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SDI APPLICATIONS IN KANSAS AND THE US

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INTRODUCTION

As the water supply for irrigation continues to become more limited either by increased multi-use demand, physical constraints, or institutional constraints, irrigators are always looking for ways to be more efficient in their practices and irrigation system. One option for irrigators is to convert their inefficient systems, such as flood irrigation, into subsurface drip irrigation (SDI). Subsurface drip irrigation not only improves system and application efficiencies but can also provide several other agronomic and management opportunities that are otherwise difficult to achieve with surface and sprinkler irrigation systems.

IRRIGATION TRENDS IN KANSAS AND THE US

Though there is not a good record of the SDI acreage in the US, of the 61 million acres of irrigated area in 2009, the International Commission on Irrigation and Drainage (ICID) estimates 4.05 million acres or 6.6 % are under the general category of microirrigation (ICID, 2012). Microirrigation encompasses all types of other irrigation systems that are not under the sprinkler and flood/ gravity irrigation category. Under the same category of microirrigation, the National Agriculture Statistics Service (NASS) captures the irrigated acreage every five years and is not very far from the ICID's estimate. Since 1994, it could be observed that there is a steady increase of farms converting to or being developed with microirrigation (Figure 1).

Kansas, in particular, shows a very similar trend of increasing acreage under the general category of microirrigation (Figure 2). From the available data in Kansas, there is still an overestimation of the actual SDI acreage. Nevertheless, if we consider the Kansas Water Use Report to be consistent, there is a general increasing interest to convert in SDI in the state of Kansas.

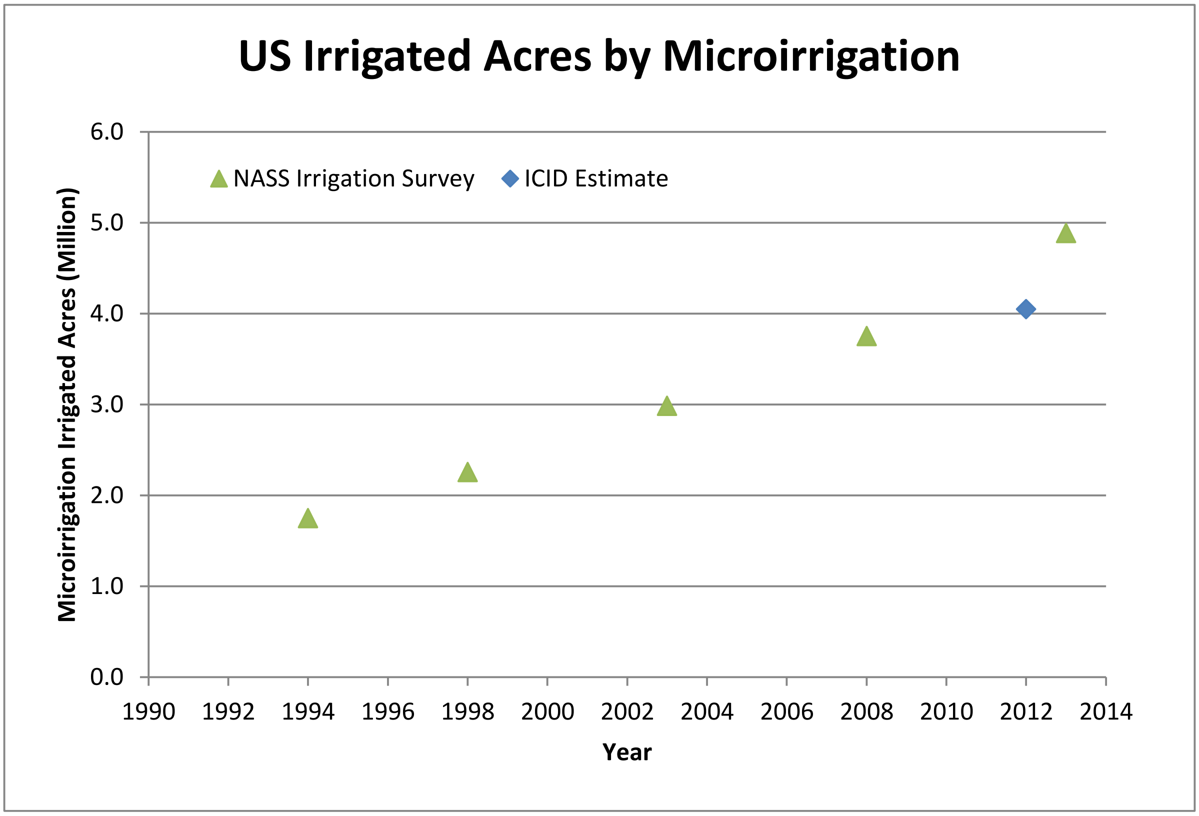

Figure 1. Microirrigated acreage in the US based on NASS Farm and Ranch Irrigation Surveys and International Commission on Irrigation and Drainage (ICID) estimates.

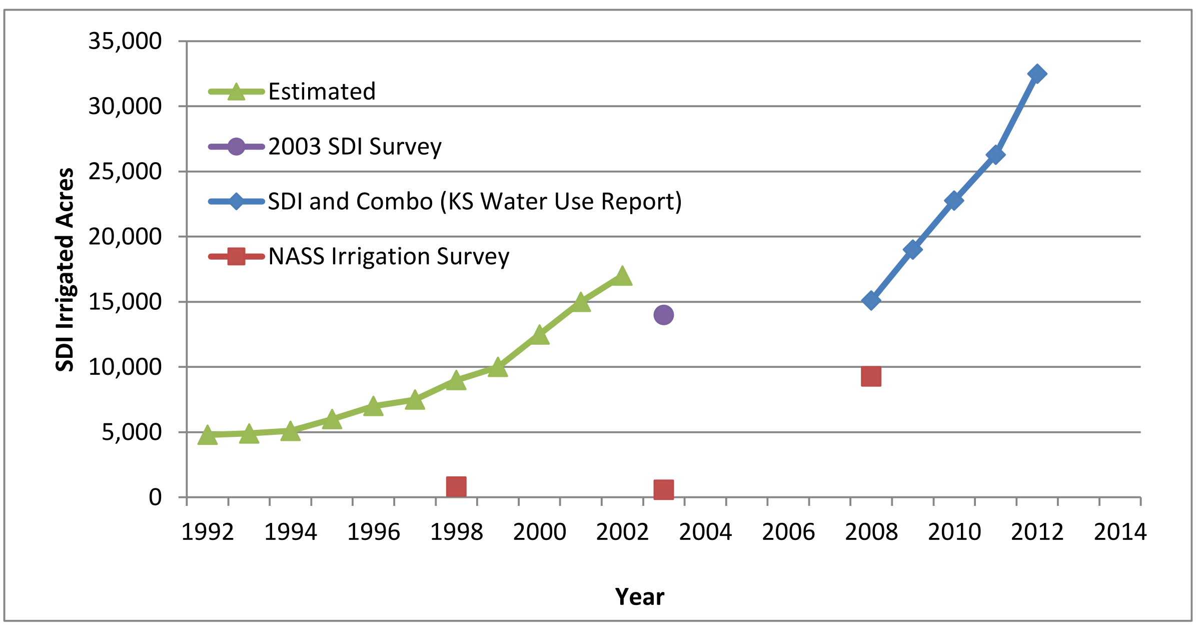

Figure 2. Increase in subsurface drip irrigation systems in Kansas. The abrupt changes in SDI area are due to survey and reporting methods and not due to abandonment of SDI systems. Adapted from Rogers and Lamm, 2012.

These survey data show that SDI systems have been successful in many parts of the Great Plains region despite minor technical difficulties during the adoption process (Lamm, et al. 2014). In a 2005 survey of SDI users, nearly 80% of Kansas producers indicated they were satisfied with the performance of their SDI system, and less than 4% indicated they were unsatisfied (Alam and Rogers, 2005). However, even satisfied users indicated a need for additional SDI management information. The most noted concern was rodent damage and subsequent repairs. A few systems had failed or been abandoned after limited use due to inadequate design, inadequate management, or a combination of both.

CRITERIA FOR SUCCESSFUL ADOPTION

The foremost criteria for the successful and long-lasting operation of SDI system are design and management. Research studies and on-farm producers consistently indicate that SDI systems result in high-yielding crops and water-conserving production practices only when the systems are properly designed, installed, operated and maintained (Lamm, et al. 2014). A system that is improperly designed and installed is difficult to operate and maintain and most likely will not achieve high irrigation water application uniformity and efficiency goals. Proper design and installation alone do not ensure high SDI efficiency and long system life, though. A successful SDI system also must be operated according to design specifications while utilizing appropriate irrigation water management techniques. SDI systems also are well-suited to automation and other advanced irrigation scheduling and management techniques. Additionally, proper maintenance is crucial for the continued life of an SDI system.

Minimum SDI System Components

The basic features of all SDI system are usually universal (Figure 3). It should have pump station, backflow prevention device, flowmeter, chemical injection system, filtration system, main and submain lines, dripline laterals, flushline, and safety components such as flush valves, air and vacuum release valves, pressure gages, and zone valves. The long-term efficient operation and maintenance of the system is seriously undermined if any of the minimum components are omitted during the design process.

SDI system design must consider individual management restraints and goals, as well as account for specific field and soil characteristics, water quality, well capabilities, desired crops, production systems, and producer goals. In most cases, the actual characteristics and field layout of an SDI system vary from site to site, and certain features could be added and tailored to accommodate, for example monitoring and automation. However, the minimum SDI system components should not be sacrificed as design and installation cost-cutting measures. If minimum SDI components cannot be included as part of the system, an alternative type of irrigation system or a dryland production system should be considered.

Water distribution components of an SDI system include the pumping station, the main, submains and dripline laterals. Sizing requirements for the mains and submains are somewhat similar to underground service pipe to center pivot sprinklers or main pipelines for surface-irrigated gravity systems and are determined by the flowrate and acceptable friction loss within the pipe. In general, the flowrate and friction loss determine the dripline size (diameter) for a given dripline lateral length and land slope. An SDI system consisting of only the distribution components has no method to monitor system performance or conduct system maintenance, and the system would not have any protection from clogging. Clogging of dripline emitters is the primary reason for SDI system failure. In addition to basic water distribution components, other components allow the producers to monitor SDI system performance, allow flushing, and protect or maintain performance by injection of chemical treatments. The injection equipment can also be used to provide additional nutrients or chemicals for crop production. A backflow prevention device is required to protect the source water from accidental contamination if backflow should occur. A detailed discussion of each component can be found in K-State Research and Extension publication MF2576 supplemented with some updated information by Lamm, et al. (2014).

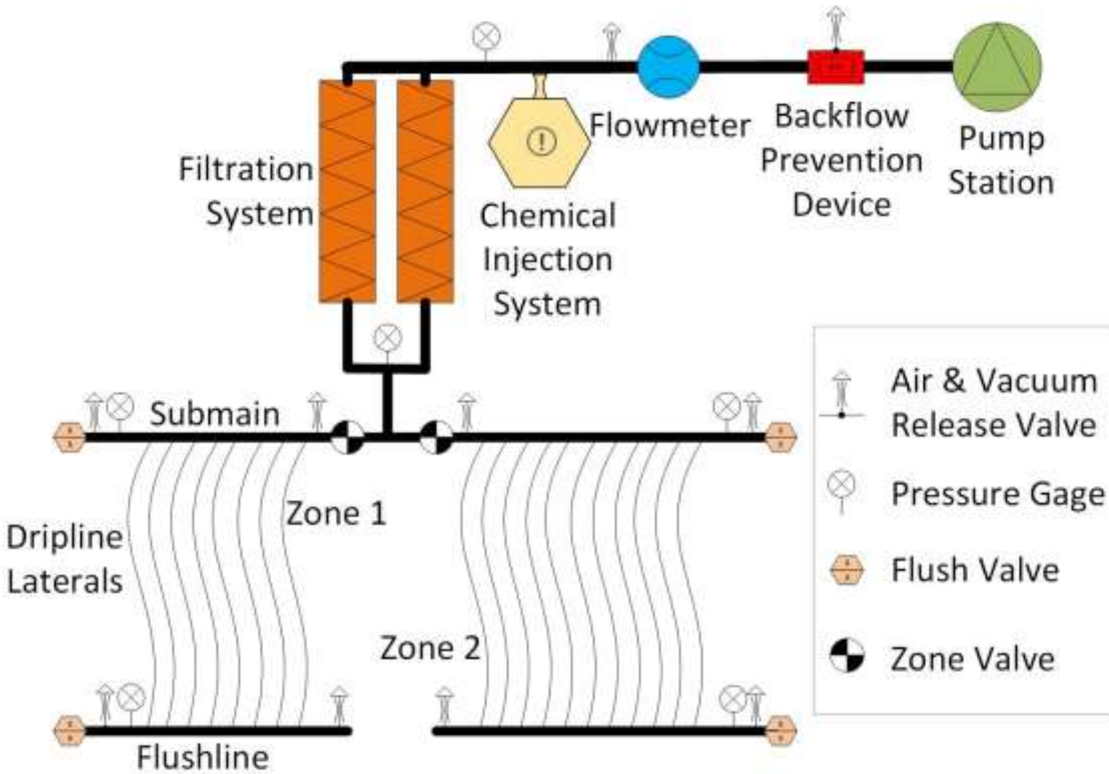

Figure 3. Minimum required components of an SDI system. Components are not to scale. After Rogers, 2003b.

Water Quality Recommendations

Because most SDI systems are planned for multiple-year use, water quality is an extremely important consideration. Clogging prevention is crucial to SDI system longevity and requires understanding of the potential hazards associated with a particular water source. Replacement of clogged driplines can be expensive, difficult, and time-consuming. Although nearly all water is potentially usable for SDI, the added cost of complex water filtration and chemical treatment of marginal-quality water might further reduce the feasibility of SDI use on lesser-value crops. Therefore, no SDI system should be designed and installed without first assessing the quality of the proposed irrigation water supply. In some cases, poor water quality can also cause crop growth and/or long-term soil problems. However, with proper treatment and management, many waters high in minerals, nutrient enrichment, or salinity can be used successfully in SDI systems. A good water quality test (Table 1) provides information to growers and designers in the early stages of the planning process so that suitable water treatment, management, maintenance plans, and system components can be selected. Although a good water quality test may cost a few hundred dollars, the absence of it may result in an unwise investment in an SDI system that is difficult and expensive to manage and maintain. Tests 1 through 7 are usually provided in a standard irrigation water quality test package, whereas Tests 8 through 11 are generally offered as individual tests. The test for the presence of oil may be helpful in oil-producing areas or if a groundwater well with oil lubrication has experienced surging, allowing existing drip oil in the water column to mix with the pumped water.

Table 1. Recommended water quality tests to be completed before designing and installing an SDI system including threshold hazard levels (after Bucks et al., 1979; Nakayama and Bucks, 1991; and Rogers et al., 2003a;).

1. **Electrical Conductivity (EC_b),** a measure of total salinity or total dissolved solids, measured in dS/m or mmhos/cm as the bulk EC of the irrigation water.	Ideal <0.75 dS/m
2. **pH,** a measure of acidity, where a value of 1 is very acid, 14 is very alkali, and 7 is neutral.	Ideal <7
3. **Cations** include Calcium (Ca^{2+}), Magnesium (Mg^{2+}), and Sodium (Na^{+}), measured in measured in meq/L, (milliequivalent/liter).	Ideal <2meq/L
4. **Anions** include Chloride (Cl^{-}), Sulfate ($SO4^{4-}$), Carbonate ($CO3^{2-}$), and Bicarbonate ($HCO3^{-}$), measured in meq/L.	Ideal <2meq/L
5. **Sodium Absorption Ratio (SAR),** a measure of the potential for sodium in the water to develop sodium sodicity, deterioration in soil permeability and toxicity to crops. SAR is sometimes reported as Adjusted (Adj) SAR. The Adj. SAR value better accounts for the effect on the $HCO3^{-}$ concentration and salinity in the water and the subsequent potential damage to the soil because of sodium.	Ideal <3.0
6. **Nitrate nitrogen (NO3 - N),** measured in mg/L (milligram/liter).	Ideal <5 mg/L
7. **Iron (Fe), Manganese (Mn), and Hydrogen Sulfide (H_2S),** measured in mg/L.	Ideal Fe<0.2 mg/L Ideal Mn<0.1 mg/L Ideal H_2S<0.2 mg/L
8. **Total suspended solids,** a measure of particles in suspension in mg/L.	Ideal <50 mg/L
9. **Bacterial population,** a measure or count of bacterial presence in # / ml, (number per milliliter)	Ideal <10,000/ml
10. **Boron*** measured in mg/L.	Ideal <0.7 mg/L
11. **Presence of oil****	-

** The boron test would be for crop toxicity concern.*

*** Oil in the water would present a concern of excessive filter clogging. It may not be a test option at some labs and could be considered an optional analysis.*

Important Management Decisions

Initial Investment

A complete SDI system does come with a price. As with nearly all types of investments, the decision of whether an SDI investment is sound lies with the investor. Wise decisions generally require a thorough understanding of the fundamentals of the particular opportunity and/or the recommendations from a trusted and proven expert. While the microirrigation (drip) industry dates back nearly 50 years and SDI application in Kansas has been researched since 1989, the network of industry support is still evolving in portions of the Great Plains region. Individuals considering SDI should spend time to determine if SDI is a viable systems option for their situation. As producers and investors, the most important question should be:

What things should I consider before purchasing an SDI system?

1. Educate yourself before contacting a service provider or salesperson by:
   a) Seeking out university and other educational resources for unbiased information. A good place to start is the K-State SDI website at www.ksre.ksu.edu/sdi. In particular, consider running the Excel template comparing the economics of center pivot sprinkler and SDI under corn production. Also read the literature or websites of microirrigation companies for additional information and latest products.
   b) Reviewing SDI minimum design components as recommended by K-State. http://www.ksre.ksu.edu/sdi/Reports/2003/mf2576.pdf
   c) Visiting other producer sites that have installed and are using SDI preferably in your area. Most current producers are willing to show their SDI systems to others. Some are even willing to give recommendations and share their own insights.
2. Interview at least two irrigation companies.
   a) Ask the representative for references, credentials (training and experience) and completed sites (including the names of contacts or references).
   b) Ask questions about design and operation details. Pay particular attention if the minimum SDI system components are met. If not, ask why. System longevity is a critical factor for economical use of SDI which is closely tied to its vital components.
   c) Ask companies to clearly define their role and responsibility in designing, installing, and servicing the system. Determine what guarantees are provided including after-sales support.
3. Obtain an independent review of the design by an individual that is not associated with the sale. This adds cost but is relatively minor in comparison to the total cost of a large SDI system.

Monitoring

In SDI systems, all water application and most water distribution components are underground. Because surface wetting seldom occurs in properly installed and operated systems, no visual cues of system operation are available to the manager. Therefore, the flow meter and pressure gauges must be used to provide operational feedback cues. The pressure gauges along the submain of each zone measure the inlet pressure to driplines. Decreasing flowrates and/or increasing pressure may indicate clogging, and increasing flowrates with decreasing pressure may indicate a major line leak. The inlet pressure gauges, along with those at the distal ends of the dripline laterals at the flushline valve, help establish the baseline performance characteristics of the system. Good quality pressure gauges should be used at each of these measurement locations and the gauges should be periodically replaced or inspected for accuracy. The flowrate and pressure measurements should be recorded and retained for the life of the system. A time series of flowrate and pressure measurements can be used as a diagnostic tool to discover operational problems and determine appropriate remediation techniques (Figure 4).

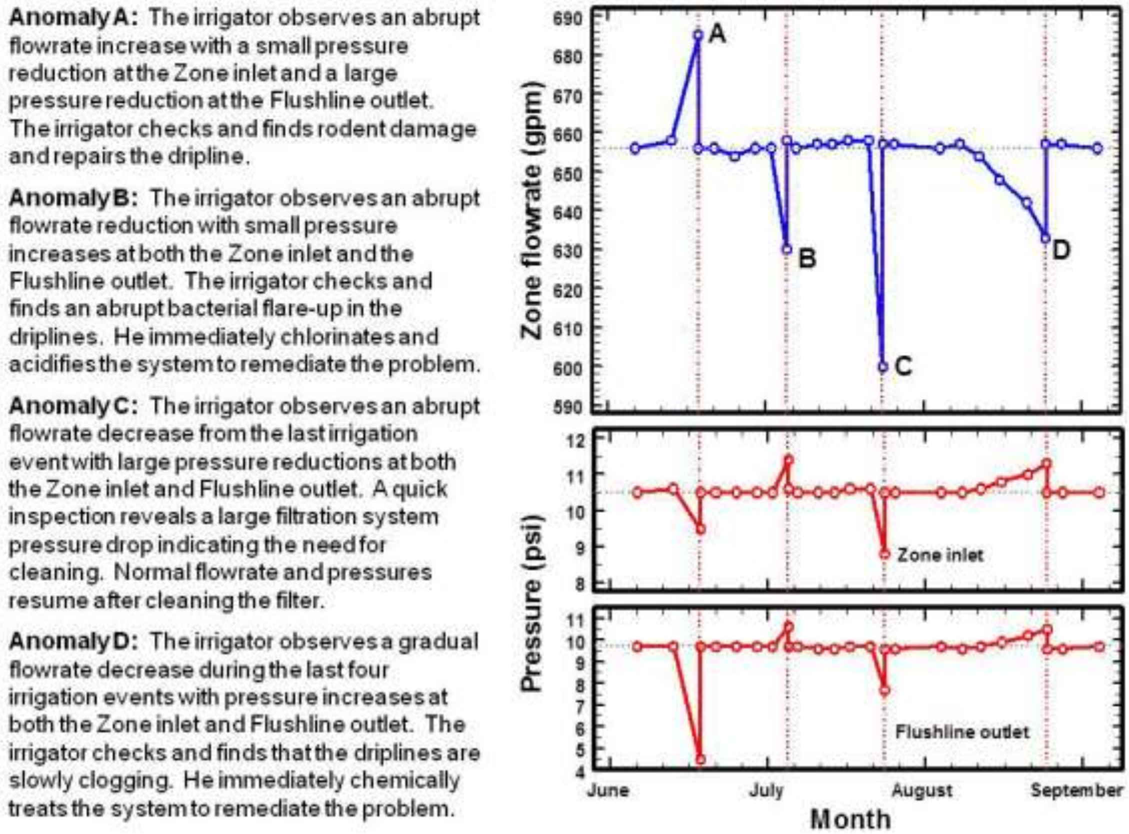

Figure 4. Hypothetical example of how pressure and flowrate measurement records could be used to discover and remediate operational problems. After Lamm and Camp (2007).

Rodent Management

Burrowing mammals, principally of the rodent family, can cause extensive leaks that reduce SDI system uniformity. Most rodents avoid digging into wet soil, so dripline leaks presumably are not caused by the animals looking for water. Rather, rodents must gnaw on hard materials, such as plastic, to wear down their continuously growing teeth. The difficulty in determining the actual location of a dripline leak is compounded by the fact that the leaking water may follow the rodent burrow path for a considerable distance before surfacing. Anecdotal reports from the Great Plains describe some of the typical habitat scenarios that tend to increase rodent problems. These scenarios include the close proximity of permanent pastures and alfalfa fields, railroad and highway easements, irrigation canals, sandy soils, crop and grain residues during an extended winter dormant period, or absence of tillage.

Cultural practices such as tillage and crop residue removal from around SDI control heads and above-ground system apparatus seem to decrease the occurrence of rodent problems. Some growers have used deep subsoiling and/or poison bait around the SDI system field perimeters as a means of reducing rodent subsurface entry into the field. Isolated patches of residue within a barren surrounding landscape provide an “oasis” effect conducive to rodent establishment. After the smaller rodents become established, other burrowing predators such as badgers can move into the field, further exacerbating the damage. Caustic, odoriferous, pungent, and unpalatable chemical materials have been applied through SDI systems in attempts to reduce rodent damage, but the success of these trials has been varied. Anecdotal reports have indicated reduction in rodents by installing owl houses on high poles around the edges of the fields (Burt and Styles, 2007b). Periodic wetting of the soil during the dormant period has been suggested as a possible means of reducing rodent damage. Deeper SDI depths (18 inches or greater) may avoid some rodent damage (Van der Gulik, 1999) since many of the burrowing mammals of concern in the United States have a typical depth range of activity that is less than 18 inches (Cline et al., 1982).

ADVANTAGES OF SDI

The following list was adapted from Lamm (2002) which may or may not necessarily be viewed as an advantage for a grower in his/her particular situation. For example, there are opportunities for improved cultural practices with SDI, while at the same time, there might be fewer tillage alternatives. These advantages may be further subdivided along the lines of water and soil issues, cropping and cultural practices and system infrastructure issues.

Advantages related to water and soil issues

More efficient water use – Soil evaporation, surface runoff, and deep percolation are greatly reduced or eliminated. Infiltration and storage of seasonal precipitation can be enhanced by drier soils with less soil crusting. In some cases, the system can be used for a small irrigation event for use in germination, depending on dripline depth, flow rate and soil constraints. The inherent ability to apply small irrigation amounts can allow better water-efficient decisions about irrigation events near the end of the cropping season. In widely spaced crops, a smaller fraction of the soil volume can be wetted, thus further reducing unnecessary irrigation water losses.

Less water quality hazards – Runoff into streams is reduced or eliminated, and there is less nutrient and chemical leaching due to deep percolation.

Improved opportunities for use of degraded waters – Smaller and more frequent irrigation applications can maintain a more consistent and lower soil matric potential that may reduce salinity hazards. Subsurface wastewater application can reduce pathogen drift and reduce human and animal contact with such waters.

Greater water application uniformity – Improved in-field uniformities can result in better control of the water, nutrients and salts. Widely spaced crops may benefit from water application closer to the crop, provided sufficient soil wetting is achieved.

Advantages related to cropping and cultural practices

Enhanced plant growth, crop yield and quality – A number of crops respond positively.

Improved plant health – Less disease and fungal pressure occurs due to drier and less-humid crop canopies. The system can also be used for some types of soil fumigation.

Improved fertilizer and pesticide management – Precise and more timely application of fertilizer and pesticides through the system can result in greater efficacy and, in some cases, reduction in their use.

Better weed control – Reductions in weed germination and weed growth often occur in drier regions

Improved double cropping opportunities – Crop timing may be enhanced since the system need not be removed at harvesting and reinstalled prior to planting the second crop.

Improved farming operations and management – Many field operations can occur during irrigation events. Field operations result in less soil compaction, and soil crusting caused by irrigation is greatly reduced. Variability in soil water regimes and redistribution are often reduced with SDI as compared to surface drip irrigation (DI). Additionally, weather-related application constraints such as high winds, freezing temperatures and wet soil surfaces are less important. Needed fertilization can be applied in a small irrigation event even when irrigation needs are low. The ability to irrigate during freezing conditions can be particularly beneficial where preseason irrigation is used to effectively increase seasonal irrigation capacity. There is also less irrigation equipment exposed to vehicular damage. Hand laborers benefit from drier soils by having reduced manual exertion and injuries.

Advantages related to system infrastructure

Automation – The closed-loop pressurized characteristic of the system that can reduce application variability and soil water and nutrient redistribution variability make the system an ideal candidate for automation and advanced irrigation control technologies.

Decreased energy costs – Operating pressures are often less than some types of sprinkler irrigation. Any water savings attributable to SDI will also reduce energy costs.

System integrity issues – There are fewer mechanized parts in an SDI system as compared to mechanical-move sprinkler irrigation systems. Most components are plastic and are less subject to irrigation system corrosion. SDI systems do not need to be removed and installed between crops and, thus, can experience less damage. The potential for vandalism is also reduced.

Design flexibility – There is increased flexibility with SDI in matching field shape and field size as compared to center pivot sprinkler irrigation systems. The SDI system can be easily and economically sized to the available water supply. In widely spaced crops, driplines can be placed for optimum water and nutrient uptake. Pressure compensating SDI systems have fewer slope limitations than surface gravity irrigation.

System longevity – SDI installations can have a long economic life when properly designed and managed. Long system life allows for amortizing investment costs over many years, thus allowing lower-value commodity crops to be economically grown with SDI.

Less pest damage – In some cases, there may be less pest damage to SDI systems from wildlife and insects than for DI systems. However, this must be tempered with the fact that pest damage to SDI systems may take more effort to detect and to repair.

CHALLENGES OF SDI

Similarly, there are circumstances and situations that present disadvantages to selection of an SDI system. These disadvantages also may be subdivided along the lines of water and soil issues, cropping and cultural practices, and system infrastructure issues.

Disadvantages related to water and soil issues

Smaller wetting pattern – The wetting pattern may be too small on coarse-textured soils, resulting in too small a crop root zone. This situation can make system capacity and system reliability extremely critical issues as there is less ability to buffer insufficient irrigation capacity or system breakdown.

Monitoring and evaluating irrigation events – Water applications may be largely unseen, and it is more difficult to evaluate system operation and application uniformity. System mismanagement can lead to underirrigation and crop yield and quality reductions or overirrigation, resulting in poor soil aeration and deep percolation problems.

Soil/Application rate interactions – Emitter discharge rates can exceed the ability of some soils to redistribute the water under normal redistribution processes. In such cases, water pressure in the region around the outside of the emitter may exceed atmospheric pressure, thus altering emitter flows. Water may inadvertently "surface" (tunneling of the emitter flow to the soil surface) causing undesirable wet spots in the field. In "surfacing" problems, small soil particles may be carried with the water, causing a "chimney effect," that provides a preferential flow path. The "chimney" may be difficult to permanently remove, since a portion of the "chimney" remains above the dripline even after tillage.

Reduced upward water movement – Using the SDI system for germination may be limited, depending on installation depth and soil characteristics. This may be particularly troublesome on soils with vertical cracking. Salinity may be increased above the dripline, increasing the salinity hazard for emerging seedlings or small transplants.

<u>Disadvantages related to cropping and cultural practices</u>

Less tillage options – Primary and secondary tillage operations may be limited by dripline placement.

Restricted plant root development – Smaller crop root zones can make irrigation and fertilization more critical issues from both an application timing and amount perspective. Smaller crop root zones may be insufficient to avoid diurnal crop water stresses even when the root zone is well watered. Application of nutrients through the SDI system may be required for optimum yields. Application of micronutrients may also become more important as the smaller soil volume becomes depleted of these nutrients sooner.

Row spacing and crop rotation issues – Since SDI systems are fixed spatially, it may be more difficult to accommodate crops of different row spacing. Some crops might require a very close dripline spacing that might be economically impractical. Additional care must be taken at the time of annual row-crop planting to ensure crop orientation and spacing are appropriately matched to the dripline location.

Plant development issues – Some crops may not develop properly under SDI in some soils and climates. Peanuts may not peg properly into dry soil. Tree crops may benefit from a larger wetting pattern.

<u>Disadvantages related to system infrastructure</u>

Costs – SDI has a high initial investment cost compared to some alternative irrigation systems. In many cases, the system has no resale value or a minimal salvage value. Lenders may require a higher equity level and more collateral before approving SDI system loans. Such large investments may not be warranted in areas with uncertain water and fuel availability, particularly if commodity price outlook is poor. SDI systems typically have a shorter design life than alternative irrigation systems which means the annualized depreciation costs must increase to provide for system replacement.

Filtration issues – As with all microirrigation systems, water filtration is a critical issue in ensuring proper system operation and system longevity. However, the issue can become more critical for long term SDI systems where a system life of greater than ten years is desired. SDI may require more complex water quality management than some surface microirrigation systems, since there are no opportunities to manually clean emitters.

Other maintenance issues – Timely and consistent maintenance and repairs are a requirement. Leaks caused by rodents can be more difficult to locate and repair, particularly for deeper SDI systems. The driplines must be monitored for root intrusion, and system operational and design procedures must employ safeguards to limit or prevent further intrusion. Roots from some perennial crops may pinch driplines, eliminating or reducing flows. Periodically, the driplines need to be flushed to remove accumulations of silt and other precipitates that may occur in the driplines.

Operational issues – Operation and management requires more consistent oversight than some alternative irrigation systems. There are fewer visual indicators of system operation and of the system application uniformity. Irrigation scheduling procedures are required to prevent underirrigation and overirrigation. Monitoring of system flowmeters and pressure gages are required to determine if the system is operating properly.

Design issues – SDI is a less-developed technology than some alternative irrigation systems. This is particularly so in some regions where growers have little exposure and experience with these systems. There are fewer turnkey systems available for purchase. In some regions, the lack of contractor capacity can result in inadequate timing of installations in wet periods. Design errors are more difficult to resolve since most of the SDI system is below ground. There are typically more components needed for SDI than DI systems. There is the possibility of soil ingestion at system shutdown if a vacuum occurs, so air relief/vacuum breaker devices must be present and operating correctly. As with any microirrigation system, zone size and length of run will be limited by system hydraulics. Compression of the dripline due to soil overburden can occur in some soils and at some depths, causing adverse effects on flow. SDI systems are not typically well suited for Site Specific Variable Application.

Abandonment issues – In some cases, there are concerns about waste plastic product (driplines) in the subsoil if the SDI system is abandoned.

SUMMARY AND CONCLUSION

SDI is a viable irrigation system option in many parts of the state and the country, in general. But, similar to other irrigation systems, it has its own set of issues. Despite the advantages and the technological advancements of SDI, many producers are not yet comfortable to deal with the issues at hand. This paper hopes to educate the producers that still, SDI is worthy to be at the toolbox of options as we deal with diminishing water resource.

OTHER AVAILABLE INFORMATION

Additional SDI-related bulletins and irrigation-related websites are listed below:

MF-2361 Filtration and Maintenance Considerations for Subsurface Drip Irrigation (SDI) Systems
http://www.ksre.ksu.edu/sdi/Reports/2003/mf2361.pdf

MF-2576 Subsurface Drip Irrigation (SDI) Components: Minimum Requirements
http://www.ksre.ksu.edu/sdi/Reports/2003/mf2576.pdf

MF-2578 Design Considerations for Subsurface Drip Irrigation
http://www.ksre.ksu.edu/sdi/Reports/2003/mf2578.pdf

MF-2590 Management Consideration for Operating a Subsurface Drip Irrigation System
http://www.ksre.ksu.edu/sdi/Reports/2003/MF2590.pdf

MF-2575 Water Quality Assessment Guidelines for Subsurface Drip Irrigation
http://www.ksre.ksu.edu/sdi/Reports/2003/mf2575.pdf

MF 2589 Shock Chlorination Treatment for Irrigation Wells
http://www.ksre.ksu.edu/sdi/Reports/2003/mf2589.pdf

Subsurface Drip Irrigation website: www.ksre.ksu.edu/sdi

General Irrigation website: www.ksre.ksu.edu/irrigate

Mobile Irrigation Lab website: www.bae.ksu/mobileirrigationlab

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