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Advantages and Disadvantages of Subsurface Drip Irrigation

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What is SDI?

Subsurface drip irrigation (SDI) applies water directly to the crop root zone using buried polyethylene tubing, also known as a dripline, dripperline, or drip tape (Figure 1). Driplines come in varying diameters and thicknesses in order to maintain acceptable irrigation uniformity for different field lengths. Smaller diameter driplines are used when short lateral lengths are required. As lateral length increases, a larger diameter dripline must be selected to maintain adequate irrigation uniformity.



Figure 1. Dripline installed underground.

The thickness of the dripline wall is directly related to its durability. Driplines with small thicknesses are mainly used for temporary installations, which will be discarded after a short time, such as when being used

to irrigate high value crops. Thicker driplines are used for permanent installations. The thicker driplines can also withstand higher operating pressures. The cost of the dripline is directly related to both diameter and thickness.

Small holes called *emitters* are usually spaced every 8 to 24 inches along the length of the dripline. During irrigation, pressure forces the water out of the emitters drop by drop. Once the water is in the soil, its movement and wetting pattern will depend on the physical characteristics of the soil. In a fine-textured soil, for instance, water will tend to move laterally and upward, compared with a sandy soil where water tends to move mainly downward. The amount of water that can be delivered through a drip system depends on dripline diameter and spacing, emitter spacing, operating pressure, emitter size, and emitter design. A variety of driplines are now available from different manufacturers to fit the specific design requirements for different soils, crops and weather conditions.

Advantages

Water Application Efficiency

One of the main advantages of SDI over other irrigation methods is that it has the *potential* to be the most efficient irrigation method available today. The word *potential* is stressed because irrigation efficiency not only depends on the irrigation system itself, but also on its proper design, installation and management. Only if designed, installed and managed correctly can SDI be more efficient than any other irrigation system.

Since the driplines are usually installed in the soil between every other crop row, the system only wets a fraction of the soil volume, compared with other

systems. This leaves space in the soil to store water from rainfall and may reduce the net irrigation requirements. Also, since driplines are buried, about 13-18 inches below the soil surface for corn, the soil surface stays dry. A dry soil surface means that practically no irrigation water is lost due to evaporation and runoff. In addition, if the system is managed correctly, deep percolation losses due to irrigation can be eliminated. The only small inevitable water losses are those needed for flushing the driplines and filtering system. Therefore, an SDI system can deliver water with an efficiency of 95 percent or higher. This means that for every inch of water that is pumped, 0.95 inch or more stays in the crop root zone, where it is needed.

Because of the potential high irrigation efficiency that can be obtained with SDI, it may be a good alternative for areas where irrigation water is limited. It should be noted, however, that although water savings is an important consideration, it should not be the only factor to consider when selecting an irrigation system.

Potential Water Savings

Researchers in Kansas have reported that net irrigation needs could be reduced by 25 percent with SDI, while maintaining high corn yields. Net irrigation need, however, does not take into account system inefficiencies. The actual water savings that can be achieved with SDI, therefore, depends on the irrigation efficiency of the system with which SDI is being compared. For instance, let's say that a producer is switching to SDI from furrow irrigation. Although it is difficult to know the average irrigation efficiency for a furrow system, let's assume the efficiency is 65 percent. It can be more or less depending on management, soil type, and other factors. If the net seasonal irrigation requirement for corn is 15 inches (taking into account water inputs from rainfall and residual soil moisture), approximately 23 inches of water will need to be applied through furrow irrigation to meet crop needs ($15 \text{ in}/0.65 = 23.1 \text{ in}$). Considering 95 percent efficiency for SDI, only about 16 inches of water needs to be applied if using the SDI system ($15 \text{ in}/0.95 = 15.8 \text{ in}$). That is a difference of about 7 inches that can be saved at the farm level by using SDI instead of furrows.

From a watershed perspective, no water is actually saved by using SDI. Water that is consumed through evaporation may go to reduce the transpiration needs of the crop, and water that leaves the field as runoff or deep percolation can be reused downstream. Still, from the producer's point of view, pumping has been reduced by 7 inches and pumping cost by approximately one third. In this case, SDI also has an environmental benefit, since the water that is applied in excess to the net irrigation requirements using the surface irrigation system has the potential of creating environmental problems such as nutrient leaching, soil erosion, and pollution of surface and groundwater sources.

If we compare SDI to a center pivot, the water savings may not be as significant as it is for furrow irrigation. For instance, given a similar situation of corn grown under a center pivot with a net irrigation requirement of 15 inches, and assuming the center pivot system has an irrigation efficiency of 85 percent, to satisfy the net irrigation requirements of 15 inches, the producer will need to apply 17.6 inches ($15 \text{ in}/0.85 = 17.6 \text{ in}$). SDI would provide a water savings of 1.8 inches, which is a lot less than the 7 inches saved when SDI was compared with the furrow system.

Switching from furrow irrigation to SDI can result in significant water savings.

Potential Yield Increases

SDI can be automated to allow frequent water applications. It also can be used to frequently inject fertilizers and other chemicals such as acids, chlorine and even pesticides with the irrigation water. SDI systems often are managed to apply small amounts of water and other inputs daily or even several times a day. Small and frequent applications can be adjusted to match the water and nutrient needs of the crop. Spoon-feeding water and nutrients could theoretically result in increased yields and decreased nutrient losses. The magnitude of the yield increase that can be obtained using SDI is still an open question for row crops like corn. A recent study in Texas compared SDI and sprinkler systems for grain sorghum (Colaizzi et al., 2003). The researchers found that under deficit irrigation, SDI resulted in higher yields, while under full irrigation, there was no yield increase. Significant yield increases, however, have long been documented for SDI in several vegetable crops.

Labor Requirements

After the system is installed, the manual labor required to operate the system is similar to that required to operate a center pivot and is much less than that required for a surface system. The SDI system also lends itself to automation, which could considerably reduce labor.

System Underground

Having the irrigation system underground (Figure 2) and keeping the soil surface dry, in addition to reducing evaporation, allows farm equipment to enter the field even during irrigation events. In arid areas, a dry soil surface could also reduce the potential for

weed germination and restrict the growth of shallow-rooted weeds. A dry soil surface also limits crusting of the soil surface, which can be a problem with other types of irrigation systems. Also, because the driplines are underground, high wind speeds do not affect irrigation uniformity and efficiency, as they do with sprinkler systems. High winds can significantly damage center pivots, but won't affect SDI systems.

Having the system permanently installed underground facilitates starting irrigation early in the growing season, without losing a considerable amount of the water applied due to the high evaporation rates that usually occur under bare soil conditions. Depending on system capacity and water availability, it may be necessary to start irrigating early in the season to refill a dry soil profile. Starting with an empty soil profile may not allow low capacity systems to keep up with crop water demand during the growing season, especially during peak water use periods.

Because the driplines are underground, SDI could be an alternative method for disposing of wastewaters, especially those with an unpleasant smell that do not adapt well to application using other methods. Although more research is needed, researchers at



Figure 2. System installed underground.

Kansas State University have successfully used SDI to apply livestock wastewater from cattle feedlot lagoons.

Field Size, Shape, and Terrain

SDI adapts well to fields of any size and shape; however, it does not work well in rolling terrain because of the pressure differential in the driplines causing non-uniform water applications. Although uniformity can be increased using pressure-compensating emitters, the additional cost may not be feasible for low-value crops.

Potential Energy Savings

Subsurface drip irrigation systems operate at relatively low pressure and deliver small flow rates. Emitters usually require a pressure of 4 to 15 PSI and deliver flow rates of 0.16 to 1 gallon per hour. Because of the low flow rate requirements, SDI systems can be operated with smaller pumps than will be required for a center pivot or furrow system, which may be an important consideration in places with low-yielding wells. Because of these characteristics, some researchers have reported significant energy savings by shifting from surface irrigation to drip (Srivastava et al., 2003). However, it should be noted that lower capacities, and therefore energy savings, are only possible because of higher efficiencies with SDI compared with the other systems.

The energy used by a pumping system depends on a combination of factors, including flowrate, pumping depth, pressure at the pump, time of operation, and pumping plant efficiency. How these factors are combined in a pumping system will determine if energy is actually saved with SDI. A surface system, for instance, will require less pressure and less operating time than SDI, although it may require higher flowrates. SDI may require less flowrate, but the pump will have to be operated for a longer time to be able to meet crop water requirements. At the end, if less water is pumped with SDI due to a significantly higher efficiency and improved water management compared with other systems, it is possible to save energy, although it may not occur in all situations.

Even though SDI emitters operate under low pressure, the pumping system should supply enough pressure to account for other pressure losses within the system. *Table 1* shows "typical" pressure losses in the different components of a well-designed SDI system reported by researchers in California. Also, by evaluating hundreds of micro-irrigation systems, including SDI systems, they found that about half of the systems operated with less than 35 PSI of pressure at the pump and the other half required higher pressures.

Table 1. "Typical" pressure losses in an SDI system (from Trout and Gartung, 2002).

System Component	Pressure Loss (PSI)
Emitter	10
Lateral hose (dripline)	1
Manifold	1
Sub-main pipeline	3
Main pipeline	3
Filter station piping	1
Filter	5
Pressure regulators, chemical injectors, control valves, flow meters	1
Total Pressure Losses	25 PSI

Disadvantages

Investment Cost

One of the main disadvantages of SDI is its high initial investment cost. SDI systems are expensive compared with other irrigation systems. Cost per acre varies widely, depending on field size and shape, location of the water source, and level of automation that is desired. Researchers in Texas estimated the investment cost for different irrigation systems (Table 2). The net cost takes into account allowed tax deductions based on two tax categories and the present value of those deductions applied over a period of several years, according to tax regulations.

Table 2. Investment cost for different irrigation systems (adapted from 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

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

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

In Nebraska, an average gross cost of between \$500 and \$800 per acre is a good estimate. This includes the cost of installation, which is usually about \$200 per acre. Depending on the location of the water source, a higher investment may be required to convert pivot corners to SDI. Therefore, for a large field, SDI cannot compete in cost with center pivots, which cost about half as much per acre.

Economic comparisons between center pivots and SDI done by Kansas State University researchers, however, have shown that as fields get smaller, SDI

becomes more cost effective. In their analyses, however, they did not include the dryland alternative. Considering the dryland alternative is important because in some situations it may be more economical to not irrigate at all.

Determining the economic break-even point between SDI and center pivots, however, is complicated since the analysis is very sensitive to expected crop prices, value of the water saved, expected yield increases with SDI, field size, and the life expectancy of the SDI system. Some of these factors are very uncertain. For instance, the life of an SDI system is not known. The longer the life of the system, the more economic sense it will make. System evaluations conducted by the Irrigation Training and Research Center in California showed that system performance, as indicated by measured distribution uniformity, was not related to the age of the system. They found 20-year-old systems with excellent performance. The life expectancy would depend a great deal on how well a system is designed, installed and maintained.

In general, center pivots make more economic sense for large areas. SDI could be a good alternative for small, odd-shaped fields, especially when irrigation water is limited. Government cost-share programs may make SDI more economically viable as the need to save water increases and as concerns about the environmental impacts of irrigation become more important.

Water Supply and System Capacity

As stated above, one of the advantages of SDI is that water and nutrients can be applied frequently and in small amounts. For growers obtaining water from an irrigation district, the water delivery schedule may not be flexible enough to take advantage of this system attribute. In these cases, a water storage tank or reservoir may be required, which will increase the cost of the system (Figure 3). To take full advantage of SDI, it is assumed that a constant supply of irrigation water is available. This can be problematic for farmers depending on water delivered from a canal system in a rotation schedule. Under this situation, irrigating early in the growing season to refill a dry soil profile, as needed with some low capacity systems, may not be possible.

Another limitation to water supply, even for farmers pumping groundwater, can be the interruption of pumping imposed by load control of electric power. This is aggravated by the fact that load control is usually imposed during the peak water use periods when crops need irrigation the most. It is important to point out that SDI systems are usually designed for frequent applications of small depths of water. For systems with low capacities, producers cannot afford to get behind in the irrigation, since they will not be able to catch up and will not be able to meet crop water requirements, especially during periods of high water demands.



Figure 3. Water tank used to store water for an SDI system.

Management Time

Management time requirements for SDI can be higher than for other irrigation systems, especially the first couple of years when the learning curve is steep. This is because operating an SDI system requires special periodic maintenance operations, such as chlorination and acid injection, which are not required for other systems. Also, applying fertilizers and other chemicals using SDI requires special care and knowledge.

Limited Dripline Lengths

In order to maintain high uniformity with SDI, dripline lengths have to be limited. The maximum dripline length is a function of the dripline diameter, emitter flow rate, slope of the land and emitter spacing. For this reason large fields may need to be divided into smaller units or irrigation zones, which may imply additional cost for mainlines and sub-mains. With current products, the maximum dripline length is limited to approximately one-half mile.

Installation

Installing an SDI system requires specialized equipment (*Figure 4*), is labor intensive and represents a significant portion of the initial cost of the system. Soon after installation, water needs to be run through the driplines to detect leaks and to open the flow path through the soil to the full extent of the tape diameter. Otherwise, soil may consolidate around the collapsed driplines, which could restrict water flow. For produc-

Figure 4a

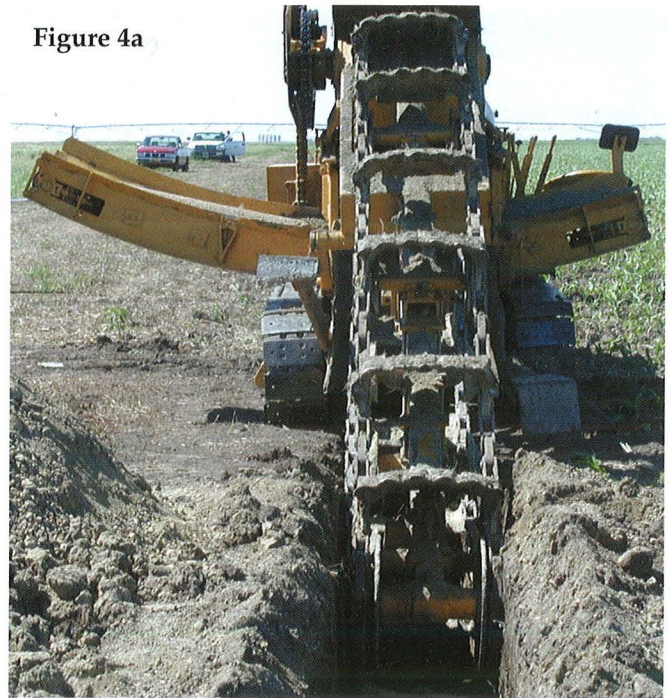


Figure 4b



Figure 4a-b. Equipment used to install an SDI system.

ers who receive water from a canal system, water may not be available in early spring and late fall when SDI systems are usually installed. Although SDI systems are relatively easy to install in the rockless soils commonly found in Nebraska and other High Plains states, installing an SDI system in rocky soils, which are common in other places, could be difficult, if not impossible.

Inflexible Design

Aside from cost, it is critical that SDI systems be properly designed, installed, operated, and maintained. During the design phase, decisions have to be made that cannot be reversed after installation. Decisions like dripline diameter, dripline length, emitter diam-

eter and spacing, dripline spacing and depth, mainline diameter, type of filtration and injection systems, etc., need to be made by both the farmer and an experienced irrigation system designer. This is particularly important since SDI systems are less forgiving of design errors than other systems, and the recovery value of an abandoned SDI system is very low. Therefore, working with an experienced SDI designer is a good investment. The producer should consider that once the system is installed, it cannot be easily changed. For instance, the installed system will have fixed dripline spacing and depth, which may limit the types of crops that can be grown and the type of tillage practice that can be used.

Emitter Clogging

One of the main problems with SDI and other types of drip irrigation systems is emitter clogging. It is a good idea to perform a water quality test before designing the system (Figure 5), to become aware of potential problems that may influence the system design, performance, and maintenance needs. Water quality tests for SDI systems, however, include parameters that are not commonly measured in standard water quality tests for irrigation. Water quality tests for SDI include bacteria population, total dissolved solids, total suspended solids, water hardness, and concentration of hydrogen sulfide, iron and manganese.

Proper maintenance is absolutely necessary for SDI systems to be successful. Since the emitters have very small diameters, they can be clogged by very small particles. This makes it absolutely necessary to keep those particles out of the system, since once the emitters are clogged, it may be difficult to unclog them, depending on the nature of the problem. Several types of particles, including soil particles, chemical precipitates, and biological particles can clog emitters. Clogging by soil particles is avoided by proper filtration and flushing. The filtration system should be considered the most critical part of the SDI system and should be carefully selected during the design stage. Chemical precipitates, such as calcium carbonate, can develop inside the driplines when the pH of the water is high. To avoid the formation of chemical precipitates, acid is usually injected in the irrigation water to lower its pH. Biological particles like algae and bacteria slime, on the other hand, are usually prevented or eliminated by chlorine injection. Also, to kill bacteria, which can live on iron, manganese, or sulfur, one might need to periodically shock-chlorinate the well.

Although the proper filtration system will keep most soil particles out of the system, some particles will still pass through the filter and settle inside the driplines. These very small particles need to be eliminated by periodically flushing the system. Therefore, it is extremely important that the proper flushing system is included in the design. This usually includes



Figure 5. Testing water quality for SDI.

connecting the driplines to a common PVC flush line installed at the bottom end of the field (Figure 6).

Crop roots growing around the driplines also can plug emitters, especially when the soil around the dripline is dry. This phenomenon is commonly known as *root intrusion*. Keeping the soil around the dripline sufficiently wet, and injecting chemical products (herbicides) to kill those roots are management practices commonly used to alleviate this problem. When water in the dripline is drained after irrigation, a negative pressure can be created inside the driplines. Under this negative pressure, soil particles from outside the driplines can be sucked into the emitters. This problem can be avoided by installing air/vacuum release valves, which allow air into the system at strategic points. Benham and Payero (2001) provided additional information about filtration and maintenance of SDI systems.

Rodents

Rodents can be one of the main problems limiting the successful use of SDI systems to irrigate row crops in Nebraska. Some rodents, such as gophers and field mice, like to chew on the driplines and this can be a major problem (Figure 7). Evidence of a leak can be detected by field inspection and by measuring pressure drops and high flow rates in the system. Locating and fixing leaks created by rodents is a difficult task since it requires digging to expose the tape. Rodents can create single leaks or may create multiple closely spaced leaks that may run distances of 10-15 feet or longer. To avoid these problems, the potential for rodent problems in the area should be evaluated prior to installation, and



Figure 6. Flushing an SDI system.

if needed, a rodent control and prevention program should be implemented. This control program should include, not only the SDI field, but also the surrounding area to keep rodents from moving into the SDI field. Currently there are no clear guidelines on how to solve this problem, however, rodent problems seem to be more severe under dry conditions, therefore, keeping the soil surrounding the dripline wet seems to alleviate the problem. Others recommend applying certain chemicals to kill or repel rodents.

Seed Germination

Since the underground SDI system keeps the soil surface dry, seed germination may be a problem and early growth can be limited by water stress. This is especially true in sandy soils, where little water moves upward in the soil profile. The depth of installation of the driplines also influences how close to the surface the water can move. In arid areas, a backup irrigation system may be needed to promote seed germination.

Soil Salinity

An important concern with SDI in arid regions is that soil salinity above the driplines can increase with time. This problem, however, may take a relatively long time to develop and is not likely to occur in areas receiving enough precipitation at any given time to move the salts down in the soil profile. Another important factor when considering the danger of developing



Figure 7. Damage to driplines caused by rodents.

soil salinity problems is the quality of the water used for irrigation. Since water used in Nebraska is of good quality from the salinity standpoint, the danger of developing soil salinity problems with SDI should not be an important concern in most systems in Nebraska.

Dripline Alignment

When driplines are installed parallel to the crop rows, as is commonly done, it can be challenging to keep the driplines and the rows aligned from season to season. Some installers also use alignment systems based on GPS technology that facilitate locating the driplines after installation.

“Surfacing” or “Chimney” Effect

If water is applied at a rate greater than the infiltration rate of the soil, a saturated zone will develop around the dripline. In some cases, the water under pressure will take the path of least resistance. If the dripline is sufficiently close to the surface, water and soil particles could pop up to the surface, creating a wet area directly above each emitter. This is known as “surfacing” or “chimney” effect. When this happens, the objective of keeping the soil surface dry is not achieved, and since water flows to the surface, it is more difficult to get water to move horizontally in the soil profile. In this situation, flow along the dripline can cause erosion away from the dripline.

Legal Issues

Although one advantage of SDI is that fertilizer and other chemicals can be applied with the irrigation water, the producer needs to be aware of some legal issues related to these applications. Before injecting any chemical, be sure to obtain a chemigation permit from the Nebraska Department of Environmental Quality (NDEQ) and comply with all legal regulations. There are regulations in place that may even affect where an SDI system can be installed, depending on the depth of the water table. Calling the NDEQ to inquire about legal requirements may be a good starting point for those considering installing an SDI system.

Conclusion

All things considered, SDI is a highly efficient system which can help improve management of both irrigation water and crop nutrients. Because of economics, it has mainly been used to produce high value crops like vegetables and fruits, but its use in row crops is beginning to spread. SDI is very new to Nebraska and the region. Like any new product or system, it will require time to gain the knowledge and confidence in operating a new irrigation system.

In Nebraska, some farmers are currently using SDI to irrigate row crops in small fields and are satisfied with the system. Other farmers have tried SDI and have encountered significant problems, mainly as a result of a bad design or installation, rodent problems, or lack of proper system maintenance. Failures occur for a variety of reasons, which may include trying to reduce cost in key system components, like filtration systems and flushing lines or underestimating maintenance requirements.

For those considering SDI, it is advisable to obtain as much information as possible in order to make intelligent decisions. If possible, try to obtain information from other farmers in your area who are already using SDI. A good resource for technical information about SDI is the Kansas State University Web site at www.oznet.ksu.edu/sdi. Information is also available from your local Natural Resource Conservation Service (NRCS) office and University of Nebraska Extension office.

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