IRRIGATION

Limited Irrigation Management: Principles and Practices

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J. Schneekloth, T. Bauder, N. Hansen[1] (Revised 1/09)

Quick Facts…

Limited irrigation occurs when water supplies are restricted and full evapotranspiration (ET) demands cannot be met.

Changes in agronomic and irrigation management practices can improve net returns.

Crop rotation can extend the irrigation season and allow for longer operation of irrigation systems with proper irrigation management.

No-till can increase the capture and utilization of precipitation and reduce irrigation water needs.

Adding lower-water requirement crops that have different critical times for water, can also reduce irrigation.

Colorado State University

Extension

Water availability in the western United States is limited and declining. Declining water supplies, drought, compact compliance, water needs for environmental restoration, and water transferred from agriculture to municipality uses have reduced the water available to irrigated agriculture. As a result, irrigation management for limited water supplies is increasingly important.

What is limited irrigation?

When water supplies are restricted, so that full evapotranspiration demands cannot be met, limited irrigation results. Limited irrigation management are practices that incorporate crop rotations, water management during the vegetative growth stages and farming practices to minimize water stress during the critical crop growth stages. Reasons for limited water supplies 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 supplies or storage – In regions that rely on surface water to supply irrigation needs, droughts and water transfers can have a major impact upon the amount of water that is 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 relationship between grain yield and water use (evapotranspiration), understanding how water stress impacts crops during several growth stages, 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.

Crop Response to Water

Yield and evapotranspiration

Evapotranspiration (ET) is the amount of water that is used by the crop and is the driving force behind crop yields. ET is the sum of evaporation of water from the soil or crop surface and transpiration by the crop. Potential crop yields typically increase linearly with the amount of water that is used by the crop (Figure 1). Water stress during critical time periods can result in lower than potential yields. 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 before any yield is produced as indicated by where the yield-ET line intersects the X-axis. Corn requires approximately 10 inches of ET to produce the first increment of yield as compared to 4.5 and 7.5 inches of ET for wheat and soybeans (Figure 1). These crops also require less ET for maximum production.

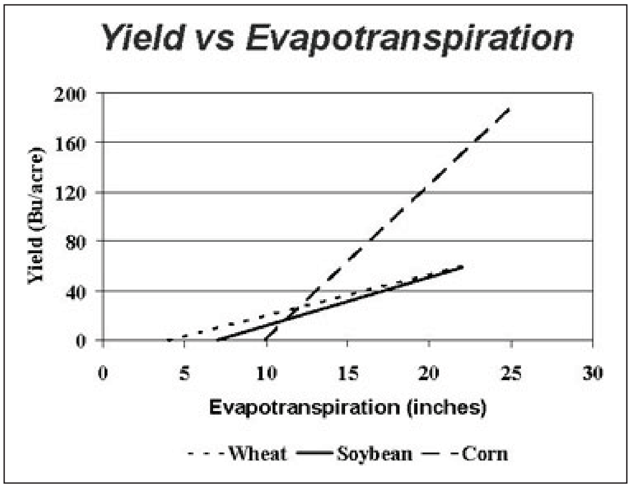

Figure 1. Grain yield vs ET relationship for corn, soybeans and winter wheat from North Platte, NE. (Schneekloth et al. 1991)

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 is 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).

Impact of Water Stress

Crops respond to water stress differently at several growth stages. Many grain crops have little yield response to water stress during the vegetative growth stage and during late reproductive or grain fill growth stages. However, crops are sensitive to water stress during the reproductive growth stages and yields will be impacted during this time period.

When producers have limited water supplies, but have control over when they can irrigate, limiting water during the growth stages that are least sensitive to water stress while saving water for the critical growth stages can be a valuable strategy to maximize yield return from water. Figure 3 shows the yield susceptibility of corn through the growing season. Early water stress has less impact on grain yield as compared to the tassel to silk period. Water stress reduces transpiration as compared to a non-stressed crop. Stressing a crop during the time periods when water use is lower limits the total impact of water use reductions as compared to water stress during growth stages that have higher potential transpiration rates.

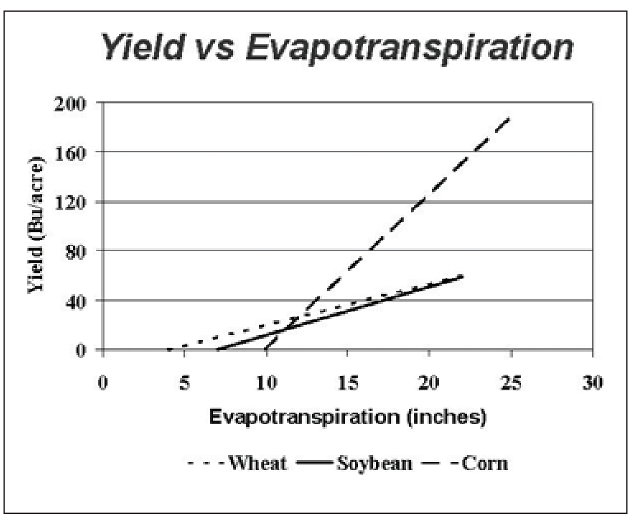

Figure 2. Grain yield vs Irrigation relationship for corn from Elsie, NE.

Agronomic Practices

Residue Management

The goal when working with limited water is to capture, store, and preserve every possible source of water in the production system. These sources include rainfall, snowfall and irrigation water. Residue management can have a significant impact on 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, improved infiltration and reduced 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 on 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.

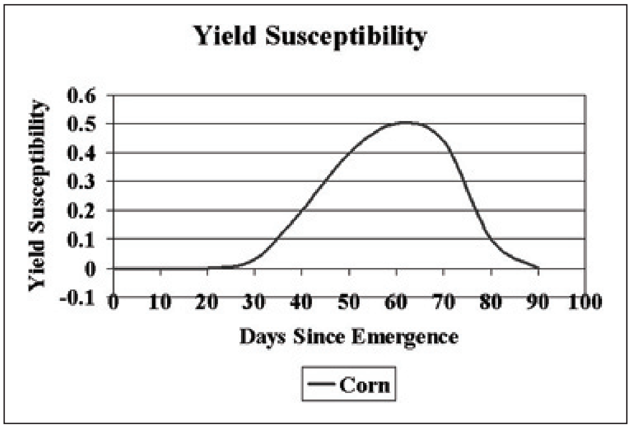

Figure 3. Yield susceptibility to water stress for corn (Sudar et al., 1981).

Surface residue during the growing season can also impact water conservation. Todd et al. (1991) found that wheat residue reduced the amount of evaporation from the soil by nearly 2.5 inches during the growing season for irrigated corn as compared to bare soil. Most of the savings 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.

Runoff from precipitation is also reduced when surface residue is present. Residue reduces the impact of rainfall and irrigation on 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. Residue also acts as small dams that slow water movement and allow for more time for the water to infiltrate into the soil.

Plant Populations

Recommended plant populations for dryland production are less than that for irrigated production. Populations are lowered to reduce ET by the crop to better match precipitation and stored soil moisture. However, when considering populations reductions for irrigated corn, populations 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. The yield penalty at higher plant populations was small compared to lower populations when minimal irrigation was applied. However, during years with above-average precipitation, higher populations have a greater yield potential.

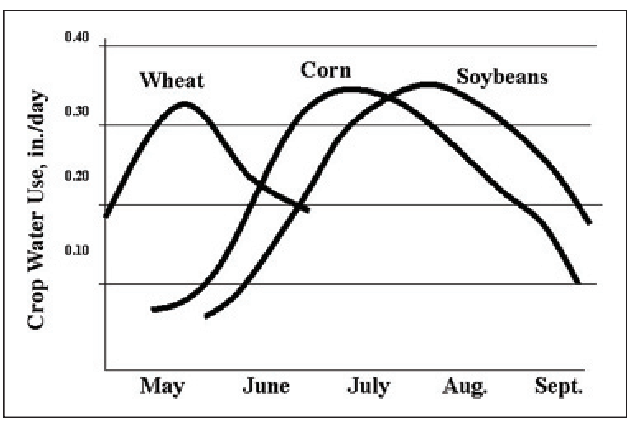

Figure 4. Example of daily ET during the growing season.

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 4).

With low capacity wells, planting the acreage with multiple crops with different peak water need periods allows for water to be applied at amounts and times when each 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 begin to irrigate early to keep the soil moisture as close to field capacity as possible in anticipation that their system cannot meet crop water needs later during peak water needs.

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. This reduction in response is due to greater losses such as leaching and more water left in the soil as applications approach full ET. 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 water allocation cannot meet full crop ET, water should be saved for the reproductive stages where it will have the most impact. Grain yields are increased when water is properly timed and applied during the reproductive growth stages.

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, irrigation decisions are better made in the spring 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 involved clean tillage; therefore, storage efficiencies were less than what may be expected with undisturbed fields.

Irrigation Capacity

Irrigation capacity on a per-irrigated acre basis is important when considering how many acres to irrigate. In western Kansas, Lamm (2004) found that net returns to land and management are reduced when all acres are irrigated with less than adequate capacities as compared to reducing irrigated acres and maintaining an adequate capacity. Potential corn yields are reduced as irrigation capacity is reduced as compared to maintaining an adequate capacity with fewer acres.

Some systems can never meet peak 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, corn yields increased by 28 percent. To achieve this change in capacity per irrigated acre, a producer would have to reduce irrigated acres by 50 percent. Profitability of increasing the irrigation capacity by reducing irrigated acres increased net returns per irrigated acre by nearly four times. Even though only half of the acres are irrigated, profits would be more than twice that of when irrigating the entire acreage.

When irrigation capacities are less than adequate, producer strategies to try to compensate for reduced capacity include pre-irrigation, beginning irrigation earlier in the growing season and not shutting off the system during wet time periods. Many times, this management results in more irrigation water being applied than what would be required with adequate capacity and less grain yields. These strategies are used to keep soil moisture at or near field capacity as long as possible into the growing season before ET becomes greater than the irrigation capacity and potential average precipitation.

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 optimum choice. A producer must determine what the difference in economic returns when increasing 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. This was partly due to less variability in grain yields with the three-year rotation as compared to continuous corn.

A producer must determine what the difference in economic returns when increasing 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.

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 rotations 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 (2001) 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. 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 irrigating soybean or wheat.

Demonstration Project

Beginning in 1996, Schneekloth and Norton (2001) initiated an irrigation demonstration project 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 with full irrigation (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 applied for LATE management was approximately 30 precent 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.

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

	Management Strategy			
	FARM	BMP	LATE	ALLOC
Site	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 by the amount of irrigation water that can be applied, changes in agronomic and irrigation management practices can improve net returns. Changes in agronomic practices such as no-till can increase the capture and utilization of precipitation and reduce irrigation water needs. Other 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. 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 each crop improve. These management changes can improve yields and stretch limited water supplies.

[1]Colorado State University Extension Golden Plains Area regional specialist; Colorado State University research scientist and water quality specialist, and associate professor, soil and crop sciences.