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LONGEVITY: AN IMPORTANT ASPECT IN SDI SUCCESS

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INTRODUCTION

Subsurface drip irrigation (SDI) for commodity cereal, oilseed and forage crop production is a viable alternative to surface and sprinkler irrigation in the Great Plains region. Subsurface drip irrigation systems are expensive and their economic competitiveness against alternative irrigation systems greatly depends on SDI system longevity. The objectives of this paper are to discuss the importance of, the potential for, and the requirements for SDI longevity.

IMPORTANCE OF SDI LONGEVITY

The predominant irrigation system for irrigated commodity crop production in the Central Great Plains is center pivot sprinkler irrigation [54, 99, and 88% of total irrigated land area in Colorado, Kansas and Nebraska, respectively according to USDA-NASS (2014)]. Although SDI land area in the Central Great Plains is currently less than 1% of the total irrigated area, it is growing at a rapid pace having increased 127 and 176% in Kansas and Nebraska, respectively, in the last 5 years according to the data (USDA NASS, 2010, 2014).

In the spring of 2002, K-State Research and Extension introduced a software spreadsheet for making economic comparisons of center pivot sprinkler irrigation (CP) and subsurface drip irrigation (SDI) for corn production (Lamm et al., 2016). Over the years, sensitivity analyses provided by the software indicate that SDI system longevity is a key factor in the economic competitiveness of SDI systems with CP systems (Lamm et al., 2015). Since that time, the spreadsheet has been periodically updated to reflect changes in input data, particularly system and corn production costs. When growing the lesser-value commodity crops, a SDI system that can be amortized over many years is an economic necessity to compete with less expensive CP systems. The competitiveness of SDI increases when a larger proportion of the field is irrigated with SDI than possible with CP systems (i.e., as much as 25% greater land area for SDI as compared to full circle CPs within square fields). Using current economic assumptions for full-sized quarter-section fields (160 acres), SDI systems are not very competitive with CP systems unless they have longevity upward of 15 years (Fig. 1). For SDI longevities less than 10 years, producers would be facing a significant economic disadvantage by choosing SDI over CP for Great Plains commodity crop production for full-sized fields. With a SDI system life of about 22 years, SDI and CP systems have nearly equal competitiveness using current economic assumptions for full-sized fields (Lamm et al., 2016). In the SDI longevity region, between 10 and 20 years, the authors encourage producers to carefully consider and use their own estimates to evaluate SDI and CP economic competitiveness.

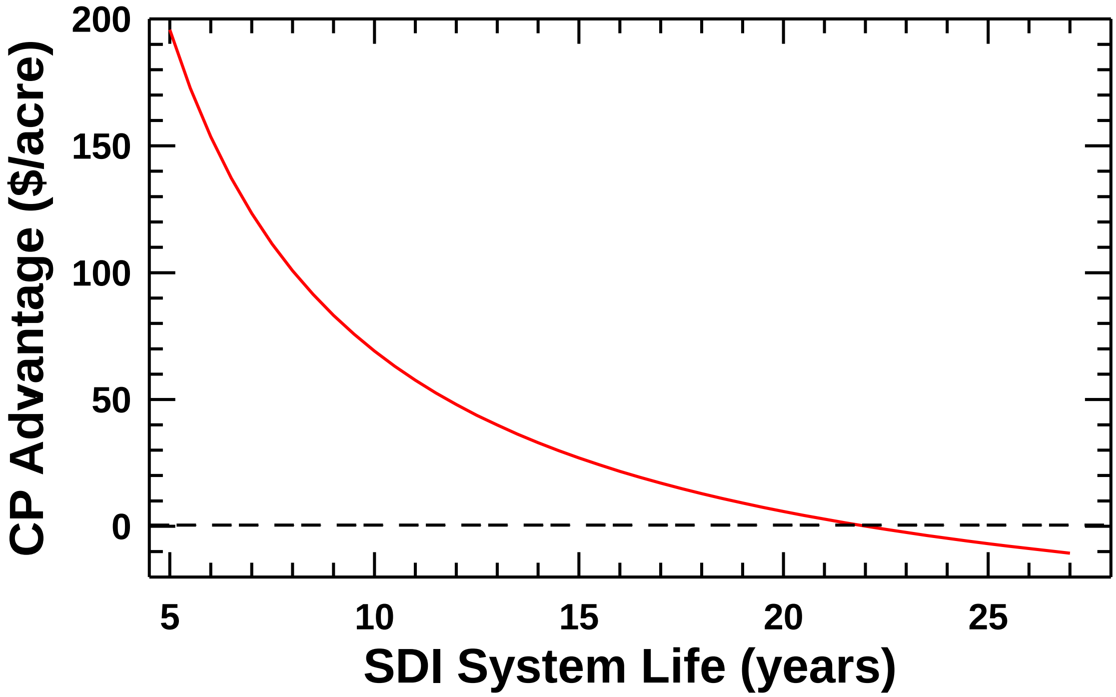

Figure 1. The annual economic advantage of center pivot sprinkler irrigation over SDI for corn production as affected by longevity of the SDI system (Data from KSU software, Lamm et al., 2016).

POTENTIAL FOR SDI LONGEVITY

Historically, SDI is not the newest irrigation methodology. The earliest reported usage of SDI for corn in the USA was in 1915-1916 on a deep silt loam soil at the West College Farm of Colorado State University (House, 1918). In this research study, porous clay tiles were installed at a depth of 2 ft on various lateral spacings of 16 to 25 ft. They concluded that the technology would not be cost effective for ordinary farm crops such as corn and that narrower lateral spacings would be needed for grain crops on this soil type. In a three-year study (1965-1967) near Georgetown, Delaware, Mitchell et al. (1969) reported some early SDI corn research evaluating flexible plastic tubing with various orifices and dripline spacings (1, 1.5, and 2 m). They reported yield increases of 12 to 2415% with SDI compared to rainfed production on a loamy sand. This report also provides some of the earliest details about installation implements and procedures for SDI, some of which are similar to today's procedures. In another related early publication, Mitchell and Tilmon (1982) suggested SDI as a good, economical, irrigation system alternative for the small farmer in the USA. This is because the components of SDI systems can be easily and economically designed to accommodate the field size (Bosch et al., 1992; O'Brien et al., 1998). Early SDI performance was often plagued by problems such as emitter clogging (chemical precipitation, biological and physical factors, and root intrusion) and poor distribution uniformity. However, as improved plastic materials, manufacturing processes, and emitter designs became available, resurgence in SDI occurred in the 1980s, both in research activities and commercial operations (Camp et al., 2000).

Research with SDI systems at the Kansas State University Northwest Research-Extension Center at Colby, Kansas began in 1989 (Lamm and Rogers, 2014) and the first system installed in 1989 was successfully operated for 26.5 years before being abandoned in the fall of 2015. Layflat thin-walled collapsible driplines (also known as drip tapes) were starting to randomly fail in the crease. Although, a few more years might have been acceptable with a small proportion of leaks on a producer's field, the leaks were unacceptable for the research field. Another study field at the Center failed for similar reasons after 22 years of usage. Industry evaluation of driplines from that earlier field concluded the bonds in the plastic were beginning to break down after the many years of usage. Pressure and flow tests were conducted annually on the 1989 system. Results indicate that plot flowrates could be maintained within +/- 5% of their initial first annual value (Fig. 2).

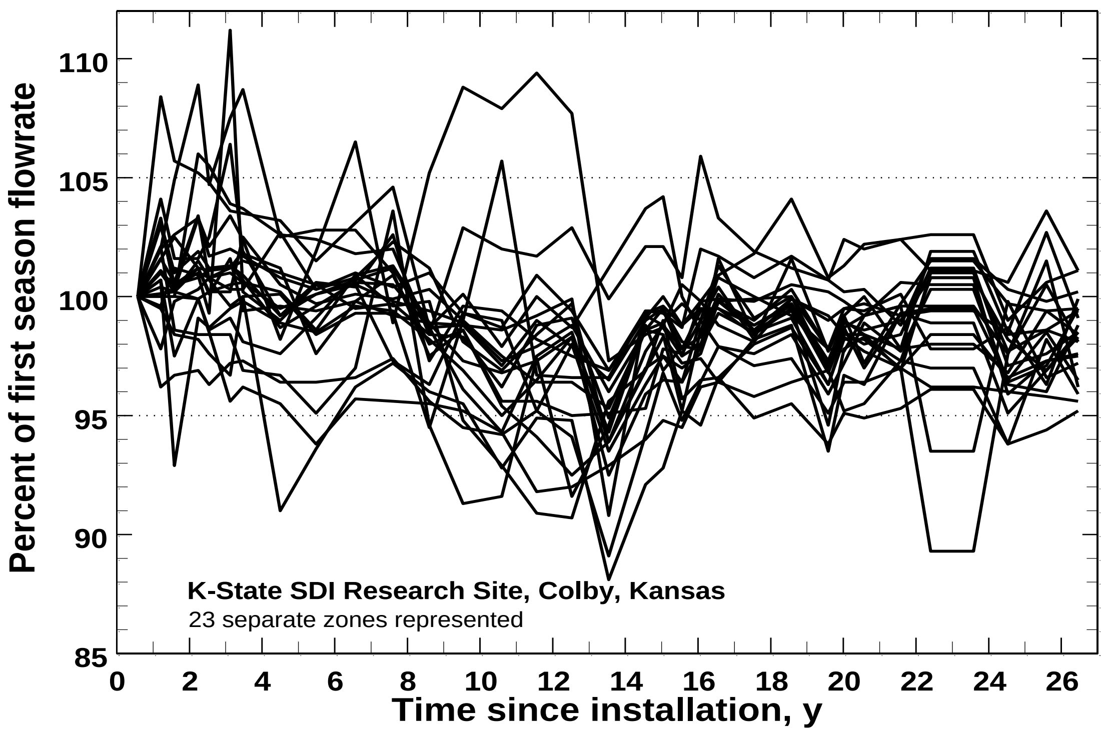

Figure 2. Plot flowrates as affected by years of operation for a 23-zone research SDI system at the KSU Northwest Research-Extension Center, Colby Kansas (1989-2015).

Similarly, corn production was excellent on the SDI system installed in 1989, averaging 232 bushels/acre (Fig. 3) with the exclusion of the year 2011, when the crop was destroyed by a hail event.

These flowrate and corn yield results indicate that with a good design, installation and maintenance protocol, an SDI system can have a long life in the Central Great Plains. There are a few SDI systems in the USA that have been operated for over 25 years without replacement (Lamm and Camp, 2007). There are other SDI systems on commercial farms in Kansas that are approximately 20 years old without replacement and it will be interesting to see how long they will remain operational.

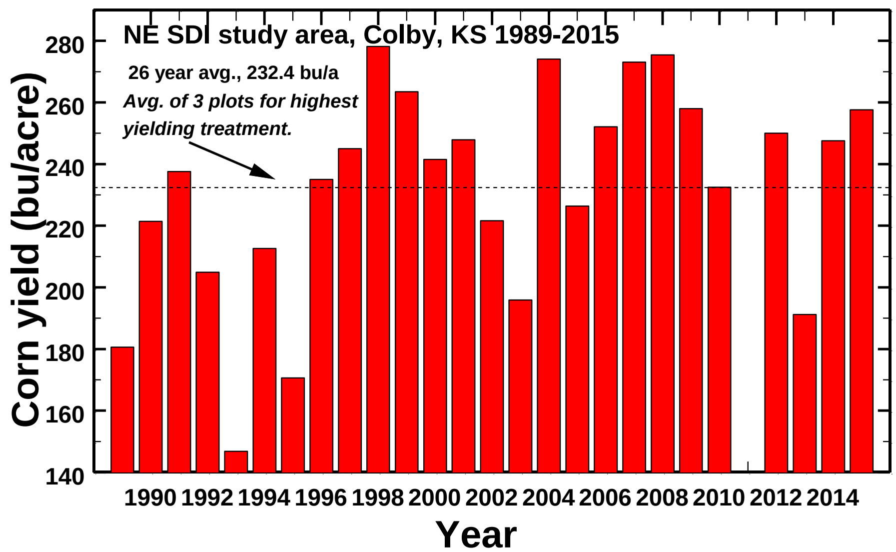

Figure 3. Corn yields as affected by years of operation for a 23-zone research SDI system at the KSU Northwest Research-Extension Center, Colby Kansas (1989-2015).

REQUIREMENTS FOR SDI LONGEVITY

Although the individual "requirements" for long term successful operation of an SDI system would likely vary from one system to the next, attention to some key factors such as water quality, system design and installation, cropping system, and operator maintenance practices would likely increase system longevity.

Water Quality and SDI Longevity

Historically, the worldwide primary cause of microirrigation system failure is emitter clogging. Replacement of clogged subsurface driplines can be expensive, difficult, and time-consuming. Therefore, the quality of the water source must be considered as a key factor in SDI longevity. It is so important the authors believe it should be the initial step in deciding if SDI is a viable option for you. Although, waters with many clogging hazards can and have been used with microirrigation systems, the producer needs to consider if the required effort to handle such difficult waters is both economical and practical for their farming operation. The authors believe some SDI systems that have been installed in the Great Plains were not a wise decision based on the quality of the water the systems are using. Some of these SDI systems may succeed through perseverance and the learning of appropriate maintenance procedures, but still may be cumbersome and frustrating to the producer.

A recommended 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 the 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.

Additional information on assessing water quality and developing water treatment plans are available from a number of sources (Rogers et al., 2003a; Burt and Styles, 2007; Schwankl, et al., 2008).

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. **pH_C**, a calculated pH obtained from the Calcium (Ca^{2+}), Bicarbonate (HCO_3^-) and total salt concentrations of the water.	Ideal pH – pH_C <0
4. **Cations** include Calcium (Ca^{2+}), Magnesium (Mg^{2+}), and Sodium (Na^+), measured in measured in meq/L, (milliequivalent/liter).	Ideal <2meq/L
5. **Anions** include Chloride (Cl^-), Sulfate (SO_4^{4-}), Carbonate (CO_3^{2-}), and Bicarbonate (HCO_3^-), measured in meq/L.	Ideal <2meq/L
6. **Nitrate nitrogen (NO_3 - 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. **Presence of oil***	-

** 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.*

Design Considerations for SDI Longevity

The SDI system design must consider individual management constraints and goals, as well as account for specific field and soil characteristics, water quality, well capabilities, desired crops, production systems, and producer goals. However, certain basic features should be universal throughout all SDI systems (Fig. 4). 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. A much longer and more detailed discussion of SDI design requirements is provided by Lamm et al. (2014) and Rogers et al. (2003b), so this discussion will be limited to specific design aspects and components that contribute greatly to system longevity.

Filtration system

The heart of the protection system for the dripline emitters is the filtration system. Many types of filtration systems are commercially available and the selected type depends on the quality characteristics of the irrigation water and the clogging hazards. Screen filters are the simplest type of filtration and are most often used in situations where the water source is relatively clean. Sand media or disc filtration is often used when there is greater amounts of physical contaminants in the water. Regardless of the type of filtration system that is selected, the scope or sizing of the filtration system is governed by the pumped flowrate and the amount of physical contaminants in the water. Filter systems are generally sized to remove particles that are approximately 1/10 the diameter of the smallest emitter passageway. Thus, the required level of filtration (often expressed in equivalent mesh size) should always and only be specified by the dripline manufacturer because they control the size of the smallest emitter passageway. Summarizing the important design aspects for SDI longevity related to the filtration system:

- Type of filtration system generally <u>should be</u> based on the physical contaminant load.
- Sizing or scope of the filtration system <u>should be</u> based on pumped flowrate and physical contaminant load.
- Level of filtration <u>must be</u> specified by dripline manufacturer.

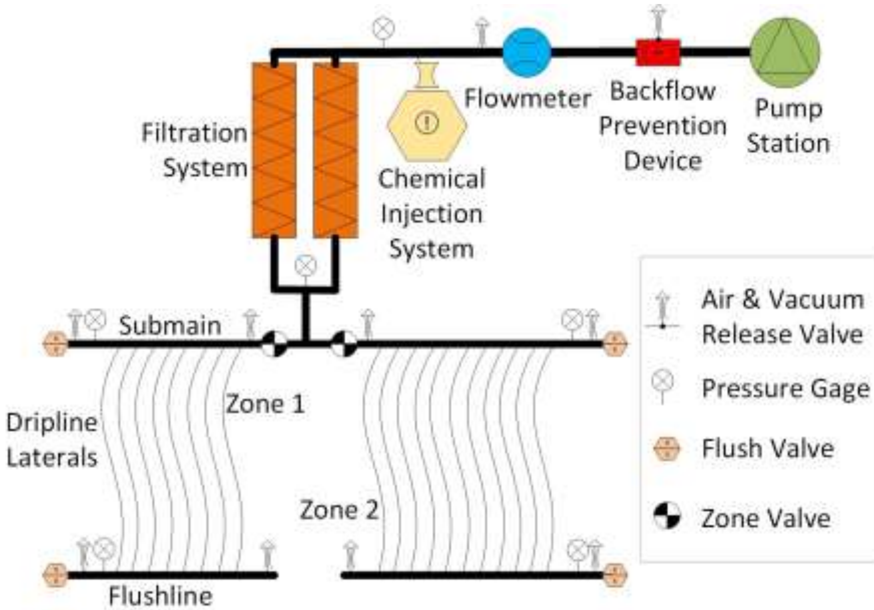

Figure 4. Minimum required components of an SDI system. Components are not to scale. After Rogers et al., 2003b.

Flushlines
A unique aspect of most SDI systems used for commodity crops in the Great Plains is the addition of a flushline at the distal end of the driplines to allow for convenient flushing of a group of driplines (usually either one-half or the entire zone). Even with good SDI filtration, small particles (e.g., silt, clay and bacteria) pass through the filter and into the driplines, and over time, they may clump together. Also, biological or chemical processes produce new contaminants that need to be removed in order to prevent emitter clogging or a build-up of material at the outlet or distal end of the system. The American Society of Agricultural and Biological Engineers (ASABE) recommends a minimum flushing velocity of 1 ft/s for microirrigation lateral maintenance (ASAE EP-405, 2008). This flushing velocity requirement needs to be carefully considered at the design stage and may dictate larger sizes for submains and flushlines to assure that maximum operating pressures for the driplines are not exceeded (Lamm and Camp, 2007). The frequency of flushing is largely determined by the quality of the irrigation water and, to a degree, the level of filtration. Recent research by Puig-Bargués and Lamm (2013) suggest that the duration of flushing is also important in moving greater amounts of contaminants out of the flushline.

Chemical injection system

In addition to enhancing SDI system protection and thus system longevity, the chemical injection system may also be used to inject nutrients or chemicals into the water to enhance plant growth or yield. Many different chemicals can be injected, including chlorine, acid, dripline cleaners, fertilizers, and some pesticides. Producers should avoid injecting any chemical into their SDI system without knowledge of the chemical compatibility with irrigation water. For example, various phosphorus fertilizers are incompatible with many water sources and may only be injected using additional precautions and management techniques. Some agrochemicals may require an injection point downstream from the filter to prevent filter damage or corrosion while other agrochemicals may require injection before the filter for protection against inadvertent chemical precipitation that would result in emitter clogging. Chlorine is commonly used to disinfect the injection system and minimize the risk of clogging from biological organisms. Acid injection can also reduce the pH chemical characteristic of the irrigation water. For example, water with a high pH can clog emitters easily because minerals drop out of solution in the dripline after the water passes through the filter. A small amount of acid added to the water to reduce the pH can minimize the potential for chemical precipitates.

Flowmeter and pressure gauges

Because all water application is underground for SDI systems, there are less visual cues of proper system operation available to the irrigator. A flow meter and pressure gauges at various points in the system can provide operational feedback cues to evaluate system performance. The flowrate and pressure measurements should be recorded and retained for the life of the SDI 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 as illustrated by examples in Lamm and Rogers (2009).

Installation Considerations for SDI Longevity

The primary interactions of SDI installation and SDI longevity are system reliability and robustness along with flexibility to accommodate cropping practices. To ensure longevity, the SDI system should not present an excessive amount of maintenance problems that frustrate the irrigator into poor maintenance or abandonment of responsibility.

Consideration should be taken to avoid SDI installation into excessively dry compacted or wet soils to avoid stretching and other damage to the dripline. It is important that dripline depth be uniform throughout the field, so that the planned depth of tillage operations can be obtained in all locations. Quality assurance and control (QA/QC) should be conducted throughout the installation process, especially with the extensive number of dripline connections to submains and flushlines. Choose a dripline connection procedure that is easy to successfully replicate and that will be durable for the anticipated life of the system.

Maintenance Considerations for SDI Longevity

Maintenance for a well-thought-out SDI system, design, and installation is not necessarily complicated, but it should be timely and consistent throughout the life of the system. Part of the process in establishing a well-thought out system begins with the decision-making process before purchasing the system. Does the water quality present concerns that will result in excessive or cumbersome water treatment requirements, in which case a better alternative method of irrigation such as center pivot sprinkler irrigation might be the best decision? Does the consistent maintenance requirement work well with other tasks and priorities in the farming operation? Is the design and installation conducive to timely and consistent maintenance?

Routine maintenance would entail flushing and cleaning of the filtration system, with perhaps the periodicity governed by overall water quality and also by diagnosis of any problems suggested by monitoring pressures and flowrates. Observations of any emitter clogging or rodent leaks would require more immediate attention to limit further damage to the system. The manufacturers are experimenting with new agrochemicals and products that may help limit clogging and rodent damage, so producers should watch for advancements. Flushlines should be periodically flushed. Evaluation of the amount of debris caught in a mesh cloth during a flushing event is an indicator of the required frequency of flushing. When only a small amount of debris is found, the flushing interval may be increased. Heavy accumulations of debris, however, mean more frequent flushing is needed.

Much more information about maintenance of microirrigation systems can be found at http://micromaintain.ucanr.edu/

CONCLUDING STATEMENTS

The longevity of SDI systems is one of the most important factors in improving the economic competitiveness of SDI with alternative pressurized irrigation systems such as center pivot sprinkler irrigation. The life of an SDI system needs to be upwards of 15 years to be economically competitive and this appears possible in the Central Great Plains with proper design, installation and maintenance. There are a few systems that have operated 20 years or longer in the USA. Some Central Great Plains systems have been installed in areas with water quality problems and these systems will likely have a troublesome life that may be shortened by insufficient care. Consistent maintenance protocols are necessary to ensure SDI system longevity, but the maintenance is not necessarily complicated. Subsurface drip irrigation remains as an emerging technology in the Central Great Plains, with the knowledge base of successful practices increasing with SDI land area expansion and experiences.

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