SUBSURFACE DRIP IRRIGATION IN NEBRASKA

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INTRODUCTION

Interest on subsurface drip irrigation (SDI) to irrigate row crops has been increasing in Nebraska in recent years. This increased interest has been due in part by limited irrigation water supplies in parts of the state. In places where water supplies are limited, some farmers have been experimenting with SDI as an alternative to surface irrigation, to produce crops with less water and to reduce labor. This is specially the case in small, odd-shaped field where installing a center pivot system in not practical. Another common use of SDI in Nebraska is to irrigate center pivot corners, which are commonly non-irrigated.

To put SDI in Nebraska in the right prospective, it should be stated that, even thought irrigated acreage in Nebraska is only second to California, only 33% of its cropland is irrigated (fig.1). At the same time, center pivots irrigate most of the irrigated land in Nebraska. Although reliable information on acreage irrigated by SDI in Nebraska are not currently available, it is safe to say that the number a acres currently irrigated by SDI is insignificant as compared with those irrigated by center pivot and surface systems.

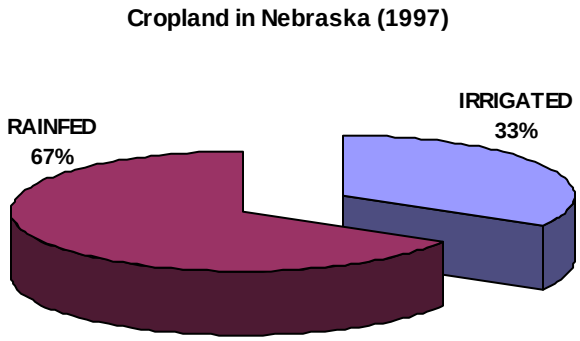

Figure 1. Partitioning of irrigated and rainfed land in Nebraska (Adapted from Bruce Johnson, Cornhusker Economics, June 20, 2001).

At the time of this writing, the Nebraska Department of Agricultural Statistics did not have any information on acres irrigated by SDI in the state, and the Nebraska Department of Environmental Quality (NDEQ) is just starting to keep records on SDI systems installed in the state. In 2001, however, the Irrigation Journal published the result of an irrigation survey, which included irrigated acreages by different irrigation systems by state and nationwide. Results for Nebraska shown in fig. 2 indicate that low-flow systems, which include systems like SDI, surface drip systems and micro-sprinklers, only represent approximately 0.04% of all irrigated acreage. By comparison, the same source indicates that in the entire United States low-flow systems represent approximately 4.9% of irrigated acreages (fig.3).

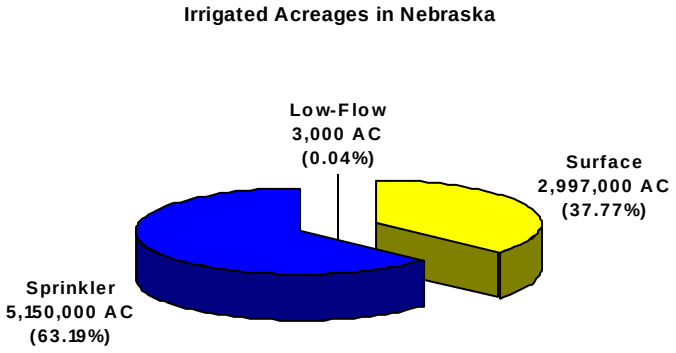

Figure 2. Irrigated acreages by irrigation method in Nebraska (Adapted from Irrigation Journal, Jan/Feb 2001).

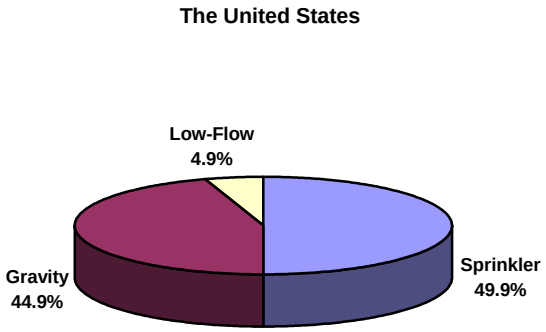

Figure 3. Percent irrigated land by irrigation method in The United States (Irrigation Journal, Jan/Feb 2001).

As suggested above, Nebraska has been slower in the adoption of low-flow system, including SDI, as compared with the national average. This may be due to a variety of factors. First, the high cost of SDI is difficult to recuperate by growing low-value crops like those commonly grown in Nebraska (such as corn, soybean and wheat). This contrasts with places like California, where SDI is used to grow high-value crops, like fruits and vegetables. Although the cost per acre of an irrigation system can vary widely depending on field size and desired level of automation, researchers in Texas have published the cost comparison for different irrigation systems shown in Table 1. It shows that an SDI system cost approximately twice as much as a center pivot. For a crop like corn, the advantages of SDI as compared with center pivots, in terms of labor and water savings, are not as significant as to justify paying approximately twice as much for an SDI system. For surface irrigators, on the other hand, even though the water and labor savings that can be realized by switching to SDI can be significant, the logical step would, however, be to switch to a center pivot if field size and shape allow. Researchers in Kansas, however, have done economic comparison between SDI and Center pivots for row crops (O'Brien et al. 1997). They have shown that as the field gets smaller, the economic feasibility of SDI becomes more attractive. The farm size at which a break-even point is reached, however, depends on a variety of factors, some of which are not well documented, such as:

- Live expectancy of the SDI system,
- Expected yield increase with SDI over center pivot,
- Expected water savings with SDI,
- Value of the water saved using SDI.

Table 1. Irrigation investment cost for different irrigation systems (adapted from or Amosson et al., 2002).

Irrigation System	Cost ($/Ac)		
	Gross	Net[1]	Net[2]
Conventional furrow	165	153	142
Center pivot	367	268	252
SDI	832	615	570

1. Assuming tax rate of 15% and discount rate of 6%.
2. Assuming tax rate of 28% and discount rate of 6%.

A second factor that drives the adoption of more efficient irrigation systems like SDI is water scarcity, which until recent years, have not been much of a problem in Nebraska. Nebraska is sitting on top of a large portion of the High Plains Aquifer and has far more ground water than any other High Plains state. The volume of groundwater stored in the Nebraska portion of the aquifer has been estimated at 2,000 million acre-feet (McGuire et al., 2003). Despite the large quantity of groundwater available in Nebraska, decreases in water table due to over-pumping are now a big problem in South West Nebraska and in Box Butte County. At the same time, due to several years of drought, surface water resources stored in reservoirs and in the soil profile in the area are at all-time lows. This situation has motivated many surface irrigators to install center pivots,

and others to consider SDI. The groundwater depletion problem, however, is not yet as widespread and severe in Nebraska as it is, for instance, in Texas, Kansas, Oklahoma, Colorado, and New Mexico (McGuire et al. 2003).

Another factor limiting SDI in Nebraska has been the fact that information for farmers wanting to install SDI systems has been very limited. For instance, even though research with SDI has been carry out for decades in California, and for over 12 years in Kansas, no similar programs have been established in Nebraska. Only now is Nebraska establishing SDI research and extension programs as a reaction to farmer's demands for information. Innovative farmers have mainly been leading the introduction of SDI to the state. Without the benefit of independent information sources, other than that provided by the industry and irrigation dealers, a share of SDI system failures have occurred. Initially, farmers started experimenting with "leaky hose" type of systems, with disappointing results, and now thin-wall drip tapes are commonly used. Also, other than cost, the main problem limiting the adoption of SDI in Nebraska is the lack of a viable solution to potential rodent problems.

What follows is a description of demonstrations, extension, and research efforts that have been made or are currently underway to either generate and/or provide information related to SDI in Nebraska.

UNL SDI RESEARCH FACILITIES

In recent years, the University of Nebraska-Lincoln (UNL) has been in the process of establishing SDI research and extension programs. So far, SDI research facilities have been installed at North Platte, Scottsbluff, Lincoln, and there are plans to install another facility at Clay Center. A Brief description of these facilities follows.

SDI Research Facility at North Platte

In 2003, installation of a SDI research and demonstration facility was completed at the UNL West Central Research and Extension Center located in North Platte, NE. Funding for this facility was obtained through grants from the Nebraska Foundation and from the US Bureau of Reclamation. The facility covers 12 acres, divided into 72 individual plots. This number of plots can accommodate 18 treatments, replicated four times. Each plot is 30 ft x 237 ft, which can accommodate 12 rows of crop planted at a 30-inch spacing. A drip tape was installed every other row (every 60 inches) at a depth of approximately 16 inches. The drip tape installed was a T-Tape TSX 515-12-340, with a wall thickness of 15 mil, an inside diameter of 0.625 inch and a nominal flowrate of 0.34 gpm/100 ft at 8 PSI of pressure.

The tapes in each plot are connected to an individual supply line at the head of the plot, and to an individual flushing line at the downstream end of the plot. The

supply line of each plot is connected to a manifold. The manifold has an air vent, electric valve, flowmeter, and pressure regulator for each plot. The electric valves are then connected to a SDM-CD16AC relay controller (Campbell Scientific, Inc, Logan UT) system that is controlled by a CR10X datalogger (Campbell Scientific, Inc, Logan UT). Eight of the plots are instrumented with ECH_20® Dielectric Aquameters (Decagon Devices, Inc, Pulman, WA) to continuously monitor soil moisture at five depths in the soil profile, to a depth of five feet. The system can be automated by programming the datalogger to respond to environmental inputs, such as soil moisture or weather information. The water supply for the system is a 720 GPM well. A Cycle Stop Valve® (Cycle Stop Valves, Inc., Lubbock, TX), pressure switch, and pressure thank combination was installed at the pump to allow irrigating a reduced number of plots at one time. A chemigation system to allow injecting fertilizer, chlorine, and acid with the irrigation water was also installed. The chemigation system was designed and installed with all the safety devices to meet NDEQ regulations (Vitzthum, 2002).

During the 2003 growing season, the system was used to irrigate a silage corn crop. The system operated as expected, with very few problems. Before installation, Rozol® pocket gopher bait (Liphatech, Inc. Milwaukee, WI) was applied all around the field, with the purpose of preventing rodent damage. No rodent problems were detected during 2003. During the next three years, the facility will be used to conduct an experiment in which several irrigation amounts, nitrogen rates, and methods of nitrogen application for corn will be evaluated. Funding has already being secured to install an additional 72 plots in an adjacent field.

SDI Research Facility at Scottsbluff

The installation of the SDI Research and demonstration facility in Scottsbluff, NE, was completed in 2003. Funding for this facility was obtained from the US Bureau of Reclamation. The facility covers approximately 8 acres and is divided into 34 plots. Each plot is 400 ft x 22 ft, which accommodates 12 rows of crop spaced 22 inches. The system has Netafim Typhoon 630-12.5 mil tapes with drippers spaced every 24 inches and a nominal dripper flowrate of 0.25 gallons per hour at 10 PSI of pressure. The tapes were installed every other row (every 44 inches) at a depth of 10-12 inches. Irrigation to each plot can be controlled using a control manifold installed in each plot. Each control manifold is instrumented with a flowmeter, pressure regulator, electric valve, manual valve, and air vent. The electric valves are connected to a programmable control panel. A flushing manifold was also installed at the downstream end of each plot. The water source for the system is canal water. Water is filtered using a Netafim Disc-Kleen disc filter. The system is also set up to be able to apply chemicals with the irrigation water.

The system was designed to grow corn and dry beans. Sugar beet, which is another important crop in the area, may also be grown with the SDI system in the

future. The system will be used for demonstration and, in the next 3 years, an irrigation frequency trial will be conducted. Even though irrigation research could not be started with the system in 2003, the system was used to irrigate a corn crop. Leaks were the main problem detected during the 2003 growing season. Approximately 50 to 60 leaks in the tapes were found, which seemed to be caused by field mice. Digging out the tapes to repair those leaks was a very time-consuming and difficult task.

SDI Research Facility at Lincoln

The objective of installing this SDI research facility was to conduct an experiment to evaluate corn yield potential under intensive management. In 1999 and 2000, the experiment was irrigated to replenish daily crop evapotranspiration via a surface drip system, with the tape placed next to the plants in each row. In 2001, a permanent SDI system was installed with drip tapes in alternate rows at a depth of about 12 to15 inches.

SDI Research Facility at Clay Center

Funding to install a SDI research facility at the UNL South Central Research and Extension Center (SCREC) has been secured since about two years ago. Delays in installing this facility, however, have occurred because of two reasons. First, the Irrigation Engineer leading the effort took a different job and move to another state. Second, because of budget cuts to UNL by the state, the SCREC was closed down and the tenured faculty was moved to Lincoln. The research farm at SCREC, however, will remain in operation and under the control of UNL faculty and some on-site support staff. Therefore, the plans to install the SDI research facility at Clay Center are still underway. Currently, a 40-acre farm is available for this purpose, and a new Irrigation Engineer has recently been hired, who is expected to lead this effort. Current plans are to start the installation during spring of 2004 and initiate a research project in 2005. Initially, a three-year experiment will compare nitrate leaching under SDI and surface irrigation. The experiment will also evaluate different irrigation levels and nitrogen fertigations scheduled using weekly chlorophyll meter readings.

SDI EXTENSION PROGRAMS IN NEBRASKA

In the last few years, a series of extension programs dealing with SDI have been taken place in Nebraska. The University of Nebraska Cooperative Extension, in collaboration with other partners, has been the main institution organizing these programs. Partners have included the Natural Resource Districts (NRD's), the Natural Resource Conservation Service (NRCS), the Nebraska Department of Environmental Quality (NDEQ), and the irrigation industry, among others. Several of the SDI extension programs that have been conducted in Nebraska include, among others:

- In 2001, the NRCS organized a one-day SDI meeting directed to provide information for NRCS personnel. This included speakers from the SDI industry, including NETAFIM, T-Tape, and Agricultural Products, Inc.

- In 2001, a coalition of groups organized an SDI meeting. Groups represented included the NRCS, the Tri-Basin Natural Resources District, the Lower Republican NRD, and the Harlan County UNL Cooperative Extension. The meeting was held in Alma, Nebraska to discuss SDI and the impact it can have to agriculture. Speakers were invited to share their knowledge and a farmer panel was presented to discuss real life experiences with the 65 people who attended.

- In 2001, UNL Cooperative Extension and NRCS organized a Farmer's Panel on SDI, as part of the Central Plains Irrigation Conference, which was conducted at Kearney, NE. The purpose of the panel was to discuss local farmer's experiences with SDI. Approximately 40 people attended the farmer's panel. Displays from the SDI industry were also presented at this conference.

- In 2001, the Nebraska Fertilizer and Agricultural Chemical Institute conducted and educational program for crop consultants, in Omaha, NE. This program included a presentation on SDI as an emerging technology by a UNL faculty.

- In 2002, a half-a-day SDI meeting was conducted at North Platte, NE. Speakers came from Kansas State University, NRCS, and NDEQ. Also, industry displays were presented. This was an informational meeting covering design, management, advantages and disadvantages of SDI, and legal requirements for SDI. The information was directed to farmers and crop consultants. Approximately 30 people attended this meeting, which included farmers, crop consultants, and agency personnel.

- In 2002, a two-day SDI informational meeting was conducted at Hastings, NE. This meeting presented speakers from the SDI industry (NETAFIM) and from the NRCS. It was mainly directed to educate UNL extension educators, UNL faculty, and personnel from the NRD, NRCS, and other local agencies. Approximately 25 people attended this program.

- In 2002, a field day was conducted at the South Central Research and Extension Center at Clay Center. A presentation on SDI by UNL faculty was included as part of this field day. Approximately 200 people attended this presentation.

- In 2003, UNL Cooperative Extension faculty conducted a series of educational programs focusing on irrigation related issues important to

farmers in the state. One of the topics of this program was a discussion of advantages and disadvantages of SDI. It also included the presentation of displays by the SDI industry. The program was offered at five different locations across Nebraska. Approximately a total of 200 people participated in this educational program.

- In addition to educational meetings on SDI, written material and TV spots have produced to educate Nebraskans about SDI (Benham and Payero, 2001; Payero, 2002; Payero, 2003).

NRCS SITES

NRCS has helped SDI in Nebraska by providing cost share funds through the EQIP program and by providing technical assistance for farmers. Following is a description of some examples of SDI demonstrations that NRCS has been involved with.

Leaky Pipe System in Phelps County, NE.

An evaluation of a 67-acre leaky pipe system installed in Phelps County, Nebraska, was conducted by a group of institutions during 1995 and 1996. Funding for the evaluation was provided by a NDEQ 319 non-point Source Water Pollution grant. Institutions involved in the evaluation included the NRCS, UNL Cooperative Extension, Central Nebraska Public Power & Irrigation District (CNPP&ID) and the Tri-basin Natural Resource District. The purpose of the evaluation was to help state and federal agencies determine if the practice was eligible for cost sharing through the Farm Service Agency (FSA) and the Great Plains Conservation Program.

In this farm, a 3/8-inch diameter leaky pipe was installed at 18-inch depth, a 6-ft spacing, and run length of 960 ft. The soil was a Holdredge silt loam with a 0-1% slope. The water source was surface water, which was filtered using a sand-and-gravel medium filter. The system was also instrumented with a venturi fertilizer injection system.
Access points were installed to measure flow and pressure changes at 5 points along three randomly selected laterals. Access tubes were also installed for weekly monitoring of soil moisture at 6-inch increments to a depth of 6 feet. Nitrogen fertigations were scheduled based on chlorophyll meter readings.

During the 1995 evaluation, it was found that the individual line Distribution Uniformity (DU) was poor. The three line tested emitted water a different rates. Section of the line with the higher pressure did not emit the most water. The average seasonal DU for the three lines was only 54%. It was determined that by the end of the growing season the smaller holes on the leaky pipe had become plugged. The average daily application for 1995 had dropped to 0.11 in/day from

0.17 in/day measured in 1994. Chemical treatment applied in 1995 did not improve flows. In August 1995, the water source was changed to well water. Chemical treatment applied in spring of 1996 was able to improve flowrates from 0.11 in/day, measured in 1995, to 0.20 in/day. On July 2, 1996, a pressure switch installed at the filter was causing the filter to continuously flush. On this date the subsurface system was abandoned and a gated pipe system was used for the remainder of the season.

SDI System in Gosper County

In 2002, an SDI system was installed in a 22.8-acre field located in Gosper County, Nebraska, which was previously irrigated by conventional gravity without reuse. In this farm, a 1 3/8 inch diameter T-Tape with a 24-inch emitter spacing was installed every other row (60-inch spacing). The field was 2000 ft in length in the West site and 2500 ft in the East site. The soil was a Holdrege Silt Loam with 0-1% slope. The system was designed to irrigate corn and soybean using a groundwater well. Filtration is accomplished with a Fresno filter with 200-mesh screen. From the producer's prospective, the goals for installing the system were:

- To reduce labor
- To save irrigation water

After two seasons operating the system, the producer feels that 2100 feet of length is the maximum length that can be irrigated with a 1 3/8-inch tape on 0-1% slopes. He feels that half-mile length is too long. In 2003, soil moisture was monitored. It was found that soil moisture stayed pretty consistent in the first 2000 feet of row length and decreased in the 2000-2500 feet section.

The producer has had very little problems with gophers. To prevent gopher problems, after harvesting in 2002 he irrigated to get the area around the tape wet for the winter. He also ran a gopher machine around the borders of the field. So far, he has only had to repair 2 holes. After the 2003 season, he just watered and is still waiting to see the results.

Regarding the quality of the well water, an iron bacteria problem was detected. Because of this, in the second season he chlorinated the well using 100 gallons of chlorine bleach in the spring and chlorinated again with 25 gallons just prior to irrigating. There were no problems during the 2003 growing season. The producer doesn't know if chlorination helped with the iron bacteria or if it was just one of those years where the iron bacteria wasn't around much. At the end of the season, the producer chlorinated the system, not the well. This will be flushed out in spring 2004.

Based on his experience, the producer advice is:

- Know your installer to make sure he knows what he is doing.
- Test your water so you know what water problems you may have to address, if any.

Regarding the original goals, he has found that labor has been reduced and he is pretty sure that there have been water savings in this field, as compared to the previous system, even though water use has not been rigorously measured. He has found, however, that with SDI the problems/headaches are not really decreased or increased, they are just different. From the NRCS prospective, the purpose in 2004 is to use this field as a demonstration site and to compare irrigation water savings between the SDI and conventional gravity irrigation with reuse system.

SDI in the Aurora, NE, Area

In this area there have been quite a bit of interest in SDI, but few have actually installed SDI systems. In 2002 a farmer converted a 15-acre field, located southwest of Aurora, to SDI. According to NRCS personnel in the area, the producer seems to be getting along well with the system. It was a system cost shared by the EQIP program, so NRCS was involved in making sure he had the proper design and installation to meet NRCS specifications. Another farmer, North of Aurora, has also been converting to SDI without NRCS assistance. He has so far installed approximately 50 acres. There have been several others who started the process of applying for help through the EQIP program but then backed out. One of them backed out because he couldn't get anyone to install the system. The others probably just were unsure or became fearful of the unknowns about this fairly new system. There have also been some installations in nearby counties.

CNPP&ID DEMONSTRATION SITES

The Central Nebraska Public Power & Irrigation District (CNPP&ID), in cooperation with The Nebraska Environmental Trust established three SDI demonstration sites in the spring of 2002. The sites are 7-9 acre pivot corners, installed in a single corner of three different pivots across the Irrigation District. CNPP&ID has the following two primary questions to resolve with SDI research:

- Can surface water be used successfully in these systems? and,
- How does water use efficiency (WUE) of SDI compare to the other types of irrigation systems used in the District?

The SDI systems performed well in the 2002 and 2003 seasons; yields on the center pivot corners have met or surpassed yields under the pivot at each of the sites. In particular, higher yields on all SDI corners were noted in 2002 when extended periods of high winds and temperatures, coupled with record low relative humidity and precipitation levels, stressed plants under the pivots for several hours of each pivot rotation. In 2003, adjusted yields for one of the Phelps County fields were 205, 220, and 29 bu/Ac for the pivot, SDI, and dryland, respectively. In-depth study of the WUE question will start in 2004 since cooperators have become familiar with system operation, and soil disturbance around the tape laterals is not as pronounced as in 2002 when the tapes were

laid down behind a deep shank chisel. Plans for the future include looking into nutrient applications, relative differences in root development, and further automation of the SDI systems.

Legal requirements for SDI in Nebraska

In Nebraska, according to NDEQ, SDI systems are considered as a Class V injection well, and therefore have to comply with all regulations of Title 122, despite the fact that Title 122 makes no mention of SDI. The full text detailing the requirements of Title 122 can be found at www.deq.state.ne.us. For this reason, before an SDI system can be installed in Nebraska, a permit needs to be obtained from NDEQ. For this, the interested party needs to fill up a NDEQ "*Application for underground injection of fluids using a sub-surface irrigation system."* This requires information, which includes:

- An aerial photograph of the section in which the SDI system is to be installed, indicating where all wells are located.
- Average flow rate of the SDI system
- Depth to groundwater where the SDI system is to be located.
- Construction details of the water wells.
- Design details of the SDI system.

Also, before chemigating, producers need to be certified by NDEQ. This is done by attending an applicator's certification training and passing a written test. In addition to this, NDEQ requires the SDI system to comply with a series of safety regulations. This is done by obtaining a Chemigation Permit from the local NRD. The NRD has to make sure that all chemigation safety measures have been included in the irrigation system before it can issue a permit, which requires a field inspection. The chemigation permit is valid for one year, which means that the NRD has to re-inspect the system every year. System safety requirements have been described by Vitzthum (2002).

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