Cropping Strategies with Water Resource Constraints

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Crop production becomes water resource constrained when soil water reserves fall below the level that a crop can easily extract, although occasionally crop water stress can occur when a prolonged period of excessive heat, low humidity and strong wind cause plant crop water use demand to exceed their capability to transport water even though well-watered. In humid areas of the U.S., growing season rainfall is generally sufficient to maintain root zone soil water within acceptable ranges for crop production, although in some years, yield limiting water stress occurs due to poor rainfall distribution. This is a more acute problem in areas with low water-holding capacity soils, like sands, or shallow soils. In these areas, the water stored in the soil is small and of insufficient reserve to supply crop needs between rainfall events. As crop production moves to more arid areas, crop production based on in-season rainfall and soil water reserves because less reliable. To increase reliability of crop productions, irrigation technology was developed to eliminate or minimize yield reduction due to insufficient soil water.

Irrigation development in Kansas has roots with western Kansas river ditch companies in the late 1800's. However, large scale irrigation development in Kansas did not begin until the 1950's with the development of the Ogallala Aquifer as a water source. Irrigated acreage peaked in the mid 70's and has stabilized around 3 million acres.

In 1945, the Kansas legislature passed the water appropriation act which provided the framework for establishing the prior appropriation doctrine as the guiding principle of water use in Kansas. All water in Kansas is dedicated to the people of Kansas and can be put to beneficial use by individuals who follow the appropriation procedure. They are allocated a water allotment based on the availability of supply and establish a permanent right to use the water. This right to use the water is based on priority or "first in time -first in right". The water right establishes a type of use, place of use, amount of use, and rate of diversion, and location of a point of diversion.

Nearly all points of diversions in Kansas are wells. There are some surface water diversions. Some surface water diversions have stream flow restrictions, such as only certain time of year, or above a certain minimum stream flow. There is also a procedure that can be instituted under which the water allocation can be modified. Modification could occur with the establishment of an intensive groundwater control area (IGCA). For example, one IGCA was established in an alluvial aquifer system in order to restore stream flow that was dependent on groundwater base flow. The IGCA required junior water rights holders to reduce water allocations by approximately two-thirds, while senior right holders faced reductions by one-third. However, instead of annual allocations, the water allocation was changed to a five year allocation rather than the normal annual allocation. Multiple water right holders were also allowed to transfer (consolidate) water right from various fields to one field.

The water allocation procedure and the resultant water right represents an institutional water resource constraint. Probably the most important of the institutional constraint is the total annual volume allocation. Other situations may have different constraining limitations; for example, reservoir/canal surface water delivery systems have a water delivery schedules that can have great influence on field irrigation schedule, management, and efficiency.

There can be also be a physical constraints associated with an irrigation water supply. Declining groundwater levels represent the primary source of physical limitation to irrigation in Kansas. Decreasing saturated thickness will eventually cause well yield to decline. Short-term reasons for well yield reduction could also be loss of pump efficiency due to change in pumping lift requirement or wear of the pump. The loss of well discharge results in a loss of irrigation capacity. Irrigation capacity is a measure of how capable an irrigation system is in supplying water to meet a crop's demand.

Well discharge rate alone does not determine irrigation capacity. However, for a fixed irrigated acreage base, a decline in well yield results in a proportional decline in irrigation capacity.

Two other examples of physical limitations of an irrigation water supply could be fixed supply, such as a farm reservoir. Another example may be a surface water diversion from a spring or intermittent stream. This would represent a physical limitation for irrigation as the supply may not be available at the necessary time.

Adjustments to Physical and Institutional Constraints

For the typical one well-one field irrigation system in Kansas, the major difference a physical and institutional constraint would likely be irrigation capacity. A physically constrained irrigation system would likely have experienced a drop in irrigation capacity. An institutionally constraint irrigation system would most likely have the total allowable application volume restricted. This difference results in different management strategy for each situation.

Possible adjustment strategies for water constraints include:

1. Acceptance of lower yield potential,
2. Change to a mixture of irrigated crops
3. Change of crops
4. Reduction of irrigated acres
5. Increase irrigation efficiency
6. Irrigation scheduling - either as ET based, soil water based, or critical growth stage
7. Improved utilization of natural precipitation or soil water reserve (cultural practices)

Some of these adjustment strategies may also be used even when full irrigation capability is available as a possible way to improve economic return or conservation of their irrigation water supply.

Acceptance of Lower Yield Potential

The crop water use or evapotransporation (ET) requirement of commonly irrigated crops are well documented, in terms of both total seasonal requirement and daily use rates. This information, in combination with climatic information, can determine the irrigation requirement. If net irrigation is reduced, then the total water available is reduced. Since crop yield is proportional to crop ET, any reduction of beneficially applied water in an amount below the total seasonal need would have a subsequent yield reduction. It could be acceptance of a lower yield potential may be the best course of action. Limited irrigation can still have a huge yield impact as illustrated in Table 1. A single irrigation, in this example, increased yield from a dryland corn yield failure to over 120 bu/acre. However, this yield level is still much less than the yield potential for the region. This strategy can be employed for both institutionally and physically constrained water supplies.

Table 1: Effect of Irrigation on Corn Yield, 1980-1991
(North Central Kansas Experiment Field. Kansas State University, Scandia, KS)

Time of Irrigation	1991 Yield Bu/ac	1980-1991 Yield Bu/ac	1991 Irrigation Dates
No Irrigation	3	56	None
Tassel	124	141	7/8
Tassel + 1 week	148	159	7/8, 7/15
Tassel & 1 + 2 week	155	164	7/8. 7/15, 7/25
65% depletion	159	172	7/1, 7/23

Change to a Mixture of Irrigated Crops

This strategy can also be employed for ether type of water constraint, although the choice of crop combination may be effected by whether irrigation capacity is limited or whether the total water allocation is limited. A common example of a crop combination mixture with a slightly limited irrigation capacity is a corn/soybean split. This would allow irrigation water to be concentrated on the corn during its critical growth stage of pollination which generally occurs earlier before the critical stage for soybeans during late bean fill. Soybeans have a lower net irrigation requirement, so this combination may also be useful to accommodate a slight total water application restriction. A more severe restriction may require a move to grain sorghum, sunflower or wheat to accommodate more severe restrictions.

Change of Crops

As discussed in the mixture of irrigated crops, a change of crop from one with a critically sensitive growth stage to one with less critically sensitive growth stage or a switch from a high water use to low water use crop may be made to better match the irrigation capability.

Reduction of Irrigated Acres

The amount of acres under irrigation can be adjusted to either meet a desired irrigation capacity or a desired total irrigation application depth. The irrigation capacity needed to be able to produce a crop without yield limiting water stress is dependent on a number of factors but an important one is the available water storage capacity of the soil. For deep silt loam soils at Colby, Kansas for example, an irrigation capacity of 0.25 inches/day (600 gpm on 126 acres) and 85% irrigation efficiency is generally considered full irrigation capacity. This capacity would have about a 90% reliability of meeting crop water needs. (Sandy soils, with less water holding capacity may need irrigation capacity approaching 0.35 inches/day to have the same reliability). If well yield is only 400 gpm, then the total allowable irrigated acreage for an irrigation capacity of 0.25 inches/day is 84 acres.

The net irrigation requirement for corn in western Kansas is approximately 14 inches/acre. At 85% efficiency, about 16.5 inches/acre would be needed. If the water allowable water allocation for a field was 1,200 acre-inches, then only about 73 acres could be fully irrigated.

Increase Irrigation Efficiency

Kansas irrigated acres were originally largely flood irrigated. However, currently over 75% of the acreage base is now center pivot irrigated. Typical flood efficiencies may have been in the 60% efficiency range, while center pivot sprinkler packages can exceed 90%. Increased irrigation efficiency increases both net irrigation capacity and total net seasonal irrigation application depth.

Irrigation Scheduling

Irrigation scheduling is a determination of when and how much water to supply in order to meet specific management goals. Most often scheduling is thought only to apply to full irrigation capacity systems and high yield goals. Proper scheduling should minimize or eliminate excess water application beyond maximum crop water use need which would also be its maximum yield potential. ET based irrigation scheduling use crop growth and climatic information to track soil water levels in the root zone, allowing the irrigator to add water only when sufficient soil water deficients exist or when the soil water level approachs the management allowable deficient. For severely restricted water allocations, the irrigation application may be targeted to a particular growth stage.

Low capacity system strategy often involves irrigating as soon as any root zone deficiency develops to try to keep the profile as full as possible for as long as possible. This can reduce over-all water use efficiency in early season situations when rainfall occurs. Low capacity scenarios often include off-season irrigation or pre-irrigation strategies. These strategies can be effective when used as a replacement for a follow period. Volume restricted strategies usually apply water in-season at critical crop growth stages or at the development of a critical soil water depletion level.

Improved Utilization of Natural Precipitation

The crop itself can be manipulated to a degree to reduce its total water requirement and irrigation requirement. Possible ways to affect water needs are through the selection of population rate, season-length or maturity, and planting date. The tillage program is also important consideration, but will not be discussed, except to note the trend to less tillage is at least partially driven by potential conservation of soil water.

Manipulation of crop water use is possible by reducing plant population, however, the populations must be drop to very low levels before ET levels are significantly reduced. Essentially the canopy cover must be thin enough to allow light penetration to the ground. Light penetration to the ground essentially represents a loss to the photosynthesis process and yield potential. Light to the ground would encourage weed growth that would have to be suppressed in order to achieve the reduced ET goal. Full ET occurs when Leaf Area Indexs (LAI) exceeds 2.7. Best yields are generally obtained when LAI is around 4.0. To reduce seasonal and peak ET rate plant population would likely have to be dropped below a normal dryland rate. This is generally not a practical way to reduce irrigation demand.

Crop maturity length, especially when used in combination with planting date, does effect crop water use need the shorter the season, the less the water requirement. However, reducing crop water use has a proportional yield reducing potential. If, however, a shorter season variety can reach its full yield potential as compared to a longer season alternative that experiences regular yield limitations due to water stress, the former may be the more desirable.

Planting date has an influence on the total crop water use and irrigation requirement. Early plant planting dates allow the plant to grow more of its life cycle in the less stressful part of the growing season. The early part of the growing season also tends to have more rainfall as compared to crop need than later part of the growing season. Table 2 shows predictions of ET and normal rainfall for Garden City, KS. ET increases and rainfall decreases for normal weather conditions with increasingly late planting date. These two factors have a resultment decrease in irrigation requirement for a given crop as estimated by the difference between ET and rain. The potential resultant savings must be balanced against possible early season frost damage if the planting date is pushed too ealry.

Table 2: The Effect of Planting Date on ET for Corn at Garden City, KS (KSU Corn-Pro Model Results)

GDD = 2,770					
Plant Date	**Emergence Date**	**Marketing Date**	**ET**	**Rain**	**ET-Rain**
4/1	4/14	8/31	25.9	12.2	13.7
4/15	4/25	9/5	26.1	11.9	14.2
5/1	5/9	9/13	26.3	11/1	15/2
5/15	5/21	9/25	26.5	10.3	16.2
6/1	6/6	10/15	26.3	9.2	17.1

Summary

Physically and institutionally constrained irrigation systems can still be effectively utilized to either prevent catastrophic yield loss or maintain a minimum yield level. The best course of action has to be determined on a field and farm basis. The goals, needs, and economic situation of the irrigator must be considered before the final determination of which of the options discussed above would be most suitable for the given situation.