Future Equipment and Research Needs Gleaned from Farmer Reactions to an Irrigation Water Conservation Education Program in Southwest Nebraska

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Introduction

Research on limited irrigation in Nebraska started in the 1970's at the former University of Nebraska's Sandhills Lab, where Gilley et al.(1980) used a line-source sprinkler irrigation system to study the effect of water-stressing corn at the vegetative, pollination and grain filling stages. They found no significant yield reduction when the crop was moderately stressed only during the vegetative stage. Significant yield reductions, however, were found when stress occurred during the reproductive stages (pollination and grain filling). Starting in the late 1980's, this idea was confirmed by further research conducted at North Platte, both using a solid-set sprinkler irrigation system and under surface irrigation.

Based on this research background, in 1996 the University of Nebraska started the Republican River Basin Irrigation Management Project, funded by the US Bureau of Reclamation (Schneekloth and Norton, 2000). The purpose of the project has been to demonstrate on farmers' fields the lessons learned at the plot-sized scale regarding the implications of alternative irrigation management strategies on water use and profitability. The ultimate purpose was to positively influence farmers to adopt the water saving strategies. The project has been conducted in southwest Nebraska, an area that has experienced substantial ground water declines and frequent seasons with less than adequate surface water supplies. This paper describes the methodology used in this project, lessons learned during the period of 1996-2003, and our thoughts about what is needed for farmers in southwest Nebraska to be able to adopt water saving strategies.

Methodology

The Republican River Basin Irrigation Management Project has been conducted in irrigated corn fields and has had two phases. The first phase was on larger one-half pivot sized fields and the second being on smaller plots in the edge of farmer fields. Both have had the farmer plant and care for the corn crop, with the timing and quantity of water application being the only variable.

Phase One (1996-2000)

The first phase of the project was started in 1996 with three on-farm sites. Two additional sites were added in 1997, a sixth site was added in 1999.

Cooperators and Site Selection: The cooperators were picked by the local Extension Educators in southwest Nebraska. They were picked because of their willingness to work with the project, interest in water issues, and excellent crop production skills. The fields that were selected ranged in soil type from sandy with a water holding capacity of about one in/ft of soil to silt loam, holding more than two in/ft (Table 1). The irrigation methods included four center pivots and two furrow systems. The tillage and cropping practices were what the farmers normally did on their farms. The North Platte site, which was surface irrigated and replicated, was on the University of Nebraska West Central Research and Extension Center farm.

Irrigation Management Strategies: The following four irrigation management strategies were demonstrated at each of the sites:

a. **FARM**-the irrigation scheduling was done the same as the farmer's current water management strategy.
b. **BMP**-the traditional Best Management Practice (BMP) irrigation management strategy focused on keeping soil-water at a high enough level to prevent moisture stress from being a limiting factor for yield. The goal of the strategy was to maintain the plant available soil-water (in the active root zone) between field capacity and 50% depletion from planting through maturity. Usually the soil was kept one-half to one inch below field capacity to allow for rain storage. After the hard dough stage, the soil was allowed to dry down to 60% depletion.
c. **LATE**- this deficit irrigation management strategy focused on saving water during the less sensitive vegetative growth stages and fully watering during the critical reproductive growth stages. Irrigation was delayed until about two weeks before tassel emergence of the corn, unless soil-water became 70% depleted (in the active root zone). Once the crop reached the reproductive growth stage, the plant available soil-water was maintained in a range between field capacity and 50% depletion. Usually the soil was kept one-half to one inch below field capacity to allow for rain storage. After the hard dough stage, the soil was allowed to dry down to 60% depletion.
d. **ALLOC**-this deficit irrigation management strategy focused on simulating an allocation system by correctly timing the application of a restricted quantity of water. Irrigation was restricted to 6 inches, except for the sandy site at Dickens, which was restricted to 10 inches during the growing season. The management strategy was to delay the application of water until about two weeks before tassel emergence, unless soil-water became 70% depleted. The available water (6 or 10 inches) was then applied between the period just before the reproductive growth stage and grain fill (approximately five weeks).

Plot Layout and Management*:* The demonstration plot layout was simple in that each treatment was only included once and the producer was allowed to pick his plot first (in each case he picked the better soils). The FARM and the BMP strategies were paired together and the LATE and ALLOC Deficit Irrigation treatments were also paired. The center pivot fields included one-half of the circle and were divided into four pie-shaped plots. Water application differences were achieved by using automated control panels that were available from the pivot manufacturer. The furrow irrigated field simply had field length strips. The irrigation scheduling was done by the project manager. Soil moisture data was gathered every two weeks by the neutron attenuation method and ET data from the High Plains Regional Climate Center was used to predict irrigation needs in-between.

***Educational Activities**:* Fields days were held at some of the sites over the years. A phone survey was conducted with the producers that farmed the demonstration fields upon completion of the first phase.

Yields and Water Usage: The yields and water usage from the first six years and averaged over the six sites are shown in Table 1. It shows that the BMP strategy obtained 101% of the yield, as compared with the FARM strategy, using only 87% of the water. Using the LATE strategies, 97% the FARM yields was obtained, using only 69% of the irrigation water. The ALLOC strategy resulted in 89% of the FARM yield, using only 50% of the irrigation.

Phase Two (2002-present)

Armed with the earlier research and the results of phase one on-farm demonstration sites, phase two was started in 2002. During this phase, the irrigation strategies were demonstrated on farmer's fields, using a small plot

Table 1. Six Year Average of Corn Yields and Water Use by Management Strategy and Site.

		Management Strategy			
	Soil WHC[1] (in/ft)	FARM	BMP	LATE	ALLOC
Site		Average Yields (bu/acre)			
Arapahoe	2.1"	188	189	198	190
Elsie	1.5"	196	196	185	162
Dickens[2]	1.0"	202	201	187	175
Benkelman	1.8"	209	210	193	172
North Platte[3]	2.0"	-	203	202	188
McCook	2.0"	153	147	133	133
All Sites[4]		191	193	185	171
Percent of FARM Yield		100	101	97	89
		FARM	BMP	LATE	ALLOC
Site		Applied Water (acre-inches/acre)			
Arapahoe	2.1"	8.1	7.4	5.3	4.3
Elsie	1.5"	10.9	10.5	8.1	6.1
Dickens[2]	1.0"	15.3	14.1	12.0	9.7
Benkelman	1.8"	12.8	12.5	9.7	6.2
North Platte[3]	2.0"	-	10.2	7.8	4.9
McCook	2.0"	16.0	9.7	8.0	5.8
All Sites[4]		12	10.7	8.4	6.2
Percent of FARM Applied Water		100	87	69	50

[1]Soil Water Holding Capacity.
[2]Data for Dickens not included in 97 due to irrigation error & soybeans in 2000.
[3]FARM management strategy not used in North Platte.
[4]Yield and applied water are weighted by the number of years of data at each site.

line-source layout, instead of a half pivot. The focus of this phase has been on facilitation of demonstrations with public field days, as well as including lecture style winter programs, and news releases. The changes in methodology were to facilitate public viewing of the demonstration from the road and to make better field day sites. The smaller line-source layout makes a better field day site because the irrigation strategies are all within a few hundred feet and the line source irrigation system shows fully watered to dryland in a range of only 50ft.

Another change that was made was to name the irrigation strategies that were being demonstrated. The names needed to be something that was more descriptive and presented a positive image. The names that were chosen included; Fully Watered for the BMP, Water Miser BMP for the LATE, and Deficit Irrigation for the ALLOC. The definitions were changed slightly also, and are as follows:

a. **Fully Watered**-the traditional Best Management Practice (BMP) irrigation management strategy focused on keeping soil-water at a high enough level to prevent moisture stress from being a limiting factor for yield. The goal of the strategy was to maintain the plant available soil-water (in the active root zone) between field capacity and 50% depletion from planting through maturity. Usually the soil was kept one-half to one inch below field capacity to allow for rain storage. After the hard dough stage, the soil was allowed to dry down to 60% depletion.
b. **Water Miser BMP** - the Water Miser BMP irrigation management strategy focused on saving water during the less sensitive vegetative growth stages and fully watering during the critical reproductive growth stages. Irrigation was delayed until about two weeks before tassel emergence of the corn, unless soil-water became 70% depleted (in the active root zone). Once the crop reached the reproductive growth stage, the plant available soil-water was maintained in a range between field capacity and 40% depletion. Usually the soil was kept one-half to one inch below field capacity to allow for rain storage. After the hard dough stage, the soil was allowed to dry down to 60% depletion.
c. **Deficit Irrigation**-The deficit irrigation management strategy focuses on correctly timing the application of a restricted quantity of water, both within the growing season as well as over a several year period. The intent is to stabilize yields between years by applying irrigations based on soil-water depletion. Less water will be applied during wetter years, while more will be applied through the drier years, with an average over the years equaling the available quantity of water. The management strategy is to delay the application of water until about 2-weeks before tassel emergence for corn, unless soil-water becomes 70% depleted. Once the crop reaches the reproductive growth stage the plant available soil-water (in the active root zone) is maintained in a range between 30 to 60% depletion. It is allowed to dry down to 70% depleted after the hard dough stage. The idea is that these depletion numbers should be changed based on the amount of water the producer has to work with. More research is needed to determine guidelines for differing water use levels.

Cooperators and Site Selection*:* The cooperators were picked with the help of the local Extension Educators and irrigation districts managers in southwest Nebraska. They were picked because of their willingness to work with the project, interest in water issues, excellent crop production skills, and location of their fields. To facilitate public viewing, the sites were located on the edge of production fields along public roadways. Big signs explaining the demonstrations were placed at each site (Fig. 1).The demonstrations were conducted at three sites 2002 and at two sites in 2003.

Figure 1. Big sign indicating the location and details about one of the demonstration sites.

Plot Layout and Management*:* The irrigation demonstration sites used three line-source sprinkler systems (Fig.2). Each line-source was irrigated following the BMP, LATE or ALLOC strategies. The FARM strategy was not demonstrated during this phase.

Figure 2. Line-source sprinkler system used during phase two of the project.

The soil types were all silt loam and ranged in water holding capacity from about 1.9-2.5 in/ft. The tillage and cropping practices were what the farmers normally did on their farms. Timing and amount of water applied were the only management variables. The irrigation scheduling was done by the project manager. Soil moisture data was gathered every two weeks by the neutron attenuation method and ET data from the High Plains Regional Climate Center was used to predict irrigation needs in-between, using an irrigation scheduling spreadsheet.

Educational Activities*:* Fields days were held at each of the sites each year with about 180 people attending during the first two years. Evaluation of the program consisted of after-meeting surveys and numerous one-on-one conversations.

Results and Discussion

Farmer Reactions

The farmers and crop consultants that were involved with the project and those attending field days were excited about the water saving strategies and indicated on surveys that they understood the concepts and planned to make changes in their operations. The end-of-meeting surveys from the 2003 field days showed that more than 90% of the participants planned to improve their management based on the knowledge and/or skills learned. They also indicated that they felt the value of the knowledge they had gained from this project was worth $15.35 per acre. The average number of cropland acres that they manage/influence annually was 1888 acres. The vast majority of the participants were farmers.

The Republican River Basin Irrigation Management Project in many ways has been a success. Producers are saying they are using less water after participating in the program and they are planning to do more in the future. However, information gathered from followup surveys and conversations with farmers and crop consultants have shown that the producers have only partially adopted the strategies. Part of the reason have been that farmers do not feel comfortable moisture stressing the crop as much as they could with their current moisture monitoring system. Therefore, they apply a little extra water to make sure they have enough. Additional limitations are that they simply do not have the time, know how, and the money to make better strategies work using current methods and equipment. These strategies can be made to work in research and even farm fields with enough labor and experience, but there is still the question of how to make them work on the average farm with the labor and expertise constraints the farmers and/or crop consultants have to deal with? In order to make the irrigation strategies work, it is necessary for the farmer to be able to follow the soil water status, either by monitoring soil moisture or by using crop water use information derived from weather data. In the current state of things, both methods present challenges for the farmers. Current systems are not as user-friendly as they need to be. And in fact, one could say that several good components are available to use in irrigation scheduling, but not a good, complete system or package is available for farmers to use.

Future Needs

Soil Moisture Monitoring Systems*:* Although soil moisture monitoring devices, like tensiometers, neutron scattering, and resistance blocks have been around for a long time, very few farmers in Nebraska actually use them. In the last few years, a new generation of moisture sensors using capacitance and time domain reflectometry technology have been developed. Many of these new sensors offer improvements over the old sensors, mainly in the form of datalogging and telemetry capabilities. Some of the same problems that have restricted the widespread adoption of the old sensors, however, still remain. One of the main restrictions is that the installation, calibration, and maintenance of current equipment require a lot of time and hard work during a very busy time of year. Simply put, most farmers and crop consultants will continue to use the hand-feel method until a system is developed that is reasonably priced and requires little, if any, additional time during the growing season. A second problem is that crop consultants do most of the irrigation scheduling in southwest Nebraska and are paid a per-acre fee by the producer. If better equipment is to be used, who will pay for it, the producer or the crop consultant?

Soil moisture monitoring systems need to be reasonably accurate, and the readout needs to be as straightforward as a fuel gage. Fuel gage readings are easy to understand and make informed management decision with their information, especially the ones in cars that tell how many more miles the car can go before refueling. Soil moisture monitoring systems of the future need to tell us where the soil moisture levels have been, where they are today, and how much water needs to be added in the near future.

The systems need to take and record the soil moisture profile at least once per day, four times per day would be better, to a sufficient depth for the crop being monitored (at least four feet for corn and soybeans). The data should be displayed by depth and the average for the root zone. The display module needs to be at the field edge or driveway and be connected to the sensors by wire or telemetry. Many producers and crop consultants would want this data uploaded into their computer in the pickup when they visit the field or better yet into the office. An industry standard file format needs to be developed to allow this data to be used in irrigation scheduling software. When this system has been developed, it could be easily interfaced with irrigation system control panels to partially or fully automate the water application.

Equipment installations need to be simple, quick, and easy. The most common complaint we hear about current and past soil moisture monitoring equipment is the installation. The problem is not just the work and precision required to install the equipment, but the time of year that it is being installed. In the early part of the growing season, farmers and crop consultants already have more to do then they can get done. Equipment that will be purchased by corn and soybean producers in the future will be permanently installed in the field during the off-season with only minor setups required each year. The components need to be placed below the soil surface during field operations (tillage, planting, cultivation, harvest, etc.) and relocated using GPS, a metal detector, field flags, measurements from a known location, etc. It will be important for the logger to continue to log data while all components are below ground. Equipment that can be installed very quickly in the crop row right after planting may meet these requirements as well. It should be kept in mind, that motor vehicles can only be driven in the field from harvest in the fall through the early plant growth stages the next spring. During the rest of the growing season only people can walk out to the equipment to install, do maintenance, or get things out of the way for harvest and components must be carried by hand that needs to be in or out of the field. Also, livestock grazing of crop residue is a common practice and permanently installed equipment need to be compatible.

The calibration of the equipment for a specific field and crop may be the biggest problem to overcome and is largely out of the control of the company that manufactures the devices. But that does not change the fact that successful calibration will be the key to making the products work in the field. Although most soil moisture sensors come with a factory calibration, our experience with several sensors indicate that developing site-specific calibration is critical to getting accurate soil moisture data. The factory calibration may be close to giving us the amount of water in the soil, but is that good enough? In addition to the soil moisture data, it would be a lot more useful for the farmers if the sensors would go the extra step to determine the available water holding capacity of the soil, field capacity, and permanent wilting point or some other moisture level that can be relate to irrigation scheduling.

Current calibration procedures have been developed by researchers for research projects where accuracy is very important (Evett and Steiner, 1995). The problem with moving these procedures to production agriculture is that they take too much time and effort. New procedures are needed that the average person can do with a minimal amount of effort and still have the accuracy needed for irrigation scheduling. If the equipment was installed during October or November, the procedure could require that data be logged for several months to do the calibration. During the off-season without crops removing soil water, the soil could be saturated and allowed to drain to field capacity. A simple easy-to-use procedure should be developed for each soil moisture monitoring system sold. Products with the best calibration procedures will be the easiest to market. Monitoring soil moisture in one spot in the field is difficult enough, but the problem of determining how that relates to the rest of the field must also be overcome. The most common method used today is the hand feel method comparing the field to the spot being monitored. A remote sensing system could accomplish this task plus could possibly eliminate the need for in-the-soil sensors and several of the problems described above. Research needs to continue into methods of using remote sensing to monitor soil moisture.

The cost a producer would be willing to pay for a soil moisture monitoring system is quite variable. If he has fairly low pumping costs and plenty of water, it may only be a few hundred dollars. However, if he is limited in how much water he can pump, it could be worth 15-16 bushels of corn for each inch of water saved or more efficiently used. This could amount to a few thousand dollars in a 100-130 acre field, which is a common size in. The impression we get from talking to producers in southwest Nebraska is that most would not be very interested once the costs get above the one thousand-dollar mark per field.

Evapotranspiration Estimates from Weather Data*:* Evapotranspiration estimates from weather stations have some distinct advantages. First, the data is very easy to get in Nebraska from newspapers, radio, telephone hotlines, and the internet. Second, there is no need to buy, install, calibrate and maintain equipment in the field. Thirdly, someone else manages the data.

So, with all this going for it, why would a producer not just use ET data and skip the infield stuff? Well, like most systems it has some short comings. First, if the producer does not adjust the data to the specific field and crop, the data is not very good. In Nebraska, this is not very hard if the data is retrieved from the High Plains Regional Climate Center web site (http://www.hprcc.unl.edu). From this site the field details can be specified once and an email will be sent to the producers' computer each day through the summer with the adjusted ET data. Secondly, the data is an estimation from a weather station that could be several miles away from the field and is usually located in a dryland pasture. Sometimes this can cause the estimated numbers to be quite high. Thirdly, the information tells you nothing about the quantity of water stored in the soil, or the amount of water added from rain or irrigation.

The data should play a very important role in any irrigation scheduling system, but needs to be corrected to the actual field's soil water level every week or two. Also, research needs to continue to increase the accuracy of the data.

Historical averages that are adjusted to the specific field location and crop are available from the web site. This data is very useful during the irrigation season in predicting the amount of water that will need to be applied in the next week or so.

Historical extremes adjusted to a specific field could provide a valuable management tool and should be developed in the future.

Data Management: The two different methods described above, evapotranspiration estimates from weather stations and soil moisture monitoring systems, both generate a phenomenal amount of data. This information is not very useful without a computerized method of retrieval, storage, viewing and analyzation. Currently, we are not aware of a software package that is designed for production agriculture in Nebraska that can help a producer or crop consultant retrieve, store, view, analyze and then help formulate an irrigation scheduling recommendation. Although very complete crop models have been developed, which are capable of providing irrigation scheduling information, most of these models are so complex that have been relegated to research applications. Other very good software exists that can do part of these functions, but not all of them in the same package. Thus, this type of software definitely fits into the future need's category.

A user friendly computer software needs to be developed that would make irrigation scheduling easy for the farmer. This software should be able to automatically obtain and update the weather data directly from the source (climate center) via the internet. It should be able to follow the soil moisture status of the field, and allow adjustments as the growing season progress. It also should be able to forecast future irrigation needs based on historical data and weather forecasting, and predict the ability of the farmer to meet the irrigation demands, based on the irrigation system capacity and water availability.

Conclusions

We currently know irrigation strategies that can save water compared to the current systems being used in production agriculture in Nebraska. Farmers and crop consultants that have learn about the strategies think they would help them use less irrigation water. The challenge to those of us in extension, industry, research, and other government agencies is to develop equipment and procedures to enable better water management. If a system can be developed, the producers in an area like water-short southwest Nebraska will be ready to purchase and use them.

References

Gilley, J.R., D.G. Watts, and C.Y. Sullivan. 1980. Management of irrigation agriculture with a limited water and energy supply. University of Nebraska-Lincoln.

Schneekloth, J., and N. Norton. 2000. Republican River basin irrigation management-A progress report of the University of Nebraska-Lincoln (UNL) limited irrigation demonstration project.

Evett, S.R., and J.L. Steiner. 1995. Precision of neutron scattering and capacitance type soil water content gauges from field calibration. Soil Science Society of American Journal 59(4):961-968.