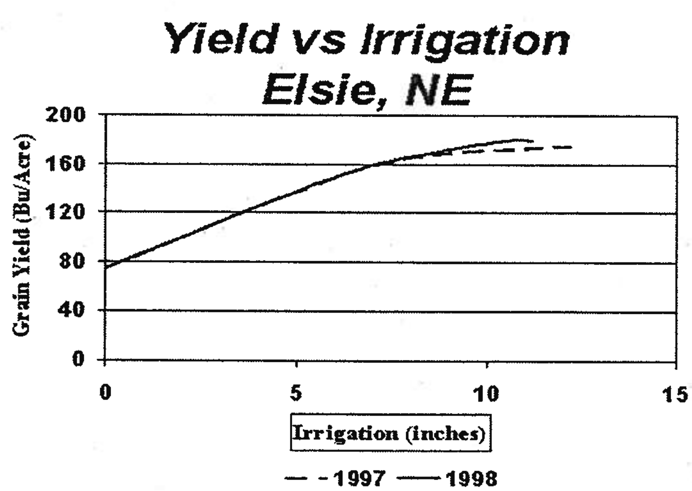

Figure 2. Grain yield vs Irrigation relationship for corn from Elsie, NE.

AGRONOMIC PRACTICES

Residue Management

The goal when working with limited water is to capture every possible source of water in the production system. These sources include rainfall, snowfall and irrigation water. Residue management can have a significant impact upon increasing the availability of water. Producers in the Central Plains have long advocated no-till for dryland production. No-till increases the amount of water stored in the soil due to reduced evaporation from tillage operations and runoff and increased snow catch during winter snowstorms. Changes in tillage management have allowed producers to change rotations from the conventional wheat-fallow rotation to more intensive rotations such as wheat-corn-fallow. The changes in tillage management can be successfully used in irrigated production for moisture conservation.

After harvest, leaving the residue standing can have a major impact upon snow catch. Nielsen (1998) found that standing sunflower residue increased the amount of snow captured in years with strong drifting storms. In most years, standing residue accounted for nearly 2 inches in increased soil moisture over flat residue. In one year, standing residue accounted for nearly 4 more inches of stored soil moisture.

Surface residue during the growing season can also have important impact upon water conservation. Todd et al. (1991) found that wheat residue reduced the amount of evaporation from the soil during the growing season for irrigated corn as compared to bare soil. The reduction in evaporation amounted to nearly 2.5 inches for the growing season. Most of these saving occurred before the corn crop reached full canopy. Water savings from corn residue would be expected to be less since it does not cover the soil completely but some savings would be expected.

Runoff from precipitation is also reduced when surface residue is present. Residue acts as small dams that slow water movement and allow for more time for the water to infiltrate into the soil. Residue also reduces the impact of rainfall and irrigation upon surface sealing which increases infiltration rates. As droplets impact the soil surface, they destroy the surface structure which will seal the soil surface and reduce infiltration rates. Residue protects the soil surface from the impact of these droplets.

Plant Populations

Plant populations for dryland production are less than that for irrigated production. Populations are reduced to reduce ET by the crop to better match precipitation and stored soil moisture. However, when considering to reduce populations on irrigated corn, producers must realize that populations for corn must be reduced to less than 18,000 plants/acre to reduce ET. Lamm and Trooien (2001) found that corn grain yields generally increased as plant populations increased from 22,000 plants/acre to 34,000 plants/acre for varying irrigation capacities. Little yield penalty was observed at higher plant populations compared to lower populations when no irrigation was applied.

Crop Rotations

Crop rotations can have a major impact upon the total water needs by irrigation. Crop rotations that have lower water use crops such as soybean or winter wheat can reduce irrigation needs. Schneekloth et al. (1991) found that when limited to 6 inches of irrigation, corn following wheat yielded 13 bu/acre (8 percent) more than continuous corn. The increased grain yield following wheat was due to increased stored soil moisture during the non-growing season that was available for ET during the growing season.

Crop rotations also spread the irrigation season over a greater time period as compared to a single crop. When planting multiple crops such as corn and winter wheat under irrigation, the irrigation season is extended from May to early October as compared to continuous corn, which is predominantly irrigated from June to early September. Crops such as corn, soybean and wheat have different timings for peak water use (Figure 3).

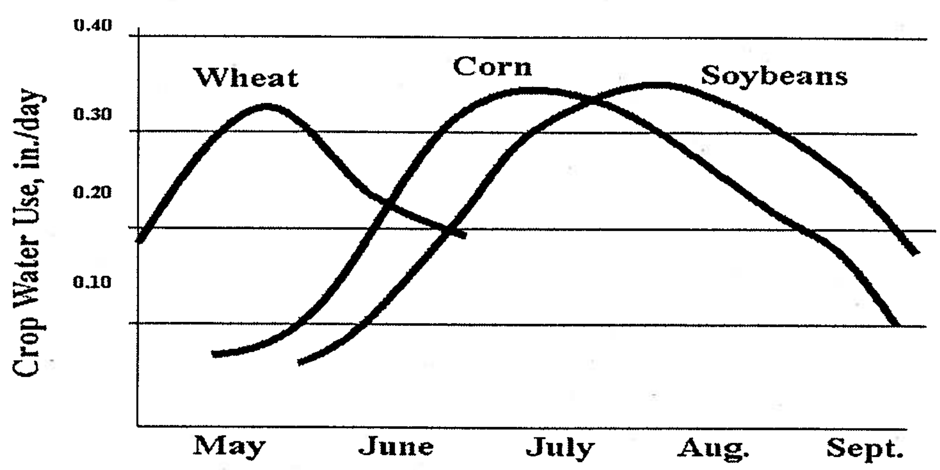

Figure 3. Example of daily ET during the growing season.

With low capacity wells, planting multiple crops with smaller acreages allows for water to be applied at amounts and times when the crop needs the water. The net effect of irrigating fewer acres at any one point in time is that ET demand of that crop can be better met. Irrigation management can be as needed rather than in anticipation of crop ET. With low capacity systems, producers generally irrigate to keep the soil moisture as close to field capacity as possible in anticipation that their system can not meet crop water needs later during peak water needs without precipitation. Some systems can never meet crop ET, even with normal precipitation. O'Brien et al. (2001) found that when irrigation system capacity was increased from 0.1 inches/day to 0.2 inches per day that yields increased 28%. To achieve this change in capacity per irrigated acre, a producer would have to reduce irrigated acres by 50%. Profitability of increasing the irrigation capacity by reducing irrigated acres increased net returns per irrigated acre by nearly 4 times. Even though only half of the acres are irrigated, profits would be greater than twice that of when irrigating the entire acreage.

IRRIGATION MANAGEMENT

In regions with allocation systems, irrigation management is critical to maximizing water inputs. As was discussed earlier, crops respond in a linear relationship to ET. However, each inch of irrigation does not return the same amount of grain yield as the previous inch of irrigation. Crops have critical time periods when water is more critical to the grain yield. Typically, that critical time period is during the reproductive growth stages of those crops. When restricted upon the total amount of water that can be applied, saving that water for the reproductive growth stages is the most advantageous. Grain yields are increased when water is properly timed and applied during the reproductive growth stages.

Corn

Corn has a greater response to water when irrigated during the reproductive growth stages, prior to tassel emergence to milk growth stages as compared to the vegetative growth stages and late grain fill. Barrett and Skogerboe (1978) found that corn yielded more when irrigated during the late vegetative and pollination growth stages as compared to irrigating during the vegetative or late grain fill growth stages in Colorado. In Kansas, Stone et al. (1978) found that irrigating during the silk emergence growth stage resulted in more grain yield than either prior to tassel or blister growth stages. If a single irrigation was to be applied, the blister growth stage had the lowest yield of the three time periods. Irrigating during each of the three growth stages did increase grain yields compared to a single irrigation.

Lamm (1989) found that when the total amount of water was restricted to less than adequate amounts for full irrigation, restricting the amount of water applied during the vegetative growth stage and conserving that water for the reproductive growth stage was advantageous for grain yields. Lamm also found that in years without severe water stress during the vegetative growth stages, limiting irrigation amounts during the vegetative growth stage and full irrigating during the reproductive growth stage conserved water (4-5 inches) with a small reduction in net returns ($11 – 22/acre) as compared to full irrigation management.

Soybean

Research with soybean have shown that irrigation during the vegetative growth stages can typically be reduced without significant reductions in grain yields and have a significant savings in water. Klocke et al. (1989) found that withholding irrigation during the vegetative growth stage for soybean resulted in little if no yield loss. However, as precipitation and/or soil water holding capacity decreased, irrigation was generally recommended to begin earlier in the reproductive growth stages. Irrigation should begin during the flower growth stage in western Nebraska on a sandy soil as compared to the pod elongation growth stage on silt loam soils.

Lamm (1989) found that reducing irrigation during the vegetative growth stages resulted in equal soybean yields as compared to full irrigation during years with normal precipitation. Reducing irrigation to 50% of ET during the vegetative growth stage and full irrigating during the reproductive growth stage reduced the amount of water applied by 22% (2.9 inches). However, in years when severe water stress occurs in the vegetative growth stages, grain yields for reduced irrigation during the vegetative growth stage were less than that of full irrigation.

Pre-Irrigation

Although there may be years that pre-irrigation is needed to refill the soil profile to field capacity, the efficiency of pre-irrigations is low. Lamm and Rogers (1985) found that the storage efficiency of non-growing season precipitation was reduced as the fall available soil water content was closer to field capacity. Although pre-irrigation may be needed in years with low precipitation, decisions on irrigating are better made in the spring as to take advantage of non-growing season precipitation. As was indicated by Nielsen (1998), the use of standing stubble increased the storage efficiency of off-season precipitation. Lamm and Rogers study was clean tilled so storage efficiencies were less than what may be expected with undisturbed fields.

ECONOMICS OF LIMITED IRRIGATION

Full irrigation management has the greatest return per acre when water (capacity or allocation) is not limiting (Lamm 1989). However, when system capacities or allocations are limiting, reducing irrigated acres and full irrigation management of a single crop is generally not the most optimum choice. A producer must determine what the difference in economic returns are when adding irrigated acres of a low water use crop at lower than optimum water levels as compared to reducing irrigated acres of a high water use crop such as corn. Crops such as soybean and wheat have greater net returns at lower amounts of irrigation as compared to corn. Schneekloth et al. (1995) found that net returns were greater when a three-year rotation of corn-soybean-wheat was irrigated with a 6 acre-inch/acre/year allocation as compared to a continuous corn rotation. This was due to the increase in corn grain yields following wheat and the inclusion of lower water use crops such as soybean and wheat which had yields that were closer to fully irrigated grain yields as compared to corn. They also found that the variability in net returns was also reduced with a three-year rotation as compared to continuous corn. Part of this reduction in variability was due to less variability in grain yields with the three-year rotation as compared to continuous corn.

As the allocations are reduced, the choice becomes do I further reduce the amount of irrigation on corn and further reduce yields or do I add a lower water use crop with less water applied in return for applying more water on corn? Schneekloth et al. (2001) found that cropping patterns switched to include lower water use crops such as soybean or wheat as the amount of water that could be pumped was reduced. As the amount of allocation is reduced, irrigation of corn is reduced to slightly less than that of optimum with little reduction in grain yield and net return. Schneekloth found that irrigated acres of lower water use crops do increase in favor of applying more water on fewer acres of corn to maximize the net return. However, as the amount of water is reduced further, irrigated corn generally is eliminated from the rotation. When allocations were reduced to 4 inches per acre, corn was no longer as profitable as compared to irrigating soybean or wheat.

Demonstration Project

Beginning in 1996, Schneekloth and Norton (2001) initiated an irrigation demonstration project. The demonstration project was located on farmer's fields throughout southwestern Nebraska on varying soil types and production systems. The purpose of this demonstration project was to educate producers on best management practices (BMP's) and limited irrigation management techniques that were developed for irrigated corn. Management practices that were demonstrated included current farmer management (Farm), BMP, beginning irrigation during the reproductive growth stage (LATE) and a strict allocation of 6 to 10 acre-inches/acre. Although yields were generally less for Late than compared to FARM or BMP, the net return was only slightly reduced and in some instances greater (Table 1). The greatest differences in net returns were on soils with lower water holding capacities such as at Elsie and Dickens. The water savings for LATE management was approximately 30% less than current farmer management. General comments by the cooperators were that they would be able to live with less water and that yields with less water managed properly were more than expected.

Table 1. Average Four-Year Net Returns[1] by Management Strategy and Site.

Site	FARM	BMP	LATE	ALLOC
		Management Strategy		
		Net Return ($/acre)		
Arapahoe	$186.69	$191.70	$212.69	$200.86
Elsie	$193.55	$193.92	$184.68	$153.86
Dickens[2]	$196.30	$198.09	$163.08	$161.57
Benkelman[3]	$193.52	$209.61	$194.15	$199.15
All Sites	$191.95	$195.53	$191.66	$173.73

[1]Net returns to land, labor, and management using 1999 average regional operating costs; assumes price of corn is $2.00/bu and pump cost is $2.50/acre-inch.
[2]Data for Dickens in 1997 not included due to irrigation error.
[3]Only 1999 data used for Benkelman site.

CONCLUSIONS

Fully irrigated crop production has greater returns per acre as compared to limited irrigation management. However, when limited on the amount of water that can be pumped, changes in agronomic and irrigation management practices can improve net returns. Changes in agronomic practices such as no-till can improve reduce water needs and increase the capture and utilization of precipitation. Changes may include adding lower water requirement crops that also have different critical times for water. Use of crop rotations can extend the irrigation season and allow for longer operation of irrigation systems with proper irrigation management. Adding different crops reduces the irrigated acres of any one crop. This allows for producers with low capacity systems to effectively manage the irrigation. Since fewer acres are irrigated at any one point in time, the ability of that system to meet ET needs of that crop improve. These management changes can improve yields and stretch limited water supplies.

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