Costs and Benefits of More Efficient Irrigation Systems for Florida Chipping Potato Production[1]

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Introduction

The goal of this article is to help producers and other interested parties understand how alternative irrigation systems can affect economic outcomes in agricultural operations. We used chipping potato production in the Hastings area in northeast Florida as an example to discuss factors to consider when selecting an irrigation system.

Investing in more efficient irrigation systems can provide significant advantages for producers. In a survey of 31 US eastern states, more than half of the surveyed farms that had improved their irrigation systems between 2003 and 2008 reported improved yield/quality (68%), reduced energy costs (57%), and/or reduced water applied (54%) (Table 1). These statistics presented a regional perspective on irrigation systems. In 2013, researchers at the University of Florida conducted a survey of Florida producers specifically on irrigation systems. The results of this survey generally complied with the regional data. For more information about irrigation systems and other drought-adaptation measures used by Florida producers, see the online presentation by Grogan and van Dijl at http://www.fred.ifas.ufl.edu/outlook-webcasts/. More information can be found in a study by van Dijl (2013).

Changes in the regulatory framework guiding water use (e.g., monitoring requirements, water fees, and reduction in water use permits) and possible reductions in water availability due to weather/climate conditions provide additional

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incentives for agricultural producers to invest in water conservation and water-efficient irrigation technologies.

In this article, we focused on chipping potato production in the Hastings area in northeast Florida (Figure 1). We first reviewed existing Florida-specific studies that identified the costs and benefits of switching to a subsurface drip irrigation system in potato production. Then we combined those cost and benefit estimates with the UF/IFAS chipping potato production budget to identify whether it is economically justifiable for producers to switch from a seepage irrigation system to a drip irrigation system or a tile drain irrigation system. Specifically, we estimated the value of switching irrigation systems over a ten-year period to enable producers to make better decisions regarding the long-term costs and benefits of alternative irrigation systems and water use.

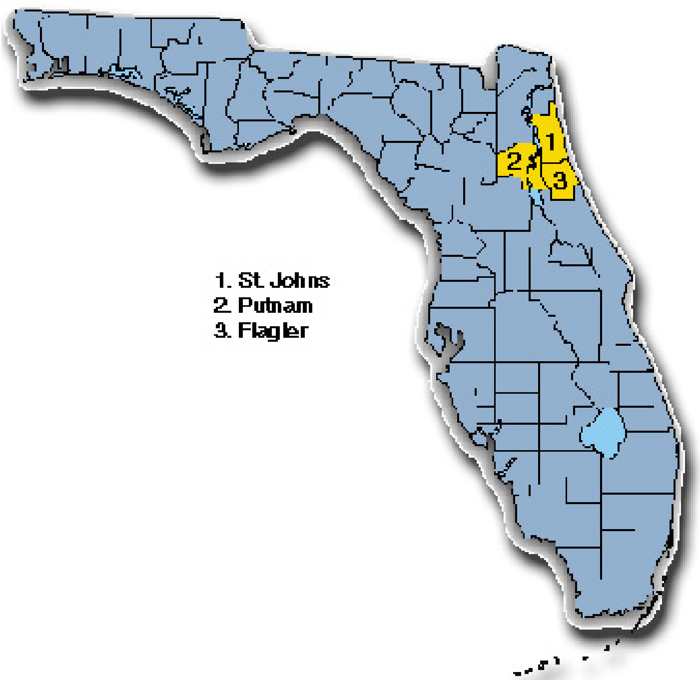

Figure 1. Counties in northeast Florida TCAA
Credit: Mossler and Hutchinson (2014)

Alternative Irrigation Systems for Florida Potato Production

The irrigation methods typically used in Florida potato production are described below.

Seepage irrigation is an irrigation system in which ground water is pumped from wells and delivered to furrows. These irrigation furrows are usually spaced 60 feet apart (the furrows set the boundaries to every bed, and each bed contains 16 potato rows). The furrow water seeps laterally across the rows. Growers use water retention structures to hold the water back in ditches to raise the water table (Reyes-Cabrera et al. 2014; Figure 2). The furrows, along with the cross-cuts, are also used to remove the water from the fields during high precipitation events (Zotarelli et al. 2013). Because historically most of the Florida potato fields were set up to use seepage irrigation, this system is the most familiar to the producers, and it is the least costly to operate. However, depending on the system management, irrigation efficiency with this system can be low (Table 2). Note that in the years with sufficient rainfall, irrigation may not be needed at all because the water table will be high enough to water plants effectively.

Drip irrigation is a micro-irrigation system that uses drip tapes placed either on the surface of the soil or four to five inches below the surface to supply water directly to the root zone (Reyes-Cabrera 2014; Figure 3). This method seeks to keep the water table low and to only place water needed

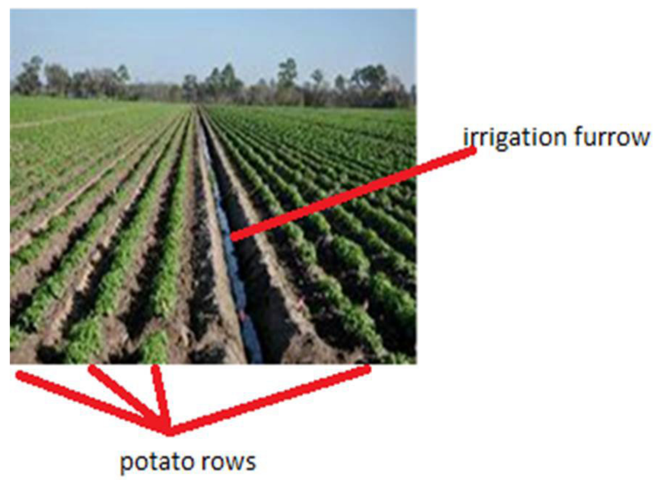

Figure 2. Traditional seepage irrigation system used to manage the water table for a potato crop in Hastings, Florida
Credit: L. Zotarelli, UF/IFAS

for plant growth at the plants' roots with one drip tape per potato row. Furrows between the beds are still required to remove excess water from the fields after rain. The advantages of the system are significant potential reductions in water use (Table 2) and opportunities for fertigation (with potential reduction in the use of fertilizers). A disadvantage is the high cost of maintenance (the drip tapes generally need to be replaced annually). For more information on drip irrigation, see Dukes et al. (2008).

Subsurface drip irrigation for water table management (WTM) is a system for which water is delivered under pressure through polyvinyl chloride (PVC) pipes (i.e., subsurface drip irrigation tape) buried two feet below the surface (Figure 4). The walls of the pipes are permeable, allowing water to enter the soil. These pipes are placed

Figure 3. Surface drip irrigation for potato production
Credit: L. Zotarelli, UF/IFAS

every fourth row in the field (or three to four drip tapes per a 60-foot-wide bed of 16 potato rows). Like seepage irrigation, subsurface drip irrigation for WTM allows for lateral seepage of water to raise the water table. In comparison with the seepage system, this system can result in water savings by eliminating water evaporation from the furrows during irrigation. However, compared to seepage irrigation, subsurface drip irrigation for WTM requires higher energy use to pressurize the water and pump it through the pipes. This system also requires annual cleaning, as well as daily spigot operation and maintenance. In addition, like seepage irrigation, subsurface drip irrigation for WTM requires furrows every 60 feet and cross-cuts in the field for drainage (Zotarelli et al. 2013).

Figure 4. Installation of subsurface drip irrigation tape at a depth of 24 inches below the soil surface in a potato field in Hastings, Florida
Credit: L. Zotarelli, UF/IFAS

Tile Drain (aka Irridrain or subsurface tile) uses corrugated 3- to 4-inch PVC pipes with permeable walls buried three feet deep every 20 to 25 feet (Figure 5). The pipes both irrigate and drain the field. The primary advantage of the tile drain irrigation system is the increased yield per area that is achieved by removing furrows to gain 11–12% more plantable ground. Another advantage is that the system decreases evaporation. Since this irrigation system does not require pressurized water pumping, energy use is comparable to seepage irrigation.

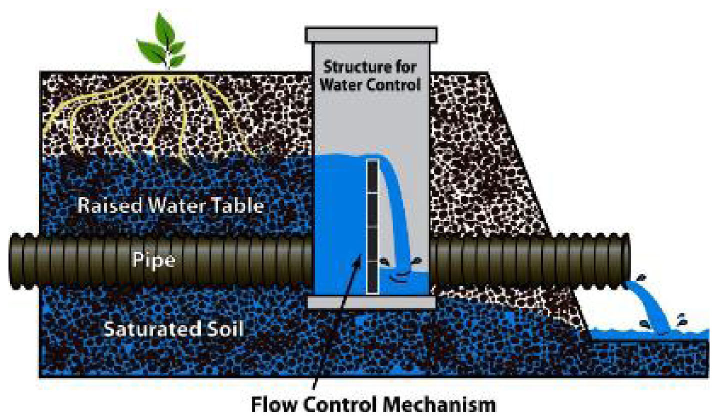

Figure 5. Title drain system
Credit: Illinois NRCS (2013)

In addition to irrigation efficiency, a variety of system characteristics are important for growers' choice of irrigation systems. Past studies have explored the changes in production costs and yields that can be attributed to replacing seepage irrigation with alternative irrigation systems (Table 3). The estimates vary widely among the studies, partially because of the different irrigation systems considered, the potato varieties examined, and the sizes of the farms analyzed. The previous studies highlight the variability in costs and benefits of alternative irrigation systems which is important for a producer to consider. Note, however, that these studies do not consider cost-share funding available from the USDA Natural Resources Conservation Service (USDA/NRCS) to reduce installation costs. The USDA/NRCS cost-share payment rate is provided to participating producers as part of the Environmental Quality Incentive Program (EQIP) that addresses natural resource concerns. A 75% cost-share rate is given to those who are farming within the designated USDA/NRCS Tri-County Agricultural Area (TCAA) to implement more efficient irrigation systems.

In this study, we specifically focus on the economics of two of the alternative irrigation systems: subsurface drip for WTM and tile drainage. We do not consider surface/subsurface drip irrigation systems because no Florida-specific studies evaluate the changes in input costs due to fertigation, which is a main advantage of these systems.

Methods and Data

To compare the economic performance of the irrigation systems, we estimated a ten-year net present value ($/acre) for each system. We disregard the costs of preparing the field for the use of the seepage irrigation system since such systems are installed on most Florida potato farms. The ten-year net present value, NPV, is estimated, where annual net returns are based on yields, prices, and production and harvesting costs. The year of irrigation system installation is assumed to be 2011. Because potato yield and price vary from year to year, 500 samples of ten-year period yields and prices are generated, and a distribution of NPV for each irrigation system type is generated using Simetar© Excel Add-In (Richardson 2001).

Seepage Irrigation, Baseline. This scenario is based on the chipping potato production budget (IATPC 2008/09) indexed to 2011 (US Bureau of Labor Statistics 2013). Information regarding average yield and price for chipping potatoes in Hastings, Florida, was obtained from the USDA for years 1984–2010 (Table 5). To forecast yields and prices for years 2011–2020, a simple regression model was used.

Subsurface drip irrigation for WTM. In this scenario, we assume that the producer installs a subsurface drip irrigation system for WTM in 2011. Note that the previous studies report a range of possible costs and benefits incurred by installing this irrigation system. In this study, we selected the following scenario, and the baseline budget for potato production was modified as follows:

- 70% increase in pumping costs (based on Smajstrla 2000)
- 25% increase in labor costs due to pipe cleaning and spigot maintenance (based on Casey 1996)
- Additional irrigation system depreciation, assuming a ten-year life span of the system and using straight-line depreciation methods

The installation costs for this system are estimated at $705 per acre based on the USDA/NRCS cost modeling procedure, with a $528.50 cost-share rate. Note that the scenario assumes an increase in production costs compared to the baseline seepage system. We also assume that expected potato yields remain the same as for the seepage irrigation system. Actual producer experiences in the field can differ.

Tile drain (Irridrain). The installation costs are estimated to be approximately $2,316 per acre based on a cost modeling procedure for determining cost-share amounts from the USDA/NRCS. In Hastings, Florida, potato producers could receive $1737 per acre for a tile drain irrigation system, which is approximately 75% of the estimated total installation cost. Also, the following modifications were made to the baseline budget (i.e., budget for the seepage irrigation method):

- 50% decrease in pumping costs (based on the data from one of the farms in Hastings, Florida, implenting tile drains)
- Additional irrigation system depreciation assuming a thirty-year life span of the system and using straight-line depreciation method

Because the system eliminates furrows and therefore allows for an 11–12% increase in plantable area as compared to a seepage system, for this scenario, we assumed a 10% increase in yields. Note that this specification ignores possible effects of increased potato yields and harvests on the potato sale price. This specification also assumes that the increase in the harvestable area does not affect yearly variability in yield.

Results and Discussion

Based on the information presented above, the ten-year NPV per acre for different irrigation systems is shown in Figure 6 and is summarized below:

- Seepage irrigation, baseline: ten-year NPV per acre, ranging from $1,729 to $20,671/acre, centered on an average NPV of $6,911/acre
- Subsurface drip irrigation for WTM: ten-year NPV per acre, ranging from $2,996 to $19,404, centered on an average NPV of $5,645
- Tile drain (Irridrain): ten-year NPV per acre, ranging from $1,155 to $21,289, centered on an average NPV of $9,209

Given the assumptions about the costs and benefits of the tile drain irrigation system, the financial analysis shows that Hastings potato producers can benefit by switching from a traditional seepage irrigation system to a tile drain irrigation system. The primary advantage of the tile drain irrigation system is the increase in plantable land area, and hence yields that offset the investment cost and the increase in operation and maintenance costs. As seen in Figure 6, the tile drain irrigation system represents the highest mean ten-year NPV.

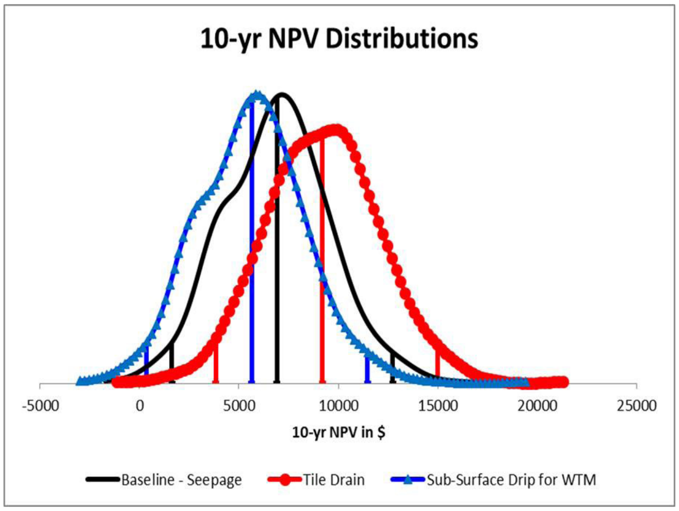

Figure 6. Ten-year NPV distributions of three irrigation systems
Credit: Authors' illustration

In contrast, given the assumptions about the increase in energy and labor costs, the subsurface drip irrigation for the WTM system does not yield as much of a benefit to the producers. In fact, it performs worse than the seepage irrigation system. Note the analysis is conducted using limited data, and hence does not account for all benefits that producers could experience from the system. For example, we did not have any information about the potential changes in yields due to potentially more effective water management provided by a subsurface drip irrigation for WTM system. To illustrate the importance of this assumption, we examined an alternative scenario for a subsurface drip irrigation for WTM system. Specifically, we assumed that the system increases yield and reduces pumping costs:

- 10% increase in yield
- 41% decrease in pumping costs (Casey 1996)
- 25% increase in labor costs due to pipe cleaning and spigot maintenance (Casey 1996)
- Additional irrigation system depreciation, assuming a ten-year lifespan of the system and using straight-line depreciation method

These modified assumptions significantly improved the performance of the subsurface drip irrigation for WTM system, making the ten-year NPV comparable with the baseline seepage irrigation system (despite the investment costs and potential increase in labor costs) (Figure 7): modified subsurface drip irrigation for WTM system, with ten-year NPV per acre, ranging from $1,768 to $19,438, centered on an average NPV of $9,338.

A summary of simulation results for the three irrigation systems is presented in Table 4. In addition, summary tables for the historic potato yields and prices (Table 5), as well as estimated average cost and revenue information for the three irrigation systems (Table 6) are provided.

Conclusions

Using an example of chipping potato production in the Hastings area of northeast Florida, we discussed the factors to be considered in selecting an alternative irrigation system. Based on the handful of existing studies, we developed scenarios to describe the potential benefits and costs of tile drain irrigation systems and subsurface drip irrigation for WTM systems, and compared these systems with the traditional seepage irrigation system.

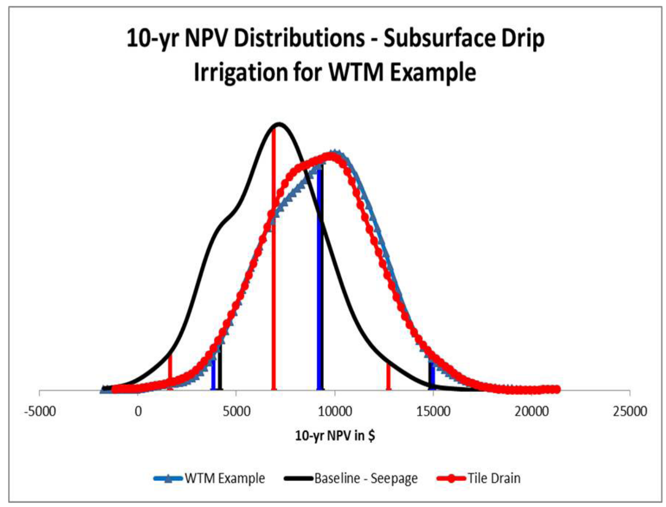

Figure 7. Ten-year NPV distributiosn of three irrigation systems, WTM example
Credit: Authors' illustration

Our analysis shows that changes in energy and labor costs can affect producers' decisions to invest in alternative irrigation systems. However, the potential increase in yields is the primary determinant of the profitability of more water-efficient irrigation systems. For example, a 10% increase in plantable area and a corresponding 10% increase in yields would make the tile drainage irrigation system out-perform the seepage irrigation system by approximately $2,000 per acre over a ten-year period. Similarly, a 10% increase in yield would make the financial performance of the subsurface drip irrigation for WTM systems comparable with the traditional seepage irrigation system, despite a potential increase in labor costs and depreciation. It is also important to mention that the

USDA/NRCS cost-share covers approximately 75% of the investment costs of more water-efficient systems, improving the financial performance for such systems.

Changes in the regulatory framework guiding water use (such as water-use monitoring requirements, water fees, or reduction in water-use permits), along with the possible reduction in available water due to weather/climate conditions, provide additional incentives for producers to invest in water conservation and water-efficient irrigation technologies. Furthermore, salinity concerns are significant in northeast Florida, as well as in other parts of the state. The tile drain irrigation system or the sub-surface drip irrigation for WTM system could be beneficial for reducing saltwater intrusion, and hence reducing/delaying the effect of salinity on yields.

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Table 1. Responses to a nationwide farm survey

Indicator	31 Eastern States
Number of farms implementing irrigation system improvements (since 2003)	11,926
Effect of system improvements (%)	
Improved crop yield/quality	67.6
Reduced energy costs	56.5
Reduced water applied	54.1
Reduced labor costs	34.7
Reduced fertilizer/pesticide loss	16.1
Reduced soil erosion	25.9
Reduced tail water runoff	11.5
Number of farms identifying barriers to energy and/or water conservation improvements (since 2003)	22,626
Barriers to making irrigation system improvements:	
Irrigation improvement not a priority	39.6
Risk of reduced yield or poorer crop quality	13.5
Physical field/crop conditions limit systems improvement	10.4
Cost reduction from improvement insufficient to cover installation costs	2.2
Cannot finance improvements	23.1
Landlord will not share costs of improvements	8.0
Uncertainty about future availability of water	4.8
Will not be farming long enough to justify improvements	11.3
Source: Schaible and Aillery (2012).	

Table 2. Irrigation efficiency of alternative irrigation systems

Irrigation System	Irrigation Efficiency
Surface or Subsurface Drip	70–95%
Subsurface Drip for WTM	65–85%
Seepage	20–80%

Note: According to Pitts et al. (2002), irrigation efficiency is measured by the percentage of the total water pumped, which is stored in the root zone of the plant.

Source: Smajstrla et al. (2002); Howell (2003); Zotarelli (2014).

Table 3. Summary of previous studies of drip irrigation for Florida vegetable production

Source:	Irrigation system and agricultural crop	Installation costs	Disadvantages (compared with seepage irrigation)	Advantages (compared with seepage irrigation)
Simonne et al. (2012)[1]	Sub-surface drip; small vegetable farms (10 acres)	$268/acre	$179/acre/year cost of irrigation system maintenance	Reduction in water use, pest problems, and pumping costs. Increase in production/yield. Increased efficiency of irrigation and fertilizer use
Reyes-Cabrera et al. (2014)[2]	Surface and subsurface drip without fertigation; potato	Not reported	A reduction in marketable yield was observed (e.g., *subsurface* drip for Atlantic, Fabula, and Red LaSoda potato varieties).	An increase in marketable yield is possible (e.g., for *surface* drip irrigation for Atlantic and Fabula potato varieties). Also, a reduction in water use was observed.
Dripmicrowizard.com (2008)[3]	Not specified (likely surface or subsurface drip); potato	$1,093/acre*	50% increase in energy costs; 20% increase in harvest costs	20% increase in yield and sale price, 50% reduction in costs of cultural practices and irrigation labor, and 20% reduction in fertilizer and chemical costs.
Smajstrla et al. (2000)[4]	Subsurface drip for WTM; potato	$612/acre*	70% higher energy use	37% reduction in water use (3-year average)
Casey et al. (1996)[5]	Subsurface drip for WTM; potato	$929acre *	Annual Fixed Costs: $212/acre* system layout, automated water control, and water supply system (5-year tubing life) Annual Variable Costs: $76/acre* (drip line cleaning, drip line flush, and electricity, plus 25% increase in labor costs)	42% savings in electricity costs

* The estimate is indexed to 2012 value using Producer Price Index industry data—new construction
[1] http://edis.ifas.ufl.edu/hs388#TABLE_1

[2] http://link.springer.com/article/10.1007%2Fs12230-014-9381-0

[3] http://www.dripmicrowizard.com/#

[4] https://elibrary.asabe.org/azdez.asp?AID=5147&T=2

[5] http://floridaswater.com/technicalreports/pdfs/SP/SJ97-SP9.pdf

Source: USBLS (2013).

Table 4. Summary of simulation results for three irrigation systems (seepage, subsurface drip for WTM, and tile drain)

Irrigation System	Estimated ten-year net present value, $/acre		
	Minimum	Mean	Maximum
Seepage	–$1,729	$6,911	$20,671
Sub-surface drip for WTM	–$2,996	$5,645	$19,404
Modified sub-surface drip for WTM	–$1,768	$9,338	$19,438
Tile drain (irridrain)	–$1,154.56	$9,209	$21,289

Table 5. Historical information of yield and price for potatoes in Hastings, Florida

Year	Yield (cwt/acre)	Price ($/cwt)
1984	260	7.35
1985	245	7.60
1986	280	6.05
1987	195	14.50
1988	235	4.50
1989	195	11.90
1990	240	8.25
1991	190	16.80
1992	240	5.05
1993	180	11.00
1994	220	6.50
1995	220	5.90
1996	230	9.50
1997	220	10.70
1998	235	10.70
1999	330	7.95
2000	295	7.20
2001	330	8.35
2002	275	10.70
2003	280	10.50
2004	320	7.45
2005	280	10.50
2006	285	14.20
2007	285	18.00
2008	285	13.90
2009	260	15.30
2010	250	14.60
Average	274.17	14.42

Table 6. Estimated costs and returns for chipping potato production in Hastings, Florida ($/acre), given alternative irrigation systems (assumed yield is 274 cwt/acre, price is $14.42/cwt, and indexing the 2008/09 budtget to year 2011)

Cost/Revenue Items	**Irrigation Systems**			
	Baseline Seepage	Tile Drain	Subsurface Drip for WTM	Modified Subsurface Drip for WTM
Pre-harvest variable costs				
Seed/transplants	$336.71	$336.71	$336.71	$336.71
Fertilizer mixed and lime	$601.03	$601.03	$601.03	$601.03
Crop insurance	$38.19	$38.19	$38.19	$38.19
Cover crop seed	$21.82	$21.82	$21.82	$21.82
Herbicide	$24.52	$24.52	$24.52	$24.52
Insecticide/Nematicide	$160.80	$160.80	$160.80	$160.80
Fungicide	$143.52	$143.52	$143.52	$143.52
Tractors & equipment	$451.75	$418.36	$498.50	$420.61
Farm truck cost (driver cost included in overhead and management expense)	$50.08	$50.08	$50.08	$50.08
General farm labor	$134.98	$134.98	$168.72	$168.72
Tractor driver labor expense	$175.02	$175.02	$175.02	$175.02
Aerial spray	$21.27	$21.27	$21.27	$21.27
Interest expense on variable costs per acre	$171.88	$171.88	$171.88	$171.88
Total pre-harvest variable costs excluding pre-harvest interest expense	$2,159.69	$2,126.30	$2,240.19	$2,162.30
Total pre-harvest variable costs including pre-harvest interest expense	$2,331.57	$2,298.18	$2,412.06	$2,334.17
Pre-harvest fixed costs				
Tractors & equipment	$111.21	$111.21	$111.21	$111.21
Land rent	$163.65	$163.65	$163.65	$163.65
Overhead and farm management cost	$486.26	$486.26	$486.26	$486.26
Total pre-harvest fixed costs excluding interest on fixed and overhead expenses	$274.86	$274.86	$274.86	$274.86
Total pre-harvest fixed costs including interest and overhead expenses	$761.11	$761.11	$761.11	$761.11
Total pre-harvest costs including total fixed and variable expenses	$3,092.69	$3,059.29	$3,173.18	$3,095.29
Harvest and marketing costs (HMC):				
HMC dig and haul	$209.25	$209.25	$209.25	$209.25
HMC grading	$89.68	$89.68	$89.68	$89.68
HMC containers	$0.00	$0.00	$0.00	$0.00
HMC organization fees	$0.00	$0.00	$0.00	$0.00
Other harvest and marketing costs	$0.00	$0.00	$0.00	$0.00
Total harvest and marketing costs	**$298.94**	**$298.94**	**$298.94**	**$298.94**
Total costs per acre	**$3,391.62**	**$3,358.23**	**$3,472.11**	**$3,394.22**
Irrigation system installation costs per acre		$2,316.00	$705.00	$705.00
Depreciation (begins 2012)		$77.20	$70.50	$70.50
Revenue per acre	$3,951.08	$3,951.08	$3,951.08	$3,951.08
NRCS cost share per acre		$1,737.00	$528.50	$528.50

* The baseline potato production budget for 2008/09 was indexed by multiplying the unit cost estimates by 1.091 to correct for inflation. Source: USBLS (2013)