

USING THE K-STATE CENTER PIVOT SPRINKLER AND SDI ECONOMIC COMPARISON SPREADSHEET - 2014

Freddie R. Lamm

Research Irrigation Engineer
Northwest Research-Extension Center
Colby, Kansas
Voice: 785-462-6281 Fax 785-462-2315
Email: flamm@ksu.edu

Daniel M. O'Brien

Extension Agricultural Economist
Northwest Research-Extension Center
Colby, Kansas
Voice: 785-462-6281 Fax 785-462-2315
Email: dobrien@ksu.edu

Danny H. Rogers

Extension Irrigation Engineer
Biological and Agricultural Engineering
Manhattan, Kansas
Voice: 785-532-5813 Fax 785-532-6944
Email: drogers@ksu.edu

Kansas State University

INTRODUCTION

In much of the Great Plains, the rate of new irrigation development is slow or zero. Although the Kansas irrigated area, as reported by producers through annual irrigation water use reports, has been approximately 3 million acres since 1990, there has been a dramatic shift in the methods of irrigation. During the period since 1990, the number of acres irrigated by center pivot irrigation systems increased from about 50 per cent of the total irrigated acreage base to about 93 percent of the base area. In 1989, subsurface drip irrigation (SDI) research plots were established at Kansas State University Research Stations to investigate SDI as a possible additional irrigation system option. Early industry and producers surveys have indicated a small but steady increase in adoption. It is estimated there are approximately 25,000 to 30,000 acres of SDI currently in Kansas. Although Kansas SDI systems represent less than 1 percent of the irrigated area, producer interest still remains high because SDI can potentially have greater irrigation efficiency and irrigation uniformity. As the farming populace and irrigation systems age, there will likely be a continued momentum for conversion to modern pressurized irrigation systems. Both center pivot sprinkler irrigation (CP) and subsurface drip irrigation (SDI) are options available to the producer for much of the Great Plains landscape (low slope and deep silt loam soils). Pressurized irrigation systems in general are a costly investment and this is particularly the case with SDI. Producers need to carefully determine their best investment options.

In the spring of 2002, a free Microsoft Excel¹ spreadsheet template was introduced by K-State Research and Extension for making economic comparisons of CP and SDI. Since that time, the spreadsheet has been periodically updated to reflect changes in input data, particularly system and corn production costs. The spreadsheet also provides sensitivity analyses for key factors. This paper will discuss how to use the spreadsheet and the key factors that most strongly affect the comparisons. The template has five worksheets (tabs), the Main, CF, Field size & SDI life, SDI cost & life, Yield & price tabs. Most of the calculations and the results are shown on the Main tab (Fig. 1).

This template determines the economics of converting existing furrow-irrigated fields to center pivot sprinkler irrigation (CP) or subsurface drip irrigation (SDI) for corn production.

Version 14.0, modified by F.R. Lamm, D. M. O'Brien, D. H. Rogers, 01-31-14

Field description and irrigation system estimates

	Total	Suggested	CP	Suggested	SDI	Suggested
Field area, acres	160	← 160	125	← 125	155	← 155
Non-cropped field area (roads and access areas), acres	5	← 5				
Cropped dryland area, acres (= Field area - Non-cropped field area - Irrigated area)			30		0	
Irrigation system investment cost, total \$			\$71,815	← \$71,815	\$202,617	← \$202,617
Irrigation system investment cost, \$/irrigated acre			\$575		\$1,307	
Irrigation system life, years			25	← 25	22	← 22
Interest rate for system investment, %	6.5%	← 6.5%				
Annual insurance rate, % of total system cost			1.60%	← 1.60%	0.60%	← 0.60%
Production cost estimates			CP	Suggested	SDI	Suggested
Total variable costs, \$/acre (See CF Tab for details on suggested values)			\$649.28	← \$649.28	\$634.29	← \$634.29
Additional SDI variable costs (+) or savings (-), \$/acre					Additional Costs → \$0.00	← \$0.00
Yield and revenue stream estimates			CP	Suggested	SDI	Suggested
Corn grain yield, bushels/acre		Suggested	220	← 220	220	← 220
Corn selling price, \$/bushel	\$4.70	← \$4.70				
Net return to cropped dryland area of field (\$/acre)	\$40.00	← \$40.00				
Advantage of SDI over Center Pivot Sprinkler *			\$/total field each year		\$2,010	
* Advantage in net returns to land and management			\$/acres each year		\$13	

You may examine sensitivity to Main worksheet (tab) assumptions on three of the tabs listed below.

Figure 1. Main worksheet (tab) of the economic comparison spreadsheet template indicating the 18 required variables (white input cells) and their suggested values when further information is lacking or uncertain.

ANALYSES METHODS AND ECONOMIC ASSUMPTIONS

There are 18 required input variables required to use the spreadsheet template, but if the user does not know a particular value there are suggested values for each of them. The user is responsible for entering and checking the values in the unprotected input cells. All other cells are protected on the Main worksheet (tab). Some error checking exists on overall field size and some items (e.g. overall results and cost savings) are highlighted differently when different results are indicated. Details and rationales behind the input variables are given in the following sections.

Field & irrigation system assumptions and estimates

Many of the early analyses assumed that an existing furrow-irrigated field with a working well and pumping plant was being converted to either CP or SDI and this still may be the base condition for some producers. However, the template can also be used to consider options for a currently center pivot irrigated field that needs to be replaced. The major change in the analysis for the replacement CP is that the cost for the new center pivot probably would not have to include buried underground pipe and electrical service in the initial investment cost. The analysis also assumes the pumping plant is located at the center of one of the field edges and is at a suitable location for the initial SDI distribution point (i.e. upslope of the field to be irrigated). Any necessary pump modifications (flow and pressure) for the CP or SDI systems are assumed to be of equal cost and thus are not considered in the analysis. However, they can easily be handled as an increased system cost for either or both of the system types.

Land costs are assumed to be equal across systems for the overall field size with no differential values in real estate taxes or in any government farm payments. Thus, these factors “fall out” or do not economically affect the analyses.

An overall field size of 160 acres (square quarter section) was assumed for the base analysis. This overall field size will accommodate either a 125 acre CP system or a 155 acre SDI system. It was assumed that there would be 5 non-cropped acres consumed by field roads and access areas. The remaining 30 acres under the CP system are available for dryland cropping systems.

Irrigation system costs are highly variable at this point in time due to rapid fluctuations in material and energy costs. Cost estimates for the 125 acre CP system and the 155 acre SDI system are provided on the current version of the spreadsheet template based on discussions with dealers and O’Brien et al. (2011), but since this is the overall basis of the comparison, it is recommended that the user apply his own estimates for his conditions. In the base analyses, the life for the two systems is assumed to be 25 and 22 years for the CP and SDI systems, respectively. No salvage value was assumed for either system. This assumption of no salvage value may be inaccurate, as both systems might have a few components that may be reusable or available for resale at the end of the system life. However, with relatively long depreciation periods of 22 and 25 years and typical financial interest rates, the zero salvage value is a very minor issue in the analysis. System life is a very important factor in the overall analyses. However, the life of the SDI system is of much greater economic importance in analysis than a similar life for the CP system because of the much greater system costs for SDI. Increasing the system life from 22 to 25 years for SDI would have a much greater economic effect than increasing the CP life from 22 to 25 years.

When the overall field size decreases, thus decreasing system size, there are large changes in cost per irrigated acre between systems. SDI costs are nearly proportional to field size, while CP costs are not proportional to field size (Fig. 2). Quadratic equations were developed to calculate system costs when less than full size 160 acre fields were used in the analysis (O’Brien et al., 1998):

$$\text{CPcost\%} = 44.4 + (0.837 \times \text{CPsize\%}) - (0.00282 \times \text{CPsize\%}^2) \quad (\text{Eq. 1})$$

$$\text{SDIcost\%} = 2.9 + (1.034 \times \text{SDIsize\%}) - (0.0006 \times \text{SDIsize\%}^2) \quad (\text{Eq. 2})$$

where CPcost% and CPsize%, and SDIcost% and SDIsize% are the respective cost and size % in relation to the full costs and sizes of irrigation systems fitting within a square 160 acre block.

The annual interest rate can be entered as a variable, but is currently assumed to be 6.5%. The total interest costs over the life of the two systems were converted to an average annual interest cost for this analysis. Annual insurance costs were assumed to be 1.6% of the total system cost for the center pivot sprinkler and 0.6% for the SDI system, but can be changed if better information is available. The smaller value for the SDI was based on the assumption that only about 40% of the system might be insurable. Many of the SDI components are not subject to the climatic conditions that are typically insured hazards for CP systems. However, system failure risk is probably greater with SDI systems which might influence any obtainable insurance rate. The cost of insurance is a minor factor in the economic comparison when using the current values.

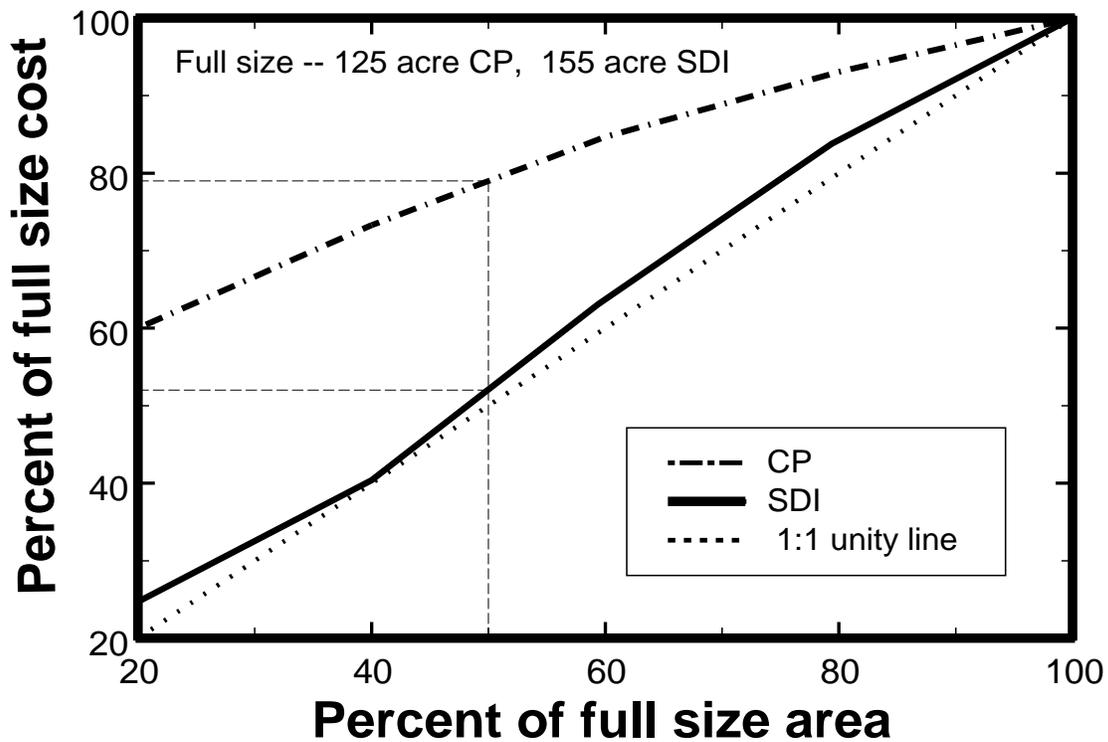


Figure 2. CP and SDI system costs as related to field size. (after O'Brien et al., 1998)

Production cost assumptions and estimates

The economic analysis expresses the results as an advantage of SDI or alternatively CP systems in net returns to land and management. Thus, many fixed costs do not affect the analysis and can be ignored. Additionally, the analysis does not indicate if either system is ultimately profitable for corn production under the assumed current economic conditions.

Production costs were adapted from KSU estimates (Dhuyvetter et al., 2014). A listing of the current costs is available on the CF worksheet (tab) (Fig. 3) and the user can enter new values to recalculate variable costs that more closely match their conditions. The sum of these costs would become the new suggested Total Variable Costs on the Main worksheet (tab), but the user must manually change the input value on the Main worksheet (White input cell box) for the economic comparison to take effect. *The user may find it easier to just change the differential production costs between the systems on the Main tab rather than changing the baseline assumptions on the CF tab. This will help maintain integrity of the baseline production cost assumptions.*

The reduction in variable costs for SDI is attributable to an assumed 25% net water savings that is consistent with research findings by Lamm et al. (1995). This translates into a 17 and 13 inch gross application amount for CP and SDI, respectively. The current estimated production costs are somewhat high reflecting increased energy and other related input costs, but fortunately crop revenues have also increased due to high demand for corn for ethanol production. This fact is pointed out because a reduction of overall variable costs favors SDI, since more irrigated cropped acres are involved, while greater overall variable costs favors CP production. The variable costs for both irrigation systems represent typical practices for western Kansas.

Factors for Variable Costs	CP		Suggested	SDI		Suggested
Seeding rate, seeds/acre	\$/1000 S	Suggested	34000	← 34000	34000	← 34000
Seed, \$/acre			\$3.52	← \$3.52	\$119.68	← \$119.68
Herbicide, \$/acre			\$64.92	← \$64.92	\$64.92	← \$64.92
Insecticide/Fungicide, \$/acre			\$30.15	← \$30.15	\$30.15	← \$30.15
Nitrogen fertilizer, lb/acre	\$/lb	Suggested	242	← 242	242	← 242
Nitrogen fertilizer, \$/acre			\$0.39	← \$0.39	\$94.38	← \$94.38
Phosphorus fertilizer, lb/acre	\$/lb	Suggested	50	← 50	50	← 50
Phosphorus fertilizer, \$/acre			\$0.52	← \$0.52	\$26.00	← \$26.00
Crop consulting, \$/acre			\$6.50	← \$6.50	\$6.50	← \$6.50
Crop insurance, \$/acre			\$34.00	← \$34.00	\$34.00	← \$34.00
Drying cost, \$/acre			\$0.00	← \$0.00	\$0.00	← \$0.00
Miscellaneous costs, \$/acre			\$0.00	← \$0.00	\$0.00	← \$0.00
Custom hire/machinery expenses, \$/acre			\$184.00	← \$184.00	\$184.00	← \$184.00
Other non-fieldwork labor, \$/acre			\$0.00	← \$0.00	\$0.00	← \$0.00
Irrigation labor, \$/acre			\$7.50	← \$7.50	\$7.50	← \$7.50
Irrigation amounts, inches			17	← 17	13	← 13
Fuel and oil for pumping, \$/inch			\$3.03	← \$3.03	\$3.03	← \$3.03
Fuel and oil for pumping, \$/acre			\$51.51	← \$51.51	\$39.39	← \$39.39
Irrigation maintenance & repairs, \$/inch			\$0.60	← \$0.60	\$0.60	← \$0.60
Irrigation maintenance & repairs, \$/acre		Suggested	\$10.20	← \$10.20	\$7.80	← \$7.80
1/2 yr. interest on variable costs, rate			6.5%	← 6.5%	\$20.44	← \$20.44
Total Variable Costs			\$649.28		\$634.29	

Figure 3. CF worksheet (tab) of the economic comparison spreadsheet template and the current production cost variables. Note that the sums at the bottom of the CF worksheet are the suggested values for total variable costs on the Main worksheet (tab).

Yield and revenue stream estimates

Corn grain yield is currently estimated at 220 bushels/acre in the base analysis with a corn price of \$4.70/bushel (See values on Main worksheet). Net returns for the 30 cropped dryland acres for the CP system (corners of field) were assumed to be \$40.00/acre which is essentially the current dryland crop cash rent estimate for western Kansas. Government payments related to irrigated crop production are assumed to be spread across the overall field size, and thus, do not affect the economic comparison of systems.

Sensitivity analyses

Changes in the economic assumptions can drastically affect which system is most profitable and by how much. The economic comparison spreadsheet also includes three worksheet (tabs) that display tabular and graphical sensitivity analyses for field size and SDI system life (Fig. 4), SDI system cost and life (Fig. 5), and corn yield and selling price (Fig. 6). These sensitivity analysis worksheets will automatically update when different assumptions are made on the Main worksheet. The elements in light blue of the sensitivity tables indicate cases where CP systems are more profitable while elements with negative signs in reddish brown are cases where SDI is more profitable.

This tab determines the CP and SDI economic sensitivity to field size, shape, and SDI system life.

The elements in the table (blue) represent the CP advantage in net returns per acre.

Field size	160	127	95	64	32	80	
CP Size	125	100	75	50	25	64	← Wiper 1/2 circle
CP Cost	\$574.52	\$670.12	\$808.81	\$1,053.78	\$1,723.90	\$1,122.11	
CP Dry	30	24	18	12	6	14	
SDI Size	155	124	93	62	31	78	
SDI Cost	\$1,307.21	\$1,336.29	\$1,367.77	\$1,415.05	\$1,525.51	\$1,387.51	
SDI life years	Note: This sensitivity valid only if full-sized CP (125 acres) and SDI (155 acres) costs exist on Main worksheet (tab) !!!!!!!						
5	\$183.15	\$184.70	\$182.85	\$174.93	\$154.12	\$168.26	
10	\$56.51	\$54.23	\$48.95	\$37.84	\$6.33	\$32.98	
15	\$14.30	\$10.74	\$4.32	-\$7.85	-\$42.93	-\$12.11	
20	-\$6.81	-\$11.01	-\$18.00	-\$30.70	-\$67.56	-\$34.66	
25	-\$19.47	-\$24.06	-\$31.39	-\$44.41	-\$82.34	-\$48.19	

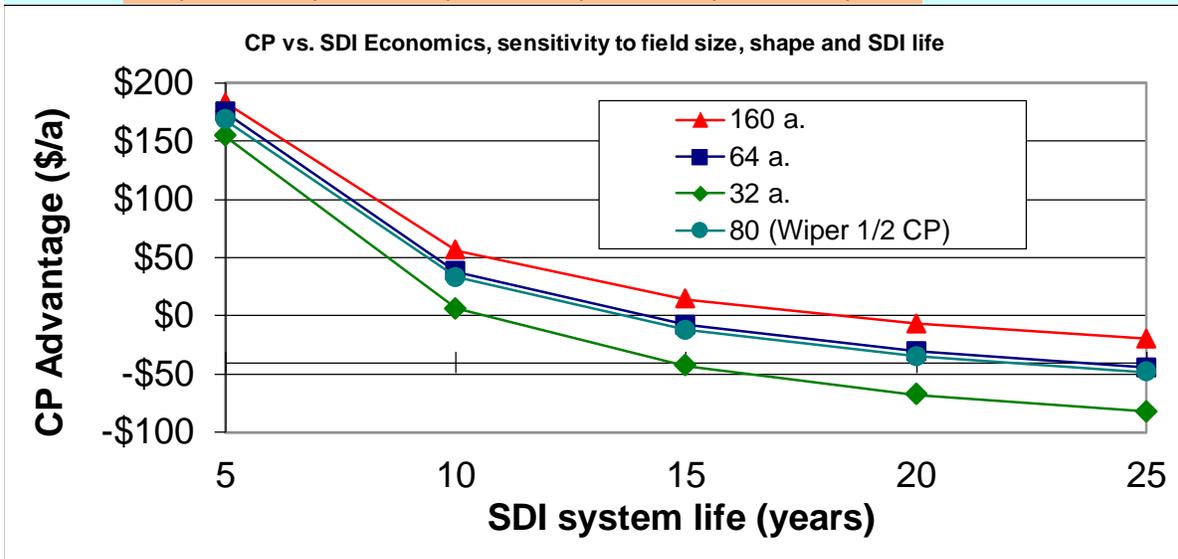


Figure 4. The Field size & SDI life worksheet (tab) sensitivity analysis. Note this is one of three worksheets (tabs) providing tabular and graphical sensitivity analyses. These worksheets automatically update to reflect changing assumptions on the Main worksheet (tab).

Previous analyses have shown that the system comparisons are very sensitive to assumptions about

- Size of CP irrigation system
- Shape of field (full vs. partial circle CP system)
- Life of SDI system
- SDI system cost

with advantages favoring larger CP systems and cheaper, longer life SDI systems.

The results are very sensitive to

- any additional production cost savings with SDI.

The results are moderately sensitive to

- corn yield
- corn price
- yield/price combinations

and very sensitive to

- greater potential yields with SDI

with advantages favoring SDI as corn yields and price increase.

This tab determines the CP and SDI economic sensitivity to SDI system life and SDI system cost.

The elements in the table (blue) represent the CP advantage in net returns per acre.

SDI Cost \$/acre	SDI system life, years					
	5	10	15	20	25	30
1000	\$112.17	\$15.29	-\$17.00	-\$33.14	-\$42.83	-\$49.29
1100	\$135.27	\$28.71	-\$6.81	-\$24.57	-\$35.23	-\$42.33
1200	\$158.38	\$42.13	\$3.38	-\$16.00	-\$27.62	-\$35.37
1300	\$181.48	\$55.54	\$13.57	-\$7.42	-\$20.02	-\$28.41
1400	\$204.59	\$68.96	\$23.75	\$1.15	-\$12.41	-\$21.46
1500	\$227.69	\$82.38	\$33.94	\$9.72	-\$4.81	-\$14.50
1600	\$250.80	\$95.80	\$44.13	\$18.30	\$2.80	-\$7.54

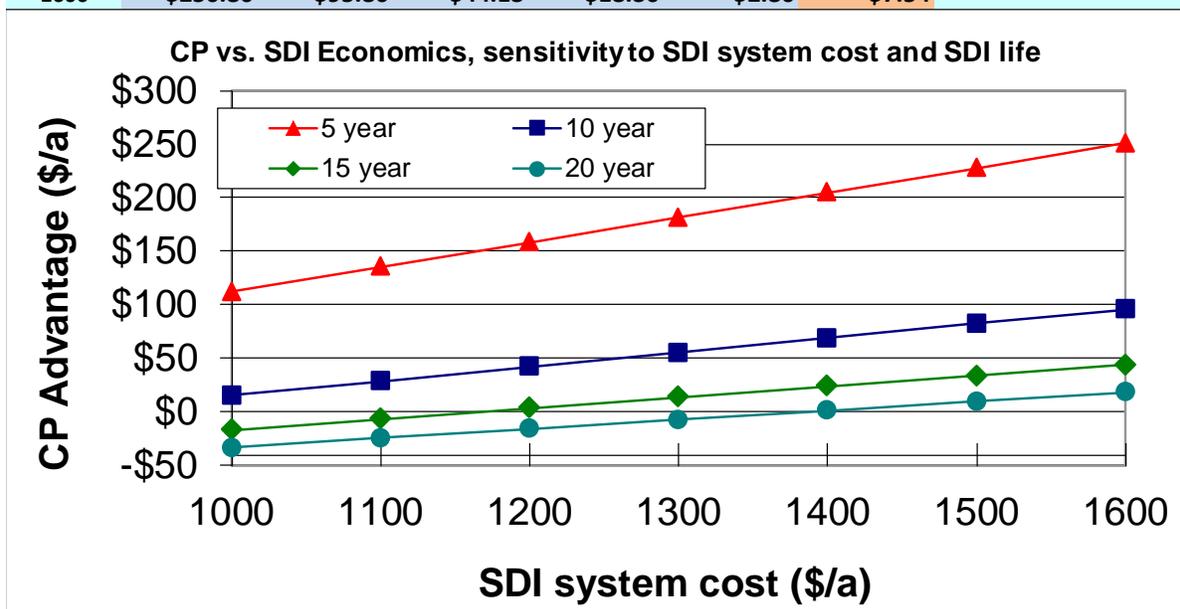


Figure 5. The SDI cost and life worksheet (tab) sensitivity analysis. Note this is one of three worksheets (tabs) providing tabular and graphical sensitivity analyses. These worksheets automatically update to reflect changing assumptions on the Main worksheet (tab).

This tab determines the CP and SDI economic sensitivity to corn yield and corn price assuming that corn yields are equal for both irrigation systems. The elements in the table (blue) represent the CP advantage in net returns per acre.



Corn Yield	Corn cash price, \$/bu							
	\$3.50	\$3.90	\$4.30	\$4.70	\$5.10	\$5.50	\$5.90	
160	\$76.31	\$64.31	\$52.31	\$40.31	\$28.31	\$16.31	\$4.31	
170	\$69.75	\$57.00	\$44.25	\$31.50	\$18.75	\$6.00	-\$6.75	
180	\$63.19	\$49.69	\$36.19	\$22.69	\$9.19	-\$4.31	-\$17.81	
190	\$56.62	\$42.37	\$28.12	\$13.87	-\$0.38	-\$14.63	-\$28.88	
200	\$50.06	\$35.06	\$20.06	\$5.06	-\$9.94	-\$24.94	-\$39.94	
210	\$43.50	\$27.75	\$12.00	-\$3.75	-\$19.50	-\$35.25	-\$51.00	
220	\$36.94	\$20.44	\$3.94	-\$12.56	-\$29.06	-\$45.56	-\$62.06	
230	\$30.37	\$13.12	-\$4.13	-\$21.38	-\$38.63	-\$55.88	-\$73.13	
240	\$23.81	\$5.81	-\$12.19	-\$30.19	-\$48.19	-\$66.19	-\$84.19	
250	\$17.25	-\$1.50	-\$20.25	-\$39.00	-\$57.75	-\$76.50	-\$95.25	
260	\$10.69	-\$8.81	-\$28.31	-\$47.81	-\$67.31	-\$86.81	-\$106.31	
270	\$4.12	-\$16.13	-\$36.38	-\$56.63	-\$76.88	-\$97.13	-\$117.38	

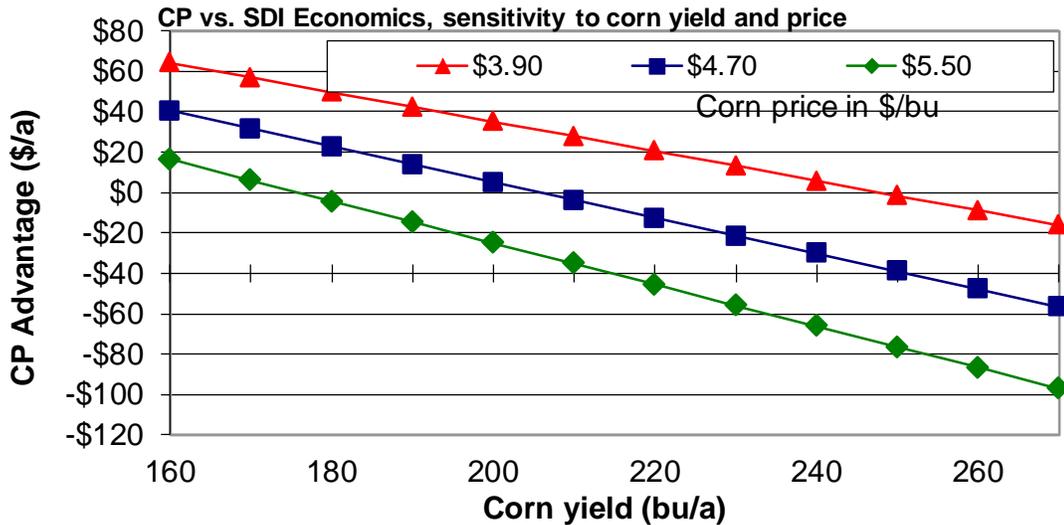


Figure 6. The Yield and Price worksheet (tab) sensitivity analysis. Note this is one of three worksheets (tabs) providing tabular and graphical sensitivity analyses. These worksheets automatically update to reflect changing assumptions on the Main worksheet (tab).

SOME KEY OBSERVATIONS FROM PREVIOUS ANALYSES

Users are encouraged to “experiment” with the input values on the Main worksheet (tab) to observe how small changes in economic assumptions can vary the bottom line economic comparison of the two irrigation systems. The following discussion will give the user “hints” about how the comparisons might be affected.

Smaller CP systems and systems which only complete part of the circle are less competitive with SDI than full size 125 acre CP systems This is primarily because the CP investment costs (\$/irrigated

acre) increase dramatically as field size decreases (Fig. 2 and 4) or when the CP system cannot complete a full circle. It should also be pointed out that part of the economic competitiveness of the more expensive SDI system with a less expensive CP system occurs simply because less land area of the field is in dryland crop production.

Increased longevity for SDI systems is probably the most important factor for SDI to gain economic competitiveness with CP systems. A research SDI system at the KSU Northwest Research-Extension Center in Colby, Kansas has been operated for 22 years with very little performance degradation, so long system life is possible. There are a few SDI systems in the United States that have been operated for over 25 years without replacement (Lamm and Camp, 2007). However, a short SDI system life that might be caused by early failure due to clogging, indicates a huge economic disadvantage that would preclude nearly all adoption of SDI systems (Fig. 4). Although SDI cost is an important factor, long SDI system life can help reduce the overall economic effect (Fig. 5). The CP advantage for SDI system lives between 15 and 20 years is greatly diminished as compared to the difference between 10 and 15 year SDI system life. The sensitivity of CP system life and cost is much less because of the much smaller initial CP cost and the much longer assumed life. Changing the CP system life from 25 to 20 years will not have a major effect on the economic comparison. However, in areas where CP life might be much less than 25 years due to corrosive waters, a sensitivity analysis with shorter CP life is warranted.

The present baseline analysis already assumes a 25% water savings with SDI. There are potentially some other production cost savings for SDI such as fertilizer and herbicides that have been reported for some crops and some locales. For example, there have been reports from other regions of less broadleaf and grassy weed pressure in SDI where the soil surface remains drier less conducive to germination of weed seeds (Lamm and Camp, 2007). Small changes in the assumptions can make a sizable difference in the economic analysis because there are more irrigated acres under the SDI system.

It has already been stated that greater corn yields and greater corn prices improve the SDI economics. These results can be seen on the Yield and Price sensitivity worksheet (tab) on the Excel template (Fig. 6). This result occurs because of the increased irrigated area for SDI in the given 160 acre field. The significance of yield and price can be illustrated by taking one step further in the economic analysis, that being the case where there is a yield difference between irrigation systems. Combining a greater overall corn yield potential with an additional small yield advantage for SDI on the Main tab can allow SDI to be very competitive with CP systems.

AVAILABILITY OF FREE SOFTWARE

A Microsoft Excel spreadsheet template has been developed to allow producers to make their own comparisons. It is available on the SDI software page of the K-State Research and Extension SDI website at <http://www.ksre.ksu.edu/sdi/>.

ACKNOWLEDGMENTS

This paper is also part of a SDI technology transfer effort beginning in 2009 involving Kansas State University, Texas A&M University and the USDA-ARS and is funded by the Ogallala Aquifer Program. To follow other activities of this educational effort, point your web browser to <http://www.ksre.ksu.edu/sdi/>. Watch for this logo.



REFERENCES

- Dhuyvetter, K. C., D. M. O'Brien, L. Haag and J. Holman. 2014. Center-pivot-irrigated corn cost-return budget in Western Kansas. KSU Farm Management Guide, MF-585. Manhattan, Kansas. 4 pp. Also available at <http://www.ksre.ksu.edu/bookstore/pubs/mf585.pdf>
- O'Brien, D. M., T. J. Dumler, and D. H. Rogers. 2011. Irrigation capital requirements and energy costs. KSU Farm Management Guide, MF-836. Manhattan, Kansas. 4 pp. Also available at <http://www.ksre.ksu.edu/bookstore/pubs/mf836.pdf>
- Lamm, F. R. and C. R. Camp. 2007. Subsurface drip irrigation. Chapter 13 in Microirrigation for Crop Production - Design, Operation and Management. F.R. Lamm, J.E. Ayars, and F.S. Nakayama (Eds.), Elsevier Publications. pp. 473-551.
- Lamm, F. R., H. L. Manges, L. R. Stone, A. H. Khan, and D. H. Rogers. 1995. Water requirement of subsurface drip-irrigated corn in northwest Kansas. Trans. ASAE, 38(2):441-448. Also available at <http://www.ksre.ksu.edu/sdi/Reports/1995/WaterReq.pdf>
- O'Brien, D. M., D. H. Rogers, F. R. Lamm, and G. A. Clark. 1998. An economic comparison of subsurface drip and center pivot sprinkler irrigation systems. App. Engr. in Agr. 14(4):391-398. Also available at <http://www.ksre.ksu.edu/sdi/Reports/1998/EconSDICP.pdf>

¹ *Mention of tradenames is for informational purposes and does not constitute endorsement by Kansas State University.*