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# Irrigating for Maximum Economic Return with Limited Water

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When irrigation water is limited, several management strategies can be implemented to achieve maximum economic returns.

## Limited Irrigation Management

Full irrigation is the amount needed to achieve maximum yield; however, when irrigation water is insufficient to meet crop demand, limited irrigation management strategies should be considered. These strategies manage the limited water to achieve the highest possible economic return. Restrictions on water supply are the primary reasons for using limited irrigation management. These restrictions may come in the form of mandated water allocations, from both ground water and surface water supplies, low yielding wells, or drought conditions which decrease available surface water supplies.

The key management choices for dealing with insufficient irrigation supplies are to: 1) reduce irrigated acreage; 2) reduce amount of irrigation water applied to all acres; 3) substitute low-water requirement crops for high-water requirement crops; 4) delay irrigation until a critical water stage; and 5) manage soil moisture to capture precipitation.

**Reducing irrigated acreage** allows the amount of irrigation per acre to more closely match full irrigation requirements and the corresponding per acre yield. Ideally, the land that reverts to dryland production should still produce some level of profitable returns.

**Reducing the amount of irrigation per acre** applied to the entire field creates the possibility for near normal crop yields if above normal precipitation occurrs. In normal to below normal rainfall years, grain yields per acre would be less than those achieved with full irrigation.

**Substituting low-water requirement crops** for high water-requirement crops, such as corn, is a possibility. Soybean, edible bean, winter wheat, and sunflower are the major Nebraska crops with lower water requirements. Splitting fields between low- and high-water requirement crops will reduce total water needed and better distribute water use across the growing season. For example, peak water demands for wheat are in May and June, while corn uses the most water in July and soybean in August. This strategy also benefits producers with low-capacity wells.

**Delaying irrigation** until critical times is also possible if water volume is limited but well capacity is normal. Water availability during reproductive and grain fill growth stages is critical to grain production. During vegetative growth some water stress can be tolerated without affecting grain yield, and root development can be encouraged so the crop uses deeper soil water. In Nebraska this period also typically coincides with high monthly rainfalls. Field research from the West Central Research and Extension Center near North Platte has shown that corn can use water from deep in the soil profile when necessary; however, irrigation systems must be able to keep up with water demands during the crop's reproductive stage if irrigation is delayed. Delayed irrigation is more feasible with center pivots than with furrow irrigation. In furrow irrigation, dry and cracked furrows do not convey water well, especially during the first irrigation. A combination of furrow packing during the ridging operation, surge irrigation, and increased stream size may overcome some of the effects of late initiation of furrow irrigation.

**Managing soil moisture to capture precipitation** is important for all limited irrigation situations. Crop residues on the soil surface intercept rainfall and snow, enhance infiltration, and reduce soil evaporation. Residue management is much easier with center pivot irrigation than with furrow irrigation. Advancing water down a furrow may be more difficult with high residue levels. Ridge-till management along with furrow packing and surge irrigation may overcome some of these problems. Leaving room in the soil to store precipitation is important during both the non-growing season and during the growing season, when it can help ensure more water is available during grain fill. With limited irrigation there is an increased risk of crop water stress and grain yield reductions. Knowing soil water levels can indicate the potential severity of water stress and help the producer avoid a disaster.

## Expected Grain Yields

Crop response to water depends on crop species. The amount of water that goes through the plant and into the atmosphere as transpiration (i.e. crop water use) is directly related to grain yield. *Figure 1* shows the relationship of crop water use with grain yield for corn, soybean, and winter wheat. (The water is from irrigation and precipitation.) These relationships were developed from field research from 1986 to 1989 at the West Central Research and Extension Center near North Platte and are valid up to the maximum yield for a particular crop. Crop species also determines how much water it takes to produce the first bushel of grain. This is shown as the intersection of the response line with the horizontal axis where grain yield is zero. Corn yields show the strongest response to increasing water, but corn also requires the most water to achieve maximum yield.

*Figure 2* shows how yields for the same crops respond to irrigation. These relationships were developed over a 10-year period and account for variations in weather. The curved lines indicate that there is a diminishing return in yields from irrigation. Irrigation systems and soils are less and less efficient in supplying water to crops as more water is applied. When the soil profile is full or almost full and more water is applied through irrigation or rainfall, some water is lost to deep percolation. Irrigation runoff along the soil surface to low spots also can lead to deep percolation.

### Net Economic Returns From Limited Irrigation

Three hypothetical water allocations were studied to determine the economic implications of reduced water supplies and the potential cropping mix. Water and land resources were allocated using a Resource Allocation Model. The water allocations were 4-, 6- and 10 inches of water per acre. Dryland and irrigated corn, soybean, and winter wheat were compared. *Table I* shows average yields for the three crops at different irrigation levels.

Several assumptions were made to analyze the potential crop mix and water allocated to each crop. The first assumption was that no more than 50 percent of the acres could be planted to soybean for any given water allocation. This was assumed due to the increased potential for wind and water erosion where soybean is grown continuously. In a three-crop mix including corn, soybean and winter wheat, one acre of winter wheat would be grown for every acre of soybean planted. A second assumption was that grain yields and production costs were not affected by rotations; however, studies have shown that rotations can have an impact on production costs and grain yields. The costs were held constant to highlight the effect of irrigation on crop yields and net returns.

*Figure 3* shows the relationship between irrigation levels and net returns. These net returns were calculated by subtracting annual operating costs (using custom rates for all field operations) from the gross revenue (calculated at average prices) generated from the crop. The net returns shown are returns to land, management and overhead. If enough water is available, corn generates the highest net return/acre with irrigation near 10 acre-inches. But as irrigation becomes more limited, soybean (at about 6 inches or less) and winter wheat (at about 4 inches or less) become more profitable than corn. When water is limited, rotating with these crops becomes more feasible. Agronomic considerations also should be considered.

Assumptions for annual operating costs for *Figure 3* and *Tables II, III* and *IV* included custom rates for all field operations such as planting, spraying and harvesting. Irrigation pumping costs were based on a 130-acre center pivot operating at 60 psi at the well with a 700-gallon per minute capacity and 170-foot lift. The fuel source was diesel at $0.60 per gallon. Nitrogen fertilizer costs were included for corn and winter wheat. Nitrogen prices were $0.15 per pound of

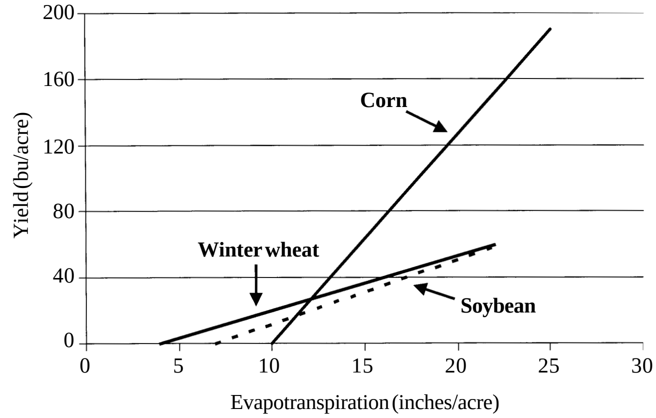


**Figure 1. Yield vs evapotranspiration for corn, soybean and winter wheat.**

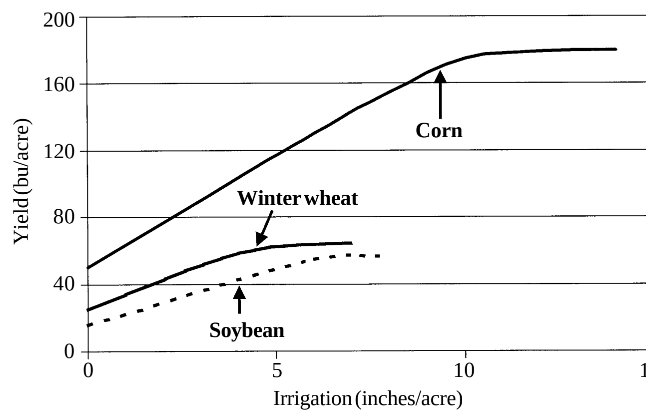


**Figure 2. Yield vs irrigation for corn, soybean and winter wheat.**

active ingredient. Application rates were 1.1 lbs of nitrogen per bushel for corn and 1.7 lbs of nitrogen per bushel for winter wheat. Other production costs for all crops included a $0.10 per bushel hauling charge at harvest.

Price assumptions for *Figure 3* and *Table II* were the 10-year market weighted average from 1989 to 1998 (See EC883, Crop and Livestock Prices for Nebraska Producers). The prices were $2.47 per bushel for corn, $5.95 per bushel for soybean and $3.44 per bushel for winter wheat. The prices for corn, soybean and winter wheat in *Table III* were $3.22, $6.56 and $4.56. This high-price scenario occurred in 1995. Although prices for 1999 were not included in the ten-year average, the average crop loan rates for Nebraska for 1999 were used in the scenario for *Table IV*. The loan rates were used because most producers received this amount (either through a non-recourse loan or LDP payment). The loan rates for corn, soybean and winter wheat in Table IV were $1.83, $4.98 and $2.52 per bushel. These are also the average Nebraska loan rates for 2000.

The highest economic return for any rotation and pricing strategy is when irrigation amounts are available to produce near maximum grain yields (*Tables II, III* and *IV*). When water allocations are reduced, net returns are reduced. The maximum net return with a 10 acre-inch/acre allocation and average prices (*Table II*) was $33,150 per center pivot (continuous corn). When the water allocation was reduced, the maximum achievable net return declined to $25,366 (corn-soybean) and $20,296 (soybean-wheat) for a 6- and 4-inch water per acre allocation, respectively. The most economical option for each water allocation typically is irrigating all acres under the center pivot. Part of these acres may be irrigated to near maximum production while the remainder receive limited irrigation.

**Table I. Grain yields by irrigation amount for corn, soybean, winter wheat grown after soybean and continuous no-till winter wheat (1986-1989).**

| | *Continuous Corn* | *Soybean* | *Winter wheat after soybean* | *Continuous winter wheat* |
|---|---|---|---|---|
| *Irrigation amount* | *Grain yield bu/acre* | | | |
| 0 | 50 | 16 | 25 | 32 |
| 2 | 75 | 35 | 50 | |
| 4 | 100 | 45 | 59 | |
| 6 | 125 | 55 | 65 | |
| 8 | 155 | 56 | 65 | |
| 10 | 175 | | | |
| 12 | 179 | | | |
| 14 | 180 | | | |
| 16 | 180 | | | |

Note: Yields are based on a silt loam soil, average rainfall conditions, and sprinkler irrigation.

Although net returns decrease when irrigation amounts are reduced, these returns are still greater than when converting irrigated acres to dryland production. The net return for the winterwheat-corn-fallow rotation in southwestern Nebraska would be $7,870 for 130 acres, which is substantially less than the 4 acre-inch per acre allocation return mentioned above.

## Optimum Crop Mix for Limited Irrigation

Relative grain prices, grain yield responses to irrigation, irrigation system efficiency, irrigation allocation levels, and dryland economic returns all play strong roles in choosing an optimum mix of crops when irrigation water is limited.

Under the 10 acre-inch allocation and average crop prices *(Table II)*, continuous irrigated corn on all acres is the most profitable option. As water availability is reduced, it becomes more economical to rotate corn with crops using less water. A 50/50 rotation of corn and soybean had the greatest net return with an allocation of 6 inches water per acre followed by an equal acreage mix of corn, soybean and winter wheat. As water allocations are reduced from 6 inches to 4 inches per acre, high-water use crops are no longer the most economical choice, given average prices.

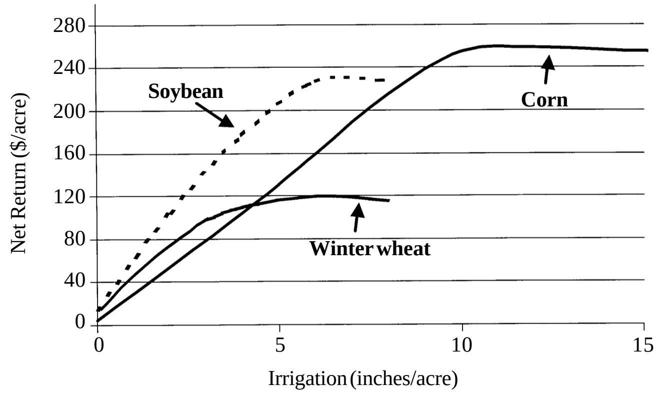


**Figure 3. Net return to land, labor and management vs irrigation for corn, soybean and winter wheat.**

In the higher price scenario, such as in 1995 *(Table III)*, the corn-to-soybean and wheat-to-soybean price ratios increase above the 10-year average price scenario in *Table II*. Comparing *Table III* with *Table II*, the optimum cropping mix is now an irrigated corn/dryland wheat rotation when water allocations are 6 inches per acre or less. With this allocation, the corn-soybean rotation is a close second at only $6 per acre less in net returns, but it has more corn acres and fewer soybean acres than in Table II. When water allocations are increased to 10 acre-inch per acre, irrigated corn should be grown on the entire irrigated acreage (same as 10-year price average).

*Table IV* depicts a low-price scenario (as seen in 1999 and 2000) when corn-to-soybean and wheat-to-soybean price (or loan rate) ratios are lower than the 10-year average price scenario. When water allocations were less than 10 acre-inch per acre, the optimum cropping mixes were the same as in *Table II*. However, the water allocation strategy is different in the 6-inch allocation: an increase in the amount of irrigation water applied to the soybean acres and a decrease in the amount applied to corn. When water allocations are 10 acre-inch/acre, corn acreage was reduced by 50 percent and replaced by soybean. Water allocated to corn production was also increased from 10 inches to 12 inches.

**Table II. Net returns to land, labor and management for three allocations and three cropping systems using average crop prices from 1989 to 1998.**

| *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* |
|---|---|---|---|---|---|---|---|---|
| *Corn and wheat-soybean* | | | *Irrigated corn and dryland wheat* | | | *Corn and soybean* | | |
| **4 acre-inch/acre allocation** | | | | | | | | |
| *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* |
| **Corn** | **0** | **0** | Corn | 65 | 8 | Corn | 65 | 4 |
| **Soybean** | **65** | **6** | | | | Soybean | 65 | 4 |
| **Wheat** | **65** | **2** | Wheat | 65 | 0 | | | |
| **Net Return** | | **$20,296** | Net Return | | $16,480 | Net Return | | $18,151 |
| **6 acre-inch/acre allocation** | | | | | | | | |
| Corn | 43.3 | 10 | Corn | 97.5 | 8 | **Corn** | **65** | **8** |
| Soybean | 43.3 | 6 | | | | **Soybean** | **65** | **4** |
| Wheat | 43.3 | 2 | Wheat | 32.5 | 0 | | | |
| Net Return | | $24,581 | Net Return | | $22,460 | **Net Return** | | **$25,366** |
| **10 acre-inch/acre allocation** | | | | | | | | |
| **Corn** | **130** | **10** | Corn | 130 | 10 | Corn | 130 | 10 |
| **Soybean** | **0** | **0** | | | | Soybean | 0 | 0 |
| **Wheat** | **0** | **0** | Wheat | 0 | 0 | | | |
| **Net Return** | | **$33,150** | Net Return | | $33,150 | Net Return | | $33,150 |

**Assumptions:** **Prices** — Corn $2.47/bu, Soybean $5.95/bu, Wheat $3.44/bu.
Net return is for center pivot irrigation on 130 acres.
Use of appropriate best management practices for the given water supply.

**Table III. Net returns to land, labor and management for three allocations and three cropping systems using crop prices for 1995 (high crop price scenario).**

| *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* |
|---|---|---|---|---|---|---|---|---|
| *Corn and wheat-soybean* | | | *Irrigated corn and dryland wheat* | | | *Corn and soybean* | | |
| **4 acre-inch/acre allocation** | | | | | | | | |
| Crop | Acres | Irrigation | Crop | Acres | Irrigation | Crop | Acres | Irrigation |
| Corn | 43.3 | 8 | **Corn** | **65** | **8** | Corn | 65 | 6 |
| Soybean | 43.3 | 2 | | | | Soybean | 65 | 2 |
| Wheat | 43.3 | 2 | **Wheat** | **65** | **0** | | | |
| Net Return | | $26,644 | **Net Return** | | **$26,726** | Net Return | | $25,405 |
| **6 acre-inch/acre allocation** | | | | | | | | |
| Corn | 86.6 | 8 | **Corn** | **97.5** | **8** | Corn | 86.7 | 8 |
| Soybean | 21.7 | 2 | | | | Soybean | 43.3 | 2 |
| Wheat | 21.7 | 2 | **Wheat** | **32.5** | **0** | | | |
| Net Return | | $34,918 | **Net Return** | | **$34,959** | Net Return | | $34,953 |
| **10 acre-inch/acre allocation** | | | | | | | | |
| **Corn** | **130** | **10** | Corn | 130 | 10 | Corn | 130 | 10 |
| **Soybean** | **0** | **0** | | | | Soybean | 0 | 0 |
| **Wheat** | **0** | **0** | Wheat | 0 | 0 | | | |
| **Net Return** | | **$50,213** | Net Return | | $50,213 | Net Return | | $50,213 |

**Assumptions:Prices** — Corn $3.22/bu, Soybean $6.56/bu, Wheat $4.56/bu.
Net return is for center pivot irrigation on 130 acres.
Use of appropriate best management practices for the given water supply.

**Table IV. Net returns to land, labor and management for three allocations and three cropping systems using average crop loan rates for Nebraska in 1999 and 2000 (low crop price scenario).**

| *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* |
|---|---|---|---|---|---|---|---|---|
| *Corn and wheat-soybean* | | | *Irrigated corn and dryland wheat* | | | *Corn and soybean* | | |
| **4 acre-inch/acre allocation** | | | | | | | | |
| *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* | *Crop* | *Acres* | *Irrigation* |
| **Corn** | **0** | **0** | Corn | 52 | 10 | Corn | 65 | 4 |
| **Soybean** | **65** | **6** | | | | Soybean | 65 | 4 |
| **Wheat** | **65** | **2** | Wheat | 78 | 0 | | | |
| **Net Return** | | **$13,839** | Net Return | | $8,500 | Net Return | | $11,154 |
| **6 acre-inch/acre allocation** | | | | | | | | |
| Corn | 26 | 10 | Corn | 78 | 10 | **Corn** | **65** | **6** |
| Soybean | 52 | 6 | | | | **Soybean** | **65** | **6** |
| Wheat | 52 | 4 | Wheat | 52 | 0 | | | |
| Net Return | | $15,544 | Net Return | | $11,863 | **Net Return** | | **$16,211** |
| **10 acre-inch/acre allocation** | | | | | | | | |
| Corn | 130 | 10 | Corn | 130 | 10 | **Corn** | **65** | **12** |
| Soybean | 0 | 0 | | | | **Soybean** | **65** | **8** |
| Wheat | 0 | 0 | Wheat | 0 | 0 | | | |
| Net Return | | $18,590 | Net Return | | $18,590 | **Net Return** | | **$20,704** |

**Assumptions:** **Prices** — Corn $1.83/bu, Soybean $4.98/bu, Wheat $2.52/bu.
Net return is for center pivot irrigation on 130 acres.
Use of appropriate best management practices for the given water supply.

## Conclusions

This study is intended to provide information for choosing the best cropping strategy when water is restricted. Many factors influence net returns to irrigation including soil type and climatic conditions, crop prices and production costs. Continuous corn was the most profitable option under the least-restrictive water allocation when prices are average or high; however, when prices are low or as water becomes more restricted, corn acres should be reduced or eliminated. For example, in the average price scenario, the corn-soybean rotation is preferable with a 6-inch allocation and a soybean-irrigated wheat rotation is best at the 4-inch allocation. There are also situations, such as the 4-inch and 6-inch allocations under the high price scenario in *Table III*, when rotation choices do not make a big difference in net returns. In all situations, but particularly when net return differences are less than $1 per acre, other factors not included in this study may determine the best cropping strategy. Certain rotations can provide cost benefits by decreasing requirements for nitrogen and insecticides. In addition, the availability of planting/harvesting equipment, familiarity with the management of certain crops, type of soil, etc. should all be important considerations in the decision.

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