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Water-Conserving Cropping Systems: Lower South Platte Irrigation Research and Demonstration Project

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Figure 1. The specialized linear-move research sprinkler system pictured above was constructed at the Iliff research location to control irrigation on nearly 150 individual plots. Courtesy of Neil Hansen.

Introduction

In 2007, Parker Water and Sanitation District (PWSD) and Colorado State University (CSU) partnered to create a comprehensive field study to develop profitable irrigated cropping systems that reduce historic consumptive water use. The study explores reduced irrigation practices as alternatives to drying up irrigated land to meet growing municipal and industrial water demand. The site near Iliff, Colorado is funded by PWSD and the Colorado Water Conservation Board and takes a systems approach to water saving including agronomic and economic considerations. A specialized sprinkler was constructed on a 35-acre site to allow irrigation control at the plot scale for nearly 150 individual plots (Figure 1). The site is designed for a detailed water accounting including a fully-automated weather station that has been integrated into the Colorado Agricultural Meteorological Network (CoAgMet, Iliff station). The weather station monitors soil moisture, depth to ground water and the controls of all applied irrigation. Water conserving cropping systems include rotational cropping, limited irrigation and partial season irrigation.

Rotational Cropping

Rotational cropping systems save water through combinations of irrigated crops and non-irrigated crops or fallow periods. Fallowing was included in the study because there is precedence for administering transfers of saved consumptive use from fallowed land. However, the drawback to fallowing is the absence of economic return to offset costs of land, equipment and management (i.e., weed control). Other concerns include that fallowed fields may not produce as well when returned to irrigation. Alternatively, rotating irrigated crops with dryland crops can improve efficiency because the non-irrigated crop scavenges water and nutrients left by the previous irrigated crop. Four rotational cropping systems are compared for water use and yield to a historical reference of continuous corn with sprinkler irrigation in the study with several interesting results (Table 1, page 8). On average, the evapotranspiration (ET) for the dryland crops (winter wheat, winter triticale, or hay millet) averaged eight in. per year compared to seven in. per year of ET during a year with clean fallow. Surface evaporation makes fallowing an inefficient approach to water savings and similar amounts of annual water savings can be achieved while producing a low-cost, dryland crop. Another important result is that there was no yield loss in irrigated corn after a one year fallow period (Table 1). In fact, corn yields are higher in rotations with either fallow or dryland crops than when produced continuously. The rotational cropping systems reduced average annual irrigation by 50-65 percent and reduced average annual ET by as much as 40 percent relative to continuous corn.

Crop Sequence	Irrigation (in)	ET (in)	Yield (units)
Historical Reference –			
Continuous Corn	19	24	146 (bu/ac)
System Annual Average	19	24	
Corn	19	24	171 (bu/ac)
Fallow	0	8	--
System Annual Average	9.5	16	
Corn	20	27	169 (bu/ac)
Fallow	0	7	--
Dryland Winter Wheat	0	10	54 (bu/ac)
System Annual Average	6.8	15	
Corn	19	23	167 (bu/ac)
Sunflower	13	19	1887 (lbs/ac)
Dryland Winter Wheat	0	8	38 (bu/ac)
Dryland Winter Triticale	0	7	2.9 (T/ac)
System Annual Average	8	14	
Corn	19	24	173 (bu/ac)
Soybean	10	17	38 (bu/ac)
Winter Wheat	0	11	48 (bu/ac)
Winter Canola	8	18	failure
System Annual Average	9	17	
Sugar Beet	14	22	35 (T/ac)
Dryland Hay Millet	0	7	1.6 (T/ac)
System Annual Average	7	15	

Table 1. Irrigation, evapotranspiration (ET) and crop yield for rotational cropping systems.

Limited Irrigation

Limited irrigation practices are a major emphasis in the study. The practices are being evaluated for corn, soybean, sunflower, canola, triticale and hay millet in three alternative crop rotations (Table 2 below and Figure 2 on p. 9). Changing the cropping mix to decrease the magnitude of consumptive use within a growing season is one alternative to drying up land. Corn, alfalfa and grassy hay crops dominate the existing irrigated acreage in the South Platte. These crops have high water demand because they are produced during the warmest period of the year, they have long growing seasons, and they are produced under conditions of complete canopy cover for most of their growing season. Adjusting the crop mix to decrease the length or alter the timing of the growing season can reduce consumptive water use while minimizing loss of farm income and the exposure of soil to erosion. Changing fully irrigated corn, alfalfa or vegetable cropping systems to include winter annual crops has the greatest potential to decrease consumptive water use. Winter annual crops that have a high potential for reducing consumptive use include winter wheat, forages, and oil seed crops.

Crop Sequence	Irrigation (in)	ET (in)	Yield (units)
Historical Reference –			
Continuous Corn	19	24	146 (bu/ac)
System Annual Average	19	24	
Corn	10	20	155 (bu/ac)
Sunflower	8.5	20	1137 (lbs/ac)
Winter Wheat	6.5	15	42 (bu/ac)
Winter Triticale	6.7	13	3.2 (T/ac)
System Annual Average	8	17	
Corn	10	21	152 (bu/ac)
Soybean	6.7	16	38 (bu/ac)
Winter Wheat	6.5	14	57 (bu/ac)
Winter Canola	4.4	15	failure
System Annual Average	8	16	
Sugar Beet	7	17	33 (T/ac)
Hay Millet	4.4	12	1.6 (T/ac)
System Annual Average	5.8	15	

Table 2. Irrigation, evapotranspiration (ET), and crop yield for limited irrigation cropping systems.

Limited irrigation is based on timing irrigations to crop growth stages and managing crop water stress to improve water use efficiency. Average annual irrigation for the limited irrigation systems was 7.5 in., compared to the reference of 19 in., and ET averaged 15 in. compared to the 24 in. per year for continuous corn. The 40 percent average savings in ET for limited irrigation systems is similar to the water savings for the rotational cropping systems. Compared to the rotational cropping approach, limited irrigation has lower yields of corn (-15 bu/ac) and sugarbeet (-2.0 T/ac), but higher yields of wheat (+5 bu/ac) and triticale hay (+ 0.3 T/ac). Whether a rotational cropping or limited irrigation approach is the preferred way to save water will depend on the production costs and commodity prices. Sugarbeet appears well-suited to limited irrigation.

Figure 2. Limited irrigation sunflower, soybean, and sugarbeet are being evaluated in limited irrigation cropping systems. The study has shown sugarbeet (right) to be well-adapted to limited irrigation. Courtesy of Neil Hansen.

Partial Season Irrigation of Perennial Hay Crops

Another portion of the study is evaluating water use of cool-season perennial grass hay crops. The cool-season grasses are typically harvested two times per year with an early harvest in early June and a late fall harvest. Cool season grasses do not produce as much during the heat of the summer. This growth pattern is of interest because the peak irrigation demand of the crops differs from that of summer annual crops like corn. Reducing water consumption during summer months could be offset by irrigating cool season crops. Fourteen different species of perennial grasses including various wheatgrasses, fescues, bromes, and orchard grass are being evaluated for biomass production potential under full and partial season irrigation. Partial season irrigation means that the hay crops are irrigated to meet full crop demand during part of the season with no irrigation during other times. The two partial season irrigation treatments are spring-only irrigation (no irrigation after first harvest in early June) and spring/fall irrigation (irrigation stops after first harvest but is resumed in mid August). While the immediate interest in these crops is for hay and pasture production, there is also interest in the potential use of these grasses as bioenergy crops. Biomass yields for the first harvest period ranged from 2.0 - -3.5 T/ac among the grass species with highest yields observed for several varieties of wheat grasses. Irrigation during the summer has had little effect on yields of the fall harvest.

Adoption Potential

The study has identified a variety of cropping systems that can conserve water and reduce ET, but could agricultural water conservation help address changing water demand in Colorado and would farmers adopt water saving systems if a water lease markets materialized? A producer survey was conducted with the objective to gauge potential adoption of limited irrigation strategies, the amount of water that might be made available in water leasing arrangements, the necessary compensation needed for farmers to participate and their perceptions of lease arrangements. The results of the survey suggest that more than 60 percent of the respondents are willing to lease garnering between 50,000 and 60,000 acre-feet of potential water supplies and preferred compensation ranges from $300-$500 per acre of irrigated cropland. Most farmers would prefer not to lease their entire water portfolio, so these respondents are likely to remain in agriculture and generate positive economic activity. The next step in this research is to uncover the barriers to adopting limited irrigation practices noting where they might be overcome with cost shares and technical assistance.

Visitors to the site can look at individual plots and compare the crops with different irrigation management. Courtesy of Neil Hansen.

Summary

A controlled research site was established in Iliff, Colorado with a linear-move sprinkler irrigation system customized for research with an on-site weather station. The site facilitates research on approximately 150 small plots where a water balance approach is used to determine evapotranspiration (ET) and drainage, crop yield, and water use efficiency for rotational cropping, limited irrigation, and partial season irrigation systems. Rotational cropping systems that alternate irrigated crops with fallow or dryland crops were effective at reducing ET, with average ET reductions of 30-40 percent compared to continuous corn. Rotating irrigated crops with dryland crops was a much more water-efficient approach than rotating with a non-cropped fallow because of high evaporation and drainage during fallow. Annual forage crops such as triticale are good choices for the dryland phase of these rotations because they use residual water and nutrients from irrigated crops and have lower production risk than dryland grain crops. Corn produced after a fallow period or a dryland crop had a higher yield and water use efficiency than continuous corn, illustrating the benefits of crop rotation to maximize water use efficiency. Limited irrigation cropping systems reduced ET by an average of 30 percent. Both rotational cropping and limited irrigation of sugarbeet and an annual forage crop saved 40 percent of the continuous corn ET. Sugar beet is drought tolerant and shows good adaptability to limited irrigation. Soybean had moderate yield but is a lower water use crop than corn even under full irrigation. Its growth and performance suggested that soybean may be a good alternative crop for water conserving cropping systems in the South Platte River basin.

Better understanding of these concepts of agricultural water conservation can be the foundation of a new approach to meeting changing water supply and demand issues in Colorado while maintaining a viable agricultural and rural economy in Colorado. Beyond the farm level issues are questions about how different models of water leasing would affect local and regional economies. The economic portion of this study is evaluating this question using a variety of techniques including enterprise analysis, state of the art economic forecasting models and models that project farm level changes to community and regional scales. We welcome input on this project.

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