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Economic evaluation of using surge valves in furrow irrigation of row crops in Louisiana: A net present value approach

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ABSTRACT

Addressing irrigation water efficiency continues to emerge as one of the potential solutions to minimize irrigation water use, improve water quality, and enhance soil health. Despite the clear importance of financial information in decision-making regarding adoption of irrigation tools, little information is available regarding the profitability outlook of such adoption. Lack of assessment of costs and returns could lead to producers resisting adoption citing profit reductions. Hence, a cost-assessment using the financial information is necessary to evaluate the tools' economic outlook. By using long-term projections of input prices, crop yield, and crop prices, this paper develops a financial analysis of irrigation using surge valves by calculating annual cash flows and net present value. The analysis is based on demonstration plot results and anecdotal estimates related to water savings and yield improvements in corn and soybeans in Louisiana and Mississippi. The positive estimates for net present value indicate that an investment in irrigation efficiency improvement is an economically sound choice. These estimates can enhance the adoption of irrigation-efficiency improvement practices by providing an initial understanding of the overall profitability independent of short-term management decisions.

1. Introduction

Gravity systems are the most common irrigation method in Louisiana. There are approximately 0.5 million hectares that receive water delivered through gravity systems, of which approximately half of those are irrigated through polypipe and the remaining half by open surface ditches and above surface pipes (USDA-FRIS, 2014). It is well documented that irrigation water application efficiency is relatively lower in furrow irrigation (Amosson et al., 2011) compared to other application methods such as center pivots/linear systems and drip irrigation. Conversion to one of the more efficient systems is an option; however, such a change often involves substantial upfront costs. Improving irrigation efficiency[1] using new technologies is becoming an important aspect of gravity systems. Any improvements in water management provide a diversity of benefits, not just to food production (Knox et al., 2010). Agriculture sits at the interface between the environments and society. Improving irrigation efficiency could mean saving water and promoting environmental sustainability.

Irrigation using surge valves in furrow irrigation of row crops is the focus of the analysis in this paper. A surge valve is used in furrow irrigation to run water down the field with on and off cycles of water delivered at the head of the furrow (Izuno and Podmore, 1986; Schaible and Aillery, 2012). Surge valves have been proven to improve irrigation water use efficiency in gravity systems (Horst et al., 2007; Shock et al., 1997). The method of irrigation has demonstrated its merits by reducing irrigation time, increasing infiltration uniformity (Podmore and Duke, 1982), and reducing nutrient loss to runoff from agricultural fields (Evans et al., 1995). On-farm demonstration of irrigation using surge valves in the Lower Rio Grande Valley has realized water savings as high as 50% in sugarcane and around 25% in cotton and corn compared to continuous irrigation (TexasAWE, 2013). Research comparing surge to continuous watering in furrow irrigation in fine loam soils has shown water savings in the range of 40–50% (Mitchell and Stevenson, 1993). Another research has shown water savings in the range of 20–30% (Varlev et al., 1998). Better soil moisture distribution along the furrow is one of the principal advantages claimed for irrigation using surge valves (Purkey and Wallender, 1988). Higher water application uniformity provides better soil nutrient distribution and consequently leads to higher crop yields (Pang et al., 1997). In a recent

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[1] One of the challenges in demonstration plot research is the issue of farmers imitating extension agents' practices and timing of production practices. Such imitation could lead to minimal differences in irrigation water use, irrigation timing, and crop yields.

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demonstration study in Mississippi, the use of irrigation using surge valves in corn produced a seven percent increase in yield coupled with a nine percent increase in returns (Krutz, 2014). The increase in returns accounts mostly from a reduction in irrigation costs, i.e., energy costs and irrigation labor costs. In Louisiana, a corn demonstration plot produced an 8.2 kg per hectare increase in yield with irrigation using surge valves compared to continuous irrigation (Burns, 2014). Studies have produced yield increases in the range of 29–40% in cotton under irrigation using surge valves compared to continuous flow furrow irrigation (Ünlü et al., 2007). The literature strongly suggests that irrigation using surge valves has its benefits in terms of reduction in irrigation water use, reduction in energy use, an increase in crop yields, and increase in net crop returns.

Despite the extensive amount of literature on irrigation efficiency, there has been a minimal effort to disseminate results from relevant research to help farmers make a sound economic assessment. Most farmer's concept of water efficiency improvements is linked to maximizing net returns, i.e., a financial view to water use. Using financial criteria for evaluating water efficiency appears to be a reasonable approach. The results are expected to provide a profitability outlook of irrigation using surge valves in the major row crops that are produced in Louisiana with an expectation that the results could be easily extended to other states in the region.

2. Materials and methods

The cropping system considered for analysis is a corn-soybean rotation on a 32-ha farm. This production system is the most common rotation pattern across Louisiana for corn and soybeans. Both crops are widely grown across the state and are mostly irrigated. Corn and soybean production area in 2014 was 160,000 and 566, 560 ha, respectively (USDA-FSA, 2014). The production area of these crops has steadily increased over the years across the state. Gross farm value of corn and soybeans in 2014 is valued at $298 million and $988 million, respectively (Westra and Nui, 2015).

For the financial analysis, Net Present Value (NPV) is used to determine the overall profitability of using surge valves for irrigation. NPV is commonly used to make agriculture decisions, especially when making first-time investment decisions. NPV, a long-term financial tool helps an individual or business decide whether to make an investment. Below is the mathematical representation of NPV calculation

$$NPV = -C_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} \quad (1)$$

where,

$-C_0$ = *Initial investment*; in US Dollars ($)

C_i = *Cash flow in year t*; in US Dollars ($)

r = *Discount rate*;

t = *Time period*; in years

NPV = *Net present value*; in US Dollars ($).

The first step in NPV calculation is to determine annual cash flow over a given period. For the analysis, a period of 10 years is used, beginning in the year 2015 and extending to the year 2024. To determine cash flow, net crop returns are estimated taking into account all crop-related expenses in the form of direct expenditures and crop revenues. Production cost values were obtained from the most recent Louisiana crop budgets published by Louisiana State University Agricultural Center (Deliberto et al., 2015a,b). Other cost categories, such as cost estimates for a surge valve and a controller are obtained from local irrigation dealers. Two surge valves and two controllers are assumed necessary for the 32-ha farm.[2] Initial cost, life, salvage value, depreciation, and taxes are accounted to estimate the per hectare cost of surge valves and controllers. The cost estimates for surge valves and controllers were obtained from Natural Resources Conservation Services' most recent cost document and as well as from local irrigation equipment dealers. The annual costs of adding two surge valves and controllers were $19 per hectare.

After determining the costs, the next step is to account for any savings because of using surge valves for irrigation. The Riparian Doctrine of water rights in Louisiana empowers the owner to use surface and ground water, the cost to use any such water is limited to the energy used to withdraw and apply the water to the field. Hence, water savings from irrigation using surge valves are converted to energy savings using Natural Resource Conservation Service's Irrigation Energy Cost Estimator (USDA-NRCS, 2012). Soybeans in the south require about 8.0–9.0 in. of irrigation water during their growing period (Heatherly, 2014; Kebede et al., 2014). Similarly, corn requires 13 inches of irrigation water during its growing period (Kebede et al., 2014). Accounting for the efficiency of furrow irrigation systems around 50% (Amosson et al., 2011), 16 and 26 in. of water needs to be pumped to deliver the necessary irrigation water required for soybeans and corn, respectively. On-farm demonstrations in the Mississippi delta region have shown water savings in row crops from using surge valves in furrow irrigation. Irrigation water savings were 50% in mixed to heavy soil types, whereas 40% in water savings in silt loam soils (Krutz, 2014). Water savings from surge valves in furrow irrigation in Northeast Louisiana is expected to be in the same range, mostly due to the fact that it the soils and crop production practices are similar to those in the delta region of the Mississippi state. As a result, water saving estimates in the range of 25% were used for the economic analysis, indicating that water savings from using surge valves account to approximately 4.0 and 6.5 in. for soybeans and corn, respectively.[3] These water saving estimates are used to generate energy savings.

The savings in energy costs are accounted during estimation of net returns. The cost savings are converted to current prices using consumer price index. Net annual crop returns are then estimated taking into account the most recent yield estimates and crop price received and all the related production costs. Change in input prices, crop yield, and crop prices from year to year is captured through crop indices reported by Food and Agricultural Policy Research Institute (Westhoff, 2015). The indices are estimates of baseline long-run projections for the U.S. agricultural sector. The most recent report provides projections up to the year 2024.

To determine discounted cash-flow (i.e., converting future annual crop net returns to present value terms), a discount rate of 5% is used for the analysis. The present values are aggregated to obtain the NPV estimate, which provides an indication of the overall farm profitability of adopting surge valves for irrigation. Finally, based on whether the investment needed to purchase surge valves and controllers is borrowed, a payment schedule is calculated for the time-period considered for the analysis. The payment

[2] Agricultural extension agents in Louisiana are promoting moving surge valves around the farm as a cost-saving measure. In other words, large farms can use one or two surge valves because these valves could be detached and connected to the other irrigation well risers across the farm.

[3] Demonstration plot research in the previous two years was affected by untimely rains followed by moderate drought, which affected proper measurement of water savings from surge irrigation. The water savings reported in this paper represent an average across demonstration plots, which are expected to provide a general understanding of potential water savings. Although the estimates reflect averages, the water savings realized are in the range that has been recorded on farms in Louisiana, Mississippi, and Arkansas. Moreover, there was no significant difference in water savings across demonstration plots.

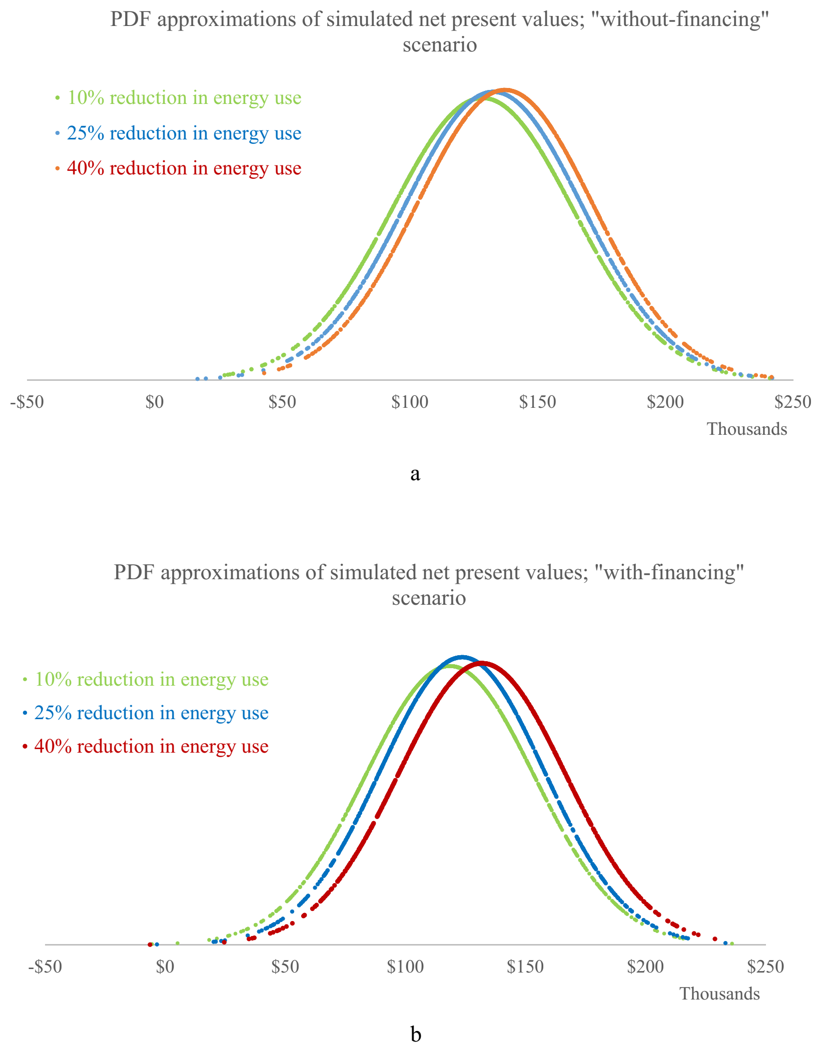

Fig. 1. PDF approximations of simulated net present values at various water (energy) reduction levels because of the adoption of surge valve for irrigation in a corn-soybean rotation assuming (a) without financing and (b) with financing.

calculation takes into account the interest rate, time-period, and the amount borrowed. The present values of net cash flows are calculated for a 10-year production scenario for two cases; one, assuming the cost of irrigation tools is entirely self-financed and/or cost-shared through a conservation agency, and two, the cost of irrigation tools is entirely borrowed. The former case is referred as 'without-financing' and the latter case as 'with-financing' in the remainder of the text. To estimate the payment schedule for the amount borrowed, a 6% interest rate is assumed. The annual interest rates and the loan period are based on discussion with local producers and financial experts.

The Monte Carlo simulation method is used to obtain the distribution of NPV based on the stochastic distribution of crop prices, energy prices, and yield. A sample of values for all stochastic variables is selected simultaneously, and the process is repeated 1000 times to estimate the probability density function for the stochastic outcomes. The simulations are carried out in MS Excel. Specifically, each probability density function (PDF) is derived for a unique water savings scenario. These are 10%, 25%, and 40%. The following stochastic variables are used to model NPV: crop price and energy price.

Table 1
Simulated NPV given a 25% reduction in irrigation water use given mean energy price[a].

	Mean	St. Dev	Minimum	Maximum
Without Financing	$132,637	$34,634	$16,761	$241,813
With Financing[b]	$123,632	$34,046	$(3420)	$233,223

[a] Mean energy price of $3.55 per gallon is used for simulating NPV estimates reported in the table.
[b] Payment amount toward financing the costs for irrigation tools for a completely financed scenario are calculated as $909 per year.

3. Results

Present values of future net returns for a corn-soybean rotation production system on a 32-ha farm are estimated. The mean of the present value of future net returns for a continuous flow system is $91,631 with a standard deviation of $35,046. The NPV estimates for a 25% water savings scenario are presented in Table 1. The present values of yearly net returns are initially negative and thereafter positive for the scenarios where the investment for the surge valves is either entirely self-financed or entirely borrowed. The initial negative returns produced are because of the investment that is needed to purchase the irrigation tools, making the overall farm profitability outlook negative in year one. Based on the assumptions and input parameters considered for this hypothetical 32-ha farm, NPV

Table 2
Simulated NPV for various levels of reduction in water (energy) use for a 32-ha corn-soybean rotation given mean energy price[a].

Mean energy price		Continuous flow irrigation	10% reduction in water application	25% reduction in water application	40% reduction in water application
$3.75/gal	Mean	$89,951	$125,513	$132,709	$136,759
	St. Dev.	$33,851	$35,002	$33,514	$35,521
	Minimum	$(1,923)	$(2,272)	$(7,270)	$(11,545)
	Maximum	$194,902	$243,429	$234,876	$239,084
$3.00/gal	Mean	$93,892	$134,037	$134,754	$143,311
	St. Dev.	$36,404	$36,570	$34,947	$35,133
	Minimum	$(1,403)	$(17,843)	$(14,629)	$(3,038)
	Maximum	$193,228	$243,833	$245,665	$254,715

[a] The estimates reflect the values for a "without-financing" financial scenario. The numbers are rounded to the nearest integer.

is positive, which indicate that investment in surge valves is an economically sound choice.

The distributions of NPV allow us to examine scenarios for changes in different variables such as crop prices and input prices. Fig. 1a and b shows the PDF approximations of simulated NPVs at various reductions in energy costs due to a decrease in expected water use. As expected, the NPV increases with a decrease in energy costs. PDF approximations of the simulated NPV for the two investment choices; without-financing and with-financing are presented in Fig. 1a and b, respectively. The graphs indicate that the overall profitability is not significantly different among various energy reduction levels within the scenarios.

Table 2 shows the summary statistics for the simulated NPVs for three different expected energy reduction scenarios under two mean energy price levels. As expected, mean NPV increases with greater savings in water use for irrigation, while the variance remains largely unchanged. Note that under high-energy price, savings to producers range from $222 per hectare at the mean (comparing 10%–25% savings in water application) to $346 per hectare at the mean (comparing 10%–40% savings in water application).[4]

4. Discussion

Irrigation efficiency practices are developed to allow agricultural operations to remain economically viable while minimizing irrigation water use and providing water quality as well as soil health benefits. Yet, comprehensive economic information is rarely part of the decision making process of whether to adopt such practices in one's production enterprise. The success of such practices is often measured based on agronomic research, with limited analysis of markets. In this paper, a farm-level economic model of corn-soybean rotation production in Louisiana is used to develop the profitability outlook of the adopting one such practice in a crop enterprise example.

Specifically, NPV estimates are calculated for adopting surge valves for irrigation, which is one of the several irrigation efficiency improvement tools. Assuming changes in water use because of adoption of surge valves as a stochastic variable, we showed the long-term profitability of adoption of surge valves. As expected, the results from the simulation show that NPV is highest for greater savings in irrigation water. The NPV estimates clearly show that an out-of-pocket investment (without-financing scenario) is a profitable option for farmers doing the corn-soybean rotation in the state. The analysis provides an initial understanding of the profitability outlook of adopting surge valves, which the farmers can use in their decision to whether such an expense to their current production practice would result in net profits.

Adopting surge valves have proven to reduce irrigation water use and the current analysis shows that surge valves are profitable on a long-term basis. Positive NPV estimates indicate that the adoption of these tools provide an economically sound investment option and would provide positive long-term returns. The analysis provides an initial financial outlook of adopting surge valves; however, data on yield improvement because of irrigation using surge valves would provide a more robust economic assessment. A formal economic analysis that takes into account input prices and yield expectations and their perceived relationship to irrigation water should be required as part of an assessment of any of these tools. Researchers could be overly optimistic about the effect of surge valves on profitability compared to farmers or vice versa, which would then require an outreach program discussing the existing-and-past research and experiences.

While the theory underlying the calculation of NPV is based on proven principles, there are many assumptions inherent in this type of analysis that could greatly affect the NPV calculation. It is important to consider that changes in commodity and input prices could materially change the expected returns per hectare that underlie the valuation of the particular irrigation tool in questions and could significantly affect the results. Similarly, change in farming methods over the timeframe of the analysis could also affect the result. Additionally, since NPV calculations in this paper are based upon forecasted expected cash flows and input costs, results may deviate in reality from the long-term predicted values.

Most farmers sensibly aim not over-or-under irrigate their crop; however, irrigation is often driven by the need to attain maximum yields, which often leads to applying irrigation more than the required agronomic demand. As a result, the increased costs of irrigation nullify the returns attributable from increased yield. In some instances, the costs of excess irrigation far exceed the increased returns from potential higher yield. In such cases, extension programs should encourage those crop producers that tend to over-or-under irrigate to adopt technologies that increase irrigation efficiency, reduce irrigation costs, and improve crop yields. Moreover, some prerequisite practices such as performing pump testing and evaluating energy alternatives (e.g. electric vs diesel) can ameliorate the benefits of adopting surge valves or any other irrigation efficiency improvement practices (e.g. moisture sensors). As mentioned earlier in the text, other crop management practices such as tillage operations, residue management, cover crops can add to the efficiency improvement achieved by surge valves, eventually providing distribution uniformity, reduced tail water, and consequent nutrient runoff from fields. In addition, improvement in efficiency is also influenced by the experience of the farmer

[4] Farmers across the Corn-Soybean growing regions of the state of Louisiana have indicated that the costs of surge valves is relatively low to get financing and is relatively higher to consider out-of-pocket investment. The numbers in Table 2 indicate that an out-of-pocket expense will produce an overall positive net profitability over the assumed 10-year period suggesting that surge valves is worth the investment. Presenting only the without-financing results was done in light of addressing the concern raised by most farmers.

and/or extension agent using surge valves. One of the reasons for not realizing spatial differences in water savings patterns could be attributed to large family farms in the region. The farms often managed by family members share information on new technologies to avoid costly mistakes and improve net profits.

Another interesting aspect is the concern raised by most producers that the cost-assistance programs offered through federal agencies are often not available to cover a single practice or an efficiency tool; however, are covered when part of a comprehensive management plan. Although such a systems approach could prove beneficial, it could come in the way of producers interested in adopting some efficiency practices and/or beneficial management practices but have voluntarily adopted other required practices. Identifying such farmers that wish to expand their production efficiency practices as part of a comprehensive conservation plan should be considered potential targets for enhanced conservation. Failure to identify such nuances could dramatically neglect conservation efforts that are voluntarily being adopted.

It is important to consider that financial information is one of the factors in a producer's decision-making process about specific management practices on a field. Analysis of economic information combined with agronomic research can help improve the adoption of these irrigation-efficiency improvement tools. A diversity of factors influencing the adoption and the variability in production and market conditions lead us to believe that policy approaches such as providing incentives along with a strong outreach program are necessary strategies to promote the long-term adoption of such tools. Moreover, a comprehensive economic analysis will enable the development of new water use policies.

Conflict of interest

The authors declare no conflict of interest.

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