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The Economic Feasibility of Automated Sub-drip Irrigation for Potato Production in Florida: A Synthesis Report

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Executive Summary*

This report investigates the costs and benefits associated with the conversion from semi-enclosed seep irrigation to either automated seep or automated sub-drip irrigation for potato production in Northeast Florida. These costs and benefits are estimated at the level of the individual grower and for the public at large. The analytical tools in the report include financial budgeting and regression analysis.

Cost analysis shows that an incremental conversion from manual to automated seep irrigation results in a net savings of about $7/acre. Incremental conversion to sub-drip irrigation, however, results in a net increase in annual production costs of $178/acre.

Net returns are highest for the automated semi-enclosed seep system. Net revenues are sensitive to yield and price levels, the variety of potato marketed, and the timing of marketing.

A regression analysis of experimental data shows that (1) yield significantly varies between the head and tail of the irrigation system, and (2) conversion from an automated seep irrigation system to an automated sub-drip system results in a loss in net revenue of $129/acre.

Based on the results of the financial budgeting analysis, and in the absence of any demonstrated improvements in yield or decreases in complementary production costs, potato growers cannot be expected to convert to sub-drip irrigation. There is, however, a potential increase in net revenue of about $7/acre through automation of the current semi-enclosed seepage irrigation system.

Social benefits of automated seep and sub-drip irrigation systems are comprised of lower amounts of water for irrigation (conservation) and decreased drainage flows (environmental protection); however, insufficient information is available to quantify these public benefits, and further research is required.

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Introduction

This synthesis report investigates the potential willingness of potato producers in the Tri-County area (Putnam, St. Johns and Flagler counties) to invest in an automated seep or sub-drip irrigation system and the conditions that would have to exist for such investment to be feasible. The report has two objectives: (1) to provide a financial and economic analysis of automated seep and sub-drip irrigation and (2) to compare the costs and benefits of these systems to the traditional manual seep irrigation system. The report combines previous preliminary financial benefit and cost analyses with new production and economic information gathered in the 1996 production year (Casey et al., 1996a and 1996b).

Automated seep and sub-drip irrigation systems were tested and studied at the Hastings Research Center Experimental Farm in 1995 and 1996. The goal of this research was to determine if automated seep or sub-drip irrigation could be a technically and financially feasible alternative to the manual seep system.

The next section provides a literature review and comparative analysis of the costs associated with various irrigation systems. Costs are analyzed for two situations: the setup of a new operation and the conversion of a manual seep system to either an automated seep or a sub-drip system. Capital investment costs, annual fixed costs, and variable costs associated with each of the irrigation systems are compared. Section 3 incorporates updated cost figures to provide new estimates of net returns for each system type. Section 4 explores private and public benefit/cost ratios for system conversion. Section 5 applies a regression model to physical and economic data to analyze what factors influence irrigation water use, crop yield, and net revenue. The final section summarizes conclusions and offers recommendations for further research.

Irrigation System Cost Analysis

This section first provides a literature review of the costs associated with drip systems for tomatoes, the only other crop in Florida for which the economic viability of drip irrigation has been investigated. Secondly, it updates previous estimates of capital investment, fixed ownership, and operating costs (Casey et al., 1996a and 1996b) for traditional semi-enclosed seep, automated seep, and sub-drip potato irrigation systems for the 1996 production year.

Literature Review of Drip Irrigation System Costs

Several studies provide drip irrigation system costs for tomatoes in Florida, but only one gives potato cost and return estimates (Libbin et al., 1989). Pitts et al. (1988) evaluate the economic feasibility of in-bed drip irrigation on tomato production and compare its cost with open-ditch and semi-enclosed seepage irrigation systems. Results from their study indicate that the yield and quality of fruit produced using the drip system are comparable to that of the fruit produced using seep irrigation; however, significantly less water is used with the drip system. Although the installation and management of the drip system are more expensive, pumping costs are not. Nonetheless, the additional capital costs associated with drip systems as compared to semi-enclosed seepage systems are estimated at $136/acre.

Pitts and Clark (1990) conducted a study over three seasons to compare the costs of in-bed drip on tomatoes to the costs of a traditional semi-enclosed seepage irrigation system. Although the authors state that on-station results show that yield and quality are not affected by the type of irrigation system, they did observe that drip-irrigated tomatoes were bigger on average, a characteristic that results in a price premium. Labor costs are not included in the study. The authors maintain that management and labor costs for drip irrigation could be significant because of high maintenance requirements associated with water treatment and filtration, pressure maintenance, and the repair of punctures on drip tubes. The use of in-bed drip results in an estimated savings of $44/acre for pumping over the traditional seep system; however, the additional total cost for in-bed drip (excluding increased labor requirements and improved tomato quality conditions) is estimated at $132/acre more than the additional cost for the traditional semi-enclosed seep system.

A risk-return analysis conducted by Prevatt et al. (undated) examines the effect of adopting drip irrigation on tomato production as a means of increasing expected returns and decreasing financial risk. They conclude that the adoption of drip irrigation for single- and double-cropped production systems results in lower levels of expected returns and higher levels of financial risk.

Using the equal yield assumption, Prevatt et al. (1992) conduct a comparative cost analysis for three tomato irrigation systems: semi-enclosed seep, fully enclosed seep, and in-bed drip irrigation. The fully enclosed seep system uses drip tubing to apply sub-surface water instead of lateral ditches. Thus, the fully enclosed seep system is the same as the sub-surface drip system that is currently being tested at Hastings. Capital investment, fixed ownership, and variable costs are estimated for each irrigation system. The results indicate that investment costs for in-bed drip are significantly higher than those for the semi-enclosed and fully enclosed systems. Variable costs for the semi-enclosed system were much lower than those for the fully enclosed and in-bed drip irrigation systems. The cost of the drip tube is the main difference between the estimated variable costs. The semi-enclosed system is therefore the least expensive tomato irrigation system under prevailing fuel costs and nonlimiting water supply conditions.

Everett et al. (1987) investigate the yield effect for two irrigation systems used on tomatoes. They report that total gross sales of in-bed drip-irrigated tomatoes averaged $1,561/acre more than sales of traditional semi-enclosed seep-irrigated tomatoes because of the increased yield and premium prices of larger tomatoes. As a result of higher yields, however, harvest and packing costs for drip-irrigated tomatoes are estimated at $691 more than those for traditional seep-irrigated tomatoes. Furthermore, the capital cost of the drip system is estimated to be $400/acre more than the cost of the traditional seep system. Despite these increased costs, it is estimated that the in-bed drip system will result in a $470/acre increase in income over the traditional seep system.

In the case of potatoes, Libbin et al. (1989) estimate that total annual irrigation costs for furrow-irrigated potatoes in New Mexico are about \$46/acre. Total production costs for drip-irrigated potatoes are estimated at about \$89/acre.

This review shows that most researchers have found in-bed drip irrigation used with tomatoes in southwest Florida to result in higher total costs per acre than the traditional seep systems. Although seasonal pumping costs decrease, fixed ownership costs increase because of the required capital investment. Previous analyses, which conclude that drip is not profitable for use with tomatoes, have assumed that there would be no difference in product yield or quality. Other research has shown that in-bed drip irrigation of tomatoes can be profitable if yield and quality differences are taken into account.

Analysis of Investment, Fixed Ownership, and Variable Costs for a New Installation

The cost analysis presented here is based on the assumption that a grower is deciding what type of irrigation system to use on a new parcel of land and not simply converting their current system to an automated seepage or a sub-drip system. This section also provides a cost analysis of the conversion of a manual seep system to either an automated seep or a sub-drip system.

The initial capital investment, fixed ownership, and variable costs for a new installation are analyzed for each of the three irrigation systems. The semi-enclosed seep irrigation system represents the baseline case.

Since none of the potato growers in North Florida use automated seep or sub-drip systems, the cost data for these irrigation systems are gathered from on-station trials and local equipment dealers. Those on-station material costs, which can be classified as aids to the research effort and which would not normally be incurred as part of producers' operations, are not included. For example, costs for a pressure tank and monitoring costs associated with measuring water usage in each of the experimental plots are ignored. On-station costs should reflect costs that commercial producers will actually face.

Capital Investment Costs

Capital costs are investments in basic irrigation infrastructure and equipment without which production could not take place. Table 1 shows expected initial capital costs (on a per-acre basis) for three components of the three alternative irrigation systems: water supply system; irrigation system layout; and automated water control. Two scenarios of the system layout costs of the automated sub-drip irrigation system are presented: (1) 20-foot spacing of drip lines (three drip lines per bed row) and (2) 30-foot spacing (two drip lines per bed row).

Table 1. Initial Capital Investment Costs for Traditional Seepage, Automated Seepage, and Automated Sub-drip Irrigation Systems, Hastings, Florida, 1996.

Item	Semi-enclosed Seep System	Automated Seep System	Automated Sub-drip System (3 tubes/bed)	Automated Sub-drip System (2 tubes/bed)
	--------------------	$/acre	--------------------	
Water Supply System				
Well (a)	98.00	98.00	98.00	98.00
Pump, power unit, & control box	67.00	67.00	67.00	67.00
Filtration	0.00	0.00	44.00	44.00
Water supply subtotal	165.00	165.00	209.00	209.00
System Layout				
PVC pipe (b)	54.00	54.00	54.00	54.00
Valves, fittings, & bushings	38.50	38.50	80.50	80.50
Drip tubing	0.00	0.00	218.00	145.00
Chemical injection pump	0.00	0.00	7.00	7.00
Flush valves	0.00	0.00	53.00	35.00
System layout subtotal	92.50	92.50	412.50	321.50
Automated Water Control				
Monitoring well, float device, & float switch	0.00	41.50	41.50	41.50
Automation equipment (c)	0.00	1.70	1.70	1.70
Automated water control subtotal	0.00	43.20	43.20	43.20
Total for initial capital investment costs	257.50	300.70	664.70	573.70

(a) Costs assume a 6" wide and 265' deep well at $14.75/foot.
(b) Costs assume 6" pipe at $1.64/foot for 33 feet per acre.
(c) Equipment includes solenoid valves, regulators, fittings, and pipes.

Water Supply System. The water supply system consists of a well, pump, power unit, and filtration device; the pump, power unit, and control box are usually sold as one unit. The well cost is typical for the Hastings area. Pumps are submersible turbines, and although some growers still irrigate using centrifugal pumps, several growers have invested in submersible turbines because recent declines in the water table have forced them to use higher powered pumps. The filtration device is required for the sub-drip system to prevent drip lines from being clogged by sand.

Initial capital investment costs for the water supply system are estimated at $165/acre for manual and automated seep systems and $209/acre for an automated sub-drip system. The differential can be attributed to the cost of the filtration device.

Irrigation System Layout. Irrigation system layout costs consist of the costs of PVC pipe and valves, fittings, and bushings for the manual and automated seep irrigation systems. The automated sub-drip system requires additional equipment including drip tubing, a chemical injection device to clean drip tubes, and flush valves. System layout costs for the manual and automated seep systems are estimated at about $93/acre, compared to about $413/acre and $322/acre for the three-tube and two-tube automated sub-drip systems, respectively. The sub-drip system not only requires new components but more valves, fittings, and bushings. The majority of the increased expenditures is attributed to drip line tubing, which represents nearly 70 percent of the additional costs.

Automated Water Control. The automation of seep and sub-drip systems requires a monitoring well, float device, and switch, and automation equipment including solenoid valves, regulators, pipes and fittings. It is assumed that only one automated water control site is required per 40-acre block. The cost of the control site is equivalent for the automated seep and sub-drip systems, about $43/acre.

Total Initial Capital Investment Costs. Total initial capital investment costs for the new installation of each irrigation system are presented in table 1. The total cost for the three-tube automated sub-drip irrigation system is about $407/acre and $334/acre greater than the total cost for the automated and manual seep irrigation systems, respectively. About 80 percent of the $407/acre difference between the sub-drip and traditional semi-enclosed systems can be attributed to the purchase of drip line tubing.

Fixed Annual Costs

Fixed costs are expenditures incurred as a result of owning capital equipment. These costs include depreciation, interest, taxes, and repairs.[1] The assumed years of useful life for the capital components of the systems differ by type of component. Salvage value is assumed to be zero, and a 10 percent average annual interest cost is used. Initial tax costs are estimated to be 6.5 percent. Annual repair costs for each system are estimated at 1 percent of the new cost. Estimates for useful life, interest rates, taxes, and repair costs are based on figures reported by a local equipment dealer.[2] Tables 2, 3, and 4 show estimated fixed costs for the water supply system, system layout, and automation site, respectively, for the three irrigation systems. The three-tube per bed spacing is used for the sub-drip system. Table 5 summarizes these data by irrigation system type. The annual fixed costs for the sub-drip system are about $130/acre more than the costs for the traditional seep system

[1]Insurance costs would normally also be included; however, most potato growers have an overall blanket policy on their farm equipment, and it would be extremely speculative to attempt to estimate what proportions of annualized insurance costs can be attributed to the various capital components of their irrigation systems.

[2]Pounds, G., personal communication. Dupont Enterprises, Hastings, Florida.

Table 2. Fixed Costs of Water Supply System for Semi-enclosed Seepage, Automated Seep, and Automated Sub-drip Irrigation Systems, Hastings, Florida, 1996.

Costs	Well*	Pump, Power Unit, & Control Box*	Filtration**	Total Component Cost
	------------------------------------$/acre------------------------------------			
Semi-enclosed Seep System				
New cost	98.00	67.00	0.00	165.00
Depreciation (a)	4.90	3.35	0.00	8.25
Interest (b)	9.80	6.70	0.00	16.50
Taxes (c)	6.37	4.36	0.00	10.73
Repairs (d)	0.98	0.67	0.00	1.65
Total fixed costs of semi-enclosed seep system	22.05	15.08	0.00	37.13
Automated Seep System				
New cost	98.00	67.00	0.00	165.00
Depreciation (a)	4.90	3.35	0.00	8.25
Interest (b)	9.80	6.70	0.00	16.50
Taxes (c)	6.37	4.36	0.00	10.73
Repairs (d)	0.98	0.67	0.00	1.65
Total fixed costs of automated seep system	22.05	15.08	0.00	37.13
Automated Sub-drip System				
New cost	98.00	67.00	44.00	209.00
Depreciation (a)	4.90	3.35	4.40	12.65
Interest (b)	9.80	6.70	4.40	20.90
Taxes (c)	6.37	4.36	2.86	13.59
Repairs (d)	0.98	0.67	0.44	2.09
Total fixed costs of automated sub-drip system	22.05	15.08	12.10	49.23

*The well and the pump, power unit, and control box have 20 years of life with all three systems.

**The filtration device has 10 years of life with the automated sub-drip system.

(a) New cost/years of life (no salvage value assumed).

(b) New cost x 10 percent.

(c) New cost x 6.5 percent.

(d) New cost x 1 percent.

Table 3. Fixed Costs of System Layout for Semi-enclosed Seepage, Automated Seepage, and Automated Sub-drip Irrigation Systems, Hastings, Florida, 1996.

Costs	PVC Pipe*	Valves, Fittings, & Bushings*	Drip Tubing**	Injection Pump**	Flush Valves**	Total Component Cost
	----------	----------	----------	$/acre	----------	----------
Semi-enclosed Seep System						
New cost	54.00	38.50	0.00	0.00	0.00	92.50
Depreciation (a)	3.60	2.57	0.00	0.00	0.00	6.17
Interest (b)	5.40	3.85	0.00	0.00	0.00	9.25
Taxes (c)	3.51	2.50	0.00	0.00	0.00	6.01
Repairs (d)	0.54	0.39	0.00	0.00	0.00	0.93
Total fixed costs of semi-enclosed seep system	13.05	9.30	0.00	0.00	0.00	22.35
Automated Seep System						
New cost	54.00	38.50	0.00	0.00	0.00	92.50
Depreciation (a)	3.60	2.57	0.00	0.00	0.00	6.17
Interest (b)	5.40	3.85	0.00	0.00	0.00	9.25
Taxes (c)	3.51	2.50	0.00	0.00	0.00	6.01
Repairs (d)	0.54	0.39	0.00	0.00	0.00	0.93
Total fixed costs of automated seep system	13.05	9.30	0.00	0.00	0.00	22.35
Automated Sub-drip System						
New cost (a)	54.00	80.50	218.00	7.00	35.00	394.50
Depreciation (b)	3.60	5.37	43.60	0.70	7.00	60.27
Interest (c)	5.40	8.05	21.80	0.70	3.50	39.45
Taxes (d)	3.51	5.23	14.17	0.46	2.28	25.64
Repairs (e)	0.54	0.81	2.18	0.07	0.35	3.95
Total fixed costs of automated sub-drip system	13.05	19.45	81.75	1.93	13.13	129.30

*PVC pipe and valves, fittings, and bushings have 15 years of life with all three systems.

**With the automated sub-drip system, drip tubing and flush valves have five years of life, and the injection pump has 10 years of life.

(a) Assumes three drip tubes per bed.

(b) New cost/years of life (no salvage value assumed).

(c) New cost x 10 percent.

(d) New cost x 6.5 percent.

(e) New cost x 1 percent.

Table 4. Fixed Costs of Automation for Semi-enclosed Seepage, Automated Seepage, and Automated Sub-drip Irrigation Systems, Hastings, Florida, 1996.

Costs	Monitoring Well, Float Device, & Switch*	Automation Equipment**	Total Component Cost
	-----------------$/acre-----------------		
Semi-enclosed Seep System			
New cost	0.00	0.00	0.00
Depreciation (a)	0.00	0.00	0.00
Interest (b)	0.00	0.00	0.00
Taxes (c)	0.00	0.00	0.00
Repairs (d)	0.00	0.00	0.00
Total fixed costs of semi-enclosed seep system	0.00	0.00	0.00
Automated Seep System			
New cost	41.50	1.70	43.20
Depreciation (a)	4.15	0.34	4.49
Interest (b)	4.15	0.17	4.32
Taxes (c)	2.70	0.11	2.81
Repairs (d)	0.42	0.02	0.43
Total fixed costs of automated seep system	11.41	0.64	12.05
Automated Sub-drip System			
New cost	41.50	1.70	43.20
Depreciation (a)	4.15	0.34	4.49
Interest (b)	4.15	0.17	4.32
Taxes (c)	2.70	0.11	2.81
Repairs (d)	0.42	0.02	0.43
Total fixed costs of automated sub-drip system	11.41	0.64	12.05

*The monitoring well, float device, and switch have 10 years of life with the automated seep and automated sub-drip systems.

**The automation equipment has five years of life with the automated seep and automated sub-drip systems.

(a) New cost/years of life (no salvage value assumed).

(b) New cost x 10 percent.

(c) New cost x 6.5 percent.

(d) New cost x 1 percent.

Table 5. Total Fixed Costs by Irrigation System Type, Hastings, Florida, 1996.

System Component	Semi-enclosed Seep System	Automated Semi-enclosed Seep System	Automated Sub-drip System
	--------	$/acre	--------
Water supply system	37.13	37.13	49.23
System layout (a)	22.35	22.35	129.30
Automated water control	0.00	12.05	12.05
Total annual fixed costs	59.48	71.53	190.58

(a) Assumes three drip tubes per bed.

and about $119/acre more than the costs for the automated seep system. System layout costs comprise approximately 83 percent of the additional fixed costs of automated sub-drip systems over the other two systems. Total annual fixed costs for the automated seep system are about $12/acre more than the costs for the traditional seep system as a result of the installation of an automated control site.

Variable Costs

Variable costs for the three systems are presented in table 6. Variable costs include electricity for pumping water and materials for cleaning and flushing drip lines.

Table 6. Variable Costs for Traditional Seepage, Automated Seepage, and Automated Sub-drip Irrigation Systems for Potatoes, Hastings, Florida, 1996.

Item	Semi-enclosed Seep System	Automated Seep System	Automated Sub-drip System
	--------	$/acre	--------
Drip line cleaning (a)	0.00	0.00	40.00
Drip line flush	0.00	0.00	22.00
Electricity (b)	25.94	6.57	10.80
Total variable costs	25.94	6.57	72.80

(a) "Dissolve" for cleaning drip lines.
(b) 1995 estimates.

The electricity cost for the traditional semi-enclosed seep system is estimated at about $26/acre (Smith and Taylor, 1995). The water usage cost to the farmer represents about 32 percent of his/her total irrigation-related expenditures.

For the automated seep system, the total number of kilowatt hours (kwh) required for irrigation is estimated at 90 kwh/acre (Smajstrla et al., 1995b).[3] At $.072/kwh the total estimated cost of pumping is $6.57/acre. This represents about 9 percent of total irrigation-related expenses and a savings of about $19.37/acre over the traditional seep system. Automated seep results in water savings because the pump is turned on only when the water table reaches a critical level below the root zone and turned off when the appropriate depth to the water table has been established.

For the automated sub-drip system, the total number of kwh used in 1995 was estimated at 150 kwh/acre (Smajstrla et al., 1995b). There is an increase in kwh and the costs of pumping relative to the automated seep system because of the need to flush and maintain adequate pressure levels in the drip lines. At $.072/kwh the total estimated cost of pumping is $10.80/acre. This represents about 3 percent of total irrigation related expenses; however, there is still a savings of $15.14/acre in electricity costs over the traditional semi-enclosed seep system. Additional expenses are required for chemical cleaning of drip lines during the production period and flushing them in the off-season to prevent bacterial growth that cause clogging.

Total variable costs are highest for the automated sub-drip irrigation system, primarily as a result of flushing and cleaning operations. The least-cost option is the automated seep system, which allows for substantial savings in electrical costs for pumping.

Total Irrigation Equipment Costs

Total costs are the lowest for the automated seep irrigation system (table 7). The electricity savings associated with the use of an automated seep system outweigh the increase in fixed costs associated with the installation of an automation unit. About $13/acre is saved by converting a manual system to an automated seep irrigation system.

Table 7. Total Costs for Traditional Seepage, Automated Seepage, and Automated Sub-drip Irrigation Systems for Potatoes, Hastings, Florida, 1996.

Item	Semi-enclosed Seep System	Automated Seep System	Automated Sub-drip System
	----------	$/acre	----------
Annual fixed costs (a)	59.48	71.53	190.58
Variable costs (b)	25.94	6.57	72.80
Total costs	85.42	78.10	263.38

(a) Costs from table 5. Assumes three drip tubes/bed.
(b) Costs from table 6.

[3]1996 electricity costs for pumping are less than 1995 season costs because of higher rainfall levels and fewer irrigation events. 1995 electrical usage data are therefore used to represent a more average year, and no yield difference is assumed.

The total costs of an automated sub-drip system are more than three times the total costs for either automated or manual seep systems. Most additional costs can be attributed to increased fixed costs for system layout (drip line, valves, etc.) and variable costs associated with cleaning and flushing drip lines.

Cost Analysis for Conversion to an Automated Seep or a Sub-drip Irrigation System

Semi-enclosed systems represent about 97 percent of the irrigated acreage in North Florida (Trippensee et al., 1995). Perhaps the most commonly faced decision for potato growers is whether to upgrade their current irrigation systems or to install entirely new systems on different acreage. This section examines the costs of making an incremental improvement from manual seep irrigation to automated seep or sub-drip irrigation. It is assumed that a grower will use the three tubes/bed option for sub-drip irrigation.

Table 8 illustrates the incremental initial capital investments costs for installing automated seep and sub-drip systems. No incremental investment is required for conversion from a manual to an automated seep system; however, the sub-drip system requires a $44/acre incremental investment for a filtration device. Additional expenditures—valves, drip line, and chemical injection pump—of $320/acre are incurred with system layout. Costs of the incremental investment required for automation of the manual system are identical for the automated seep and sub-drip systems ($43.20/acre). The total incremental investment for the conversion of a manual to an automated seep or sub-drip system is $43.20/acre and $407.20/acre, respectively. More than one-half of the additional investment is the drip tubing expense.

Table 9 shows the incremental fixed cost changes for conversion from a manual seep system to an automated seep or sub-drip system. Manual to automated seep system conversion costs about $12/acre more in annual fixed costs. Compared to an automated seep system, an automated sub-drip system costs about $131/acre more in annual fixed costs. Recall that it was earlier assumed that the life span of the drip line, the most expensive piece of capital equipment, was only five years because of the need to sub-soil and avoid compaction. If no need to sub-soil exists, then the fixed costs for drip tubing will be cut in half and total fixed costs will decrease by about $90/acre.

Table 8. Incremental Capital Investment for Potato Irrigation Systems, Hastings, Florida, 1996.

Item	Automated Seep System	Automated Sub-drip System
	--------------$/acre----------------	
Water Supply System		
filtration device	0.00	44.00
Incremental Change:		
water supply	0.00	44.00
System Layout		
valves, fittings, and bushings	0.00	42.00
drip tubing	0.00	218.00
chemical injection pump	0.00	7.00
flush valves	0.00	53.00
Incremental Change:		
water supply	0.00	320.00
Automated Water Control		
monitoring well, float device, and switch	41.50	41.50
automation equipment (b)	1.70	1.70
Incremental Change:		
automation	43.20	43.20
Total Incremental Capital Investment Costs	43.20	407.20

Table 9. Incremental Fixed Costs for Potato Irrigation Systems, Hastings, Florida, 1996.

Item	Automated Seep System	Automated Sub-drip System
	--------------$/acre----------------	
Water Supply System		
filtration device	0.00	12.10
Incremental Change:		
water supply	0.00	12.10
System Layout		
valves, fittings, and bushings	0.00	10.15
drip tubing	0.00	81.75
chemical injection pump	0.00	1.93
flush valves	0.00	13.13
Incremental Change:		
water supply	0.00	106.96
Automated Water Control		
monitoring well, float device, and switch	11.41	11.41
automation equipment (b)	0.64	0.64
Incremental Change:		
automation	12.05	12.05
Incremental Fixed Costs	12.05	131.11

The incremental variable costs required for the automated systems are shown in table 10. An automated seep system offers incremental *savings* of about $19/acre over the traditional manual seep system as a result of decreased electricity costs. On the other hand, variable costs for an automated sub-drip system are $47/acre more than the costs of a manual seep system and $66/acre more than the costs of an automated seep system.

Table 10. Incremental Changes in Costs for Traditional Seepage, Automated Seepage, and Automated Sub-drip Irrigation Systems, Potatoes, Hastings, Florida, 1996.

Costs	Automated Seep Compared to Manual Seep (a)	Automated Sub-drip Compared to Manual Seep (a)	Automated Sub-drip Compared to Automated Seep (a)
		---$/acre---	
Annual fixed costs	12.00	131.00	106.00
Variable costs (b)	(19.00)	47.00	66.00
Difference in total costs	(7.00)	178.00	172.00

(a) Calculations based on amounts in table 7. Figures rounded to the nearest dollar.
(b) Figures in parentheses represent negative values or savings.

Table 10 also shows the expected net change in total costs as a result of converting from one type of irrigation system to another. Conversion from a manual seep system to an automated seep system results in a net decrease in total costs of $7/acre; however, installation of an automated sub-drip system results in a net increase in total annual costs of $178/acre as compared to the manual seep system and $172/acre as compared to the automated seep system.

From a cost standpoint, the most appealing system is the automated seep system because it can result in a net savings. In the absence of regulatory controls that limit water usage or set irrigation performance standards, demonstrated improvements in potato quality and yield, or decreased usage of complementary inputs (for example, fertilizer and pesticides), growers would not be likely to adopt sub-drip irrigation that requires an estimated incremental annual expenditure of $178/acre more than the current manual seep irrigation system.

Analysis of Net Returns by Irrigation System Type

Farm budgets are analyzed for each of the irrigation systems, and the following assumptions are made. The first assumption is that the grower is converting a manual seep system to either an automated seep or a sub-drip system. Thus, only the incremental changes in fixed and variable costs are added to each subsequent irrigation system scenario. The second assumption is that growers are using turbine submersible pumps and that switching pump type is not included as part of the conversion cost.

Production Budget and Net Return Calculations

The calculated net returns for each production budget represent returns to a grower's labor and management input. Expected changes in labor and management for the two automated systems are discussed later in this section.

Manual Seep Irrigation

Table 11 reports estimates of total revenue, total costs, and net returns for potatoes irrigated with manual seep systems. Representative farm cost data reported by Smith and Taylor (1995) are used. Yield and price are averages for the 1996 season for chip potatoes in which an estimated gross return of $1,575/acre was generated. 1996 prices for chip potatoes range from $7.50/cwt in late May to $3/cwt at the end of June. These prices were extremely low compared to the average of $9/cwt received between 1982 and 1994.

Irrigation system costs are included in the operating and fixed machinery categories of table 11. Table 12 summarizes farm machine use, fixed costs and variable costs for the Hastings production area, including electrical pump costs for irrigation (Smith and Taylor, 1995). The hours per acre represent the number of hours of pump operation, and the fixed cost is the annual capital cost of the pump. Variable cost represents the electricity bill for pumping water onto the field. In essence, the electricity bill ($25.94/acre) is the cost to the farmer for water usage, and it is included as part of the machinery component of the operating costs shown in table 11. It is a fairly insignificant part of the producer's overall production budget, representing only about 2 percent of total operating expenses.

The total cost of production using manual seep irrigation is estimated at about $1,841/acre. The 1996 net return is -$266/acre at the 1996 average price of $5/cwt price, but net return increases to $994/acre at the 1982-94 average price of $9/cwt.

Automated Seep Irrigation

Table 13 presents total revenue, cost, and net return estimates for the automated seep irrigation system, using 1996 average yield and price. The yield estimate of 315 cwt/acre represents the average from the automated seep-irrigated plots at the Hastings Experiment Station. Gross revenue remains at $1,575/acre.

All but two of the operational cost categories remain as reported by Smith and Taylor (1995). The first cost component that changes is the variable cost for electricity to run the pump. Again, the estimated cost of pumping is $6.57/acre, a savings of $19.37/acre over the manual seep system. The revised cost is incorporated into the machinery component of operating costs.

Table 11. Estimated Production Costs and Returns for Chip Potato Production, Traditional Seep Irrigation, Hastings, Florida, 1994-95 (1).

Category	Average per Acre
Yield (cwt)	315
Price ($/cwt)	5.00
Total Revenue	$1,575
Production and Marketing Costs	
Operating Costs (1)	
Seed	308.62
Fertilizer	157.06
Fumigant	60.24
Fungicide	119.63
Herbicide	19.64
Insecticide	42.26
Nematicide	38.10
Labor	205.64
Machinery	113.06
Interest	72.64
Miscellaneous	
Aerial spraying	13.75
Cover crop seed	6.40
Crop insurance	21.00
Farm vehicles	22.17
Total operating costs	1,200.21
Fixed Costs (1)	
Land rent	100.00
Machinery	77.51
Overhead	261.01
Total fixed costs	438.52
Total pre-harvest production costs	1,638.73
Harvest and Marketing Costs	
Dig and Haul	135.00
Grading	67.50
Total harvest and marketing costs	202.50
Total production and marketing costs	1,841.23
Net Return (Revenue – Costs)	-266.28

(1) Price and cost data obtained from Smith and Taylor (1995).

Table 12. Chip Potato: Summary of Machine Use and Costs in the Hastings Area, 1994-95 (1).

Description	Time Spent	Costs		
		Fixed	Variable	Total
	hours/acre	-----------------$/acre--------------		
Tractors				
125 hp	7.19	42.74	63.97	106.71
140 hp	0.79	5.09	7.75	12.84
Implements				
13-ft. harrow	0.37	0.78	0.24	1.02
V-ditcher	2.40	2.22	1.71	3.93
8-row chopper	0.47	2.07	0.69	2.76
Lister	0.10	0.57	0.29	0.86
8-row bedder	0.55	4.37	1.33	5.70
8-row cross ditcher	0.21	2.26	0.37	2.63
4-row potato planter	0.14	1.69	3.12	4.81
Boom sprayer	0.40	2.92	2.16	5.08
Potato cutter	0.23	3.68	0.47	4.15
Side mower	2.67	4.49	3.50	7.99
Bulk spreader	0.50	0.84	0.75	1.59
3-row fumigator	0.17	0.76	0.77	1.53
Miscellaneous				
10-hp electric pump	24.10	3.03	25.94	28.97
Total Machinery	40.29	77.51	113.06	190.57

(1) Smith and Taylor (1995).

Table 13. Potato Production Costs and Returns, Automated Seep Irrigation, Hastings Research Station.

Category	Average per Acre
Yield (cwt)	315
Price ($/cwt) (1)	5.00
Total Revenue	$1,575
Production and Marketing Costs	
Operating Costs (1)	
Seed	308.62
Fertilizer	157.06
Fumigant	60.24
Fungicide	119.63
Herbicide	19.64
Insecticide	42.26
Nematicide	38.10
Labor	205.64
Machinery	93.69
Interest	72.64
Miscellaneous	
Aerial spraying	13.75
Cover crop seed	6.40
Crop insurance	21.00
Farm vehicles	22.17
Total operating costs	1,180.84
Fixed Costs (1)	
Land rent	100.00
Machinery	77.51
Overhead	261.01
Total fixed costs	438.52
Total pre-harvest production costs	1,619.36
Harvest and Marketing Costs	
Dig and Haul	135.00
Grading	67.50
Total harvest and marketing costs	202.50
Costs of Automating Irrigation System	12.05
Total Production and Marketing Costs	1,833.91
Net Return (Revenue – Costs)	-258.91

(1) Price and cost data obtained from Smith and Taylor (1995).

The incremental $12.05/acre cost of automation is shown in table 5. All other variable and fixed costs are assumed to remain unchanged from the estimates presented in table 11.

Total production and marketing costs are estimated at about $1,834/acre. At 1996 price and yield levels, net return to a grower's labor and management is estimated at about -$259/acre. Net revenue reaches about $1,000/acre at $9/cwt.

Automated Sub-drip Irrigation

Table 14 shows total revenue, total cost, and net revenue estimations for automated sub-drip systems. Under 1996 yield and price conditions, gross revenue remains at $1,575.

As in the case of the automated seep system, the electrical cost for pumping decreases ($10.80/acre) and is incorporated into the machinery component for operating costs. As indicated in Section 2, there are several additional equipment costs for the sub-drip system: costs of automation, drip line tubing, media filters, chemicals and injection pumps to prevent drip lines from plugging, and valves and fittings to allow the flushing of pipelines. These costs have been incorporated into table 14. Under 1996 price and yield conditions, net revenue is estimated at about -$382/acre. At the 12-year average price of $9/cwt, net revenue is $878/acre.

Factors Affecting Net Revenue and Irrigation System Choice

Net revenue will vary in response to changes in prices, yield levels, or costs of production. In this section, a discussion of the factors that could affect gross revenue is followed by an explanation of the factors that could affect costs.

Price, Variety and Yield Effects on Net Revenue

Table 15 summarizes net return estimates, assuming constant costs, for the different irrigation systems under various price and yield scenarios. These scenarios can be used to represent the effects of various biological, technical, or economic changes on net revenue.

Prices. Recall that under *average* 1996 price and yield conditions, net revenue for chip potatoes was negative for all three irrigation system scenarios. Assuming a constant yield of 315 cwt/acre, net revenues can be estimated if growers had sold most or all of their production at the beginning of the season. Table 16 illustrates the price difference in the Hastings area by marketing date. If growers had sold their production at the beginning of the season, estimated net revenue would be positive, about $443/acre, $450/acre, and $327/acre for the manual seep, automated seep, and automated sub-drip systems, respectively. Net revenue for the automated seep system exceeds the manual seep system by $7/acre.

Table 14. Potato Production Costs and Returns, Automated Drip Irrigation, Hastings Research Station.

Category	Average per Acre
Yield (cwt)	315
Price ($/cwt)	5.00
Total Revenue	$1,575
Production and Marketing Costs	
Operating Costs (1)	
Seed	308.62
Fertilizer	157.06
Fumigant	60.24
Fungicide	119.63
Herbicide	19.64
Insecticide	42.26
Nematicide	38.10
Labor	205.64
Machinery	97.92
Interest	72.64
Miscellaneous	
Aerial spraying	13.75
Cover crop seed	6.40
Crop insurance	21.00
Farm vehicles	22.17
Total operating costs	1,185.07
Fixed Costs (1)	
Land rent	100.00
Machinery	77.51
Overhead	261.01
Total fixed costs	438.52
Total pre-harvest production costs	1,623.59
Harvest and Marketing Costs (1)	
Dig and Haul	135.00
Grading	67.50
Total harvest and marketing costs	202.50
Total Production and Marketing Costs	1,826.09
Sub-drip Costs (2)	131.11
Net Return (Revenue – Costs)	-382.20

(1) Price and cost data obtained from Smith and Taylor (1995).
(2) Additional sub-drip costs include the incremental fixed and variable costs of converting to drip irrigation.

Table 15. Comparison of Estimated New Revenue by Irrigation System Type for Various Price and Yield Combinations, Hastings, Florida, 1996.

System Type	Semi-enclosed Seep System			Automated Seep System			Automated Sub-drip System		
-price ($/cwt)-	5	7.25	9	5	7.25	9	5	7.25	9
-yield (cwt/acre)-					-$/acre-				
175	-966	-572	-266	-959	-565	-259	-1082	-688	-382
225	-716	-210	184	-709	-203	-191	-832	-326	-68
275	-466	153	634	-459	160	641	-582	37	518
315	-266	443	994	-259	450	1001	-382	327	878

Table 16. Evolution of 1996 Potato Prices, Hastings, Florida.

Date	Grade A (a) Table Potatoes	Grade B (b) Chip Potatoes
	-$/cwt-	
May 7	16.00	—
May 24	16.00	7.00-7.50
May 31	16.00	6.25
June 11	11.00-12.00	3.25-3.75
June 11	11.00-12.00	3.00-3.25

(a) Grade A table potatoes are between 1 7/8 inches and 3.75 inches.

(b) Grade B chip potatoes are between 1.5 inches and 1.75 inches.

1996 chip prices are below recent averages. The average price for chip potatoes for the 1982-94 period was approximately $9/cwt. At this price (table 15), net returns for all three irrigation systems are positive at all yield levels except 175 cwt/acre. At 315 cwt/acre, using the $9/cwt price results in substantial increase in net revenue under all system types, the $1,000/acre under the automated seep system is about $130/acre more than the automated sub-drip price results.

Yield. The average 12-year yield from 1982-84 is about 225 cwt/acre. At the average yield and price level for this period, net income is positive for all three systems but again is highest for the automated seep system. At the 1996 average price level ($5/cwt) and the high early season price ($7.50/cwt), however, net revenue is negative at 225 cwt/acre.

Potato Variety. Table 16 also illustrates what net returns would be if growers produced and marketed table potatoes instead of chip potatoes. Chip and table potatoes represent about 73 percent and 27 percent of total 1996 Hastings production, respectively.[4] The average 1996 price for table potatoes is approximately $14.50/cwt. If growers sold either all or part of their production as table potatoes, assuming a 315 cwt/acre yield, net revenues would increase and perhaps become positive, depending on the percentage of table potatoes sold and when they were sold.

Market Volatility. Potato growers may not only be discouraged to invest in sub-drip irrigation because of the additional fixed, variable, and labor costs associated with sub-drip but also because of the relatively volatile nature of the market for potatoes in recent years. Some of the effects of varying potato market prices, quantities, and varieties were discussed above. Beyond the conditions in any single year, however, growers also consider past market conditions and expectations of future market conditions when making capital investment decisions.

Figure 1 illustrates the evolution in harvested chip potato area, yield, and price in the Hastings area for the 1982-94 period. It is clear that, despite the relative stability in harvested area, yield per acre and price have been quite volatile. Although price has the expected inverse relationship with harvest area, price movements are far too erratic to be explained by only increases or decreases in supply. Indeed, price and hence farm revenue are subject not only to the uncertainty associated with biophysical conditions but also contract conditions and number of buyers in the market. The uncertainty caused by the volatility of prices from year to year, as illustrated in figure 1, acts as a deterrent to investment in an expensive system like sub-drip irrigation.

The above discussion illustrates the importance of the influence of potato yields, prices, and the variety marketed on grower net revenue. Depending on the yield level and variety produced and sold, and the timing of the marketing for either variety, net revenue could be positive or negative for any given year, irrespective of the type of irrigation system.

Production Practices and Physical Conditions

A specific production practice that influences the profitability of automated seep and sub-drip systems is the timing of a grower's plant and harvest dates. Early plant and harvest dates can result in less water for irrigation because of lower evapotranspiration rates early in the season. While the fixed costs of automated seep and sub-drip would not change, variable costs associated with electricity use and flushing drip lines would decrease. Variable cost savings on the sub-drip system, however, would have to be quite substantial in order for it to be competitive with the automated seep system.

Depending on market conditions, early harvest dates can also mean higher product prices. Although higher prices may make sub-drip more affordable, the problem of serious market volatility still exists.

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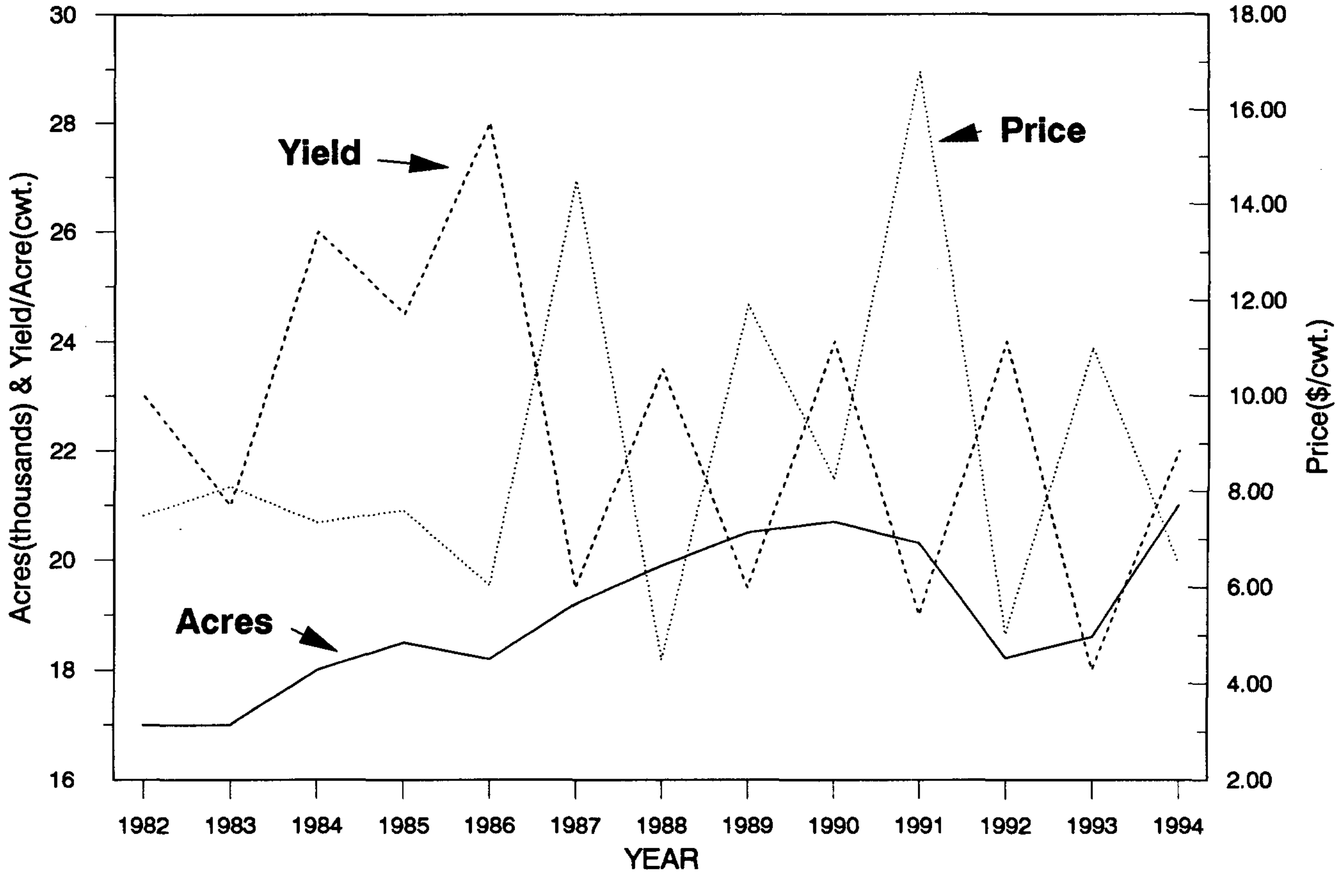
[4]Cotton, Bill, personal communication. President, Florida Potato Exchange.

Figure 1. Potato Production and Prices
1982-1994, St. Johns County, Florida



Physical factors thought to affect the financial appeal of automated seep and sub-drip systems include rainfall, disease, and soil type. In years of very low rainfall and increased irrigation events, the automated systems show improved savings in electricity costs for pumping. With increased irrigation, however, there may be more of an expenditure in keeping drip lines clear. In years of high or low rainfall, the automated seep system would still yield a higher net revenue than the automated sub-drip system simply because of its substantially lower fixed costs.

To date, no evidence exists to show any significant relationship between the type of irrigation system used and disease occurrence in potatoes. No matter what irrigation system is used, water management and controlling moisture levels are crucial to the production of a healthy crop.

Sandier soils could increase the profitability of sub-drip relative to seep irrigation by allowing for more precise water applications in raising the water table. In essence, sandier soils would have the same effect as low rainfall. Similarly, more frequent use of the sub-drip system could result in higher costs associated with cleaning and maintenance.

Cost Factors

Several factors affect the costs associated with each type of irrigation system. These are briefly discussed below and include labor and management and the influence of various production practices.

Machinery and Material Costs. As a result of the experimental nature of the data, machinery costs associated with the installation of automated seep and sub-drip systems are not included but would nevertheless have to be incurred by growers. As was mentioned in Section 2, five years of useful life are assumed for the drip line, with an associated fixed-cost of depreciation of about $44/acre per year (table 3). The five-year life of the drip line is determined by the fact that growers will deep sub-soil every five years to avoid soil compaction. In the process the drip line will be damaged and will require replacement. Drip lines would normally have at least 10 years of life, reducing by half the amount of fixed cost spent on depreciation. If some other way were found to avoid compaction, this expense would decrease. Nonetheless, despite the fixed cost savings from extending the usefulness of the drip line, the additional fixed costs associated with sub-drip would still be more than $100/acre higher than the additional costs for either the manual or automated seep systems (table 9). The cost of the electrical wire for the automation unit is not specified but would nevertheless have to be included in any cost estimation by growers.

Labor and Management Costs. The net revenue figures represent returns to an owner's labor and management; however, two types of labor-related costs exist that are not included in the net revenue calculations. The first type is the incremental expenditure on the additional labor required for the installation of the automated seep and sub-drip irrigation systems (well construction, float devices, wiring). For the automated seep system this would simply entail the variable costs associated with the installation and deinstallation of the automation site each season. Deinstallation is required for harvest and preparation of the following year's beds.

In addition to the above labor and management costs, automated sub-drip requires the installation of drip lines, flush valves, a filtration device, and an injection pump. Realistic estimates of the installation costs could not be obtained because of the experimental nature of the automated seep and sub-drip systems.

The second type of labor- and management-related cost that is not included in the net revenue calculations is the cost of monitoring the system's operation. Growers have traditionally monitored the operation of their irrigation systems by checking the moisture level in the water furrows and feeling the ground.

With the automated seep and sub-drip systems, the amount of labor and management time will increase. Monitoring the traditional seep irrigation system typically requires about one hour a day per every 250 acres.[5] This amounts to about 10 minutes per 40-acre block per day, assuming there are no pump breakdowns and irrigation is continuous.

Based on the experience at the Hastings station, an increase in the labor and management costs associated with monitoring and maintaining the automated seep and sub-drip systems is anticipated. The *extra* monitoring time required for the automated seep system is based on the level of activity of the Hastings station field agent. Assuming no major pump problems, monitoring the automated seepage irrigation system requires 12.5 minutes per day per 40-acre block, or a 25 percent increase in labor over the traditional non-automated seepage irrigation system. The increased time is due to the maintenance required for the automation unit.

The monitoring time required for the automated sub-drip system increases even further. In addition to monitoring the automation unit, extra labor and management are required for checking fluid levels to maintain clear drip lines, backwashing media filters at the pump sites, and cleaning and maintaining field filters and flush valves. The estimated time expended to complete all of these activities for a 40-acre block is about 23 minutes per day. Thus, labor and management time expended with the sub-drip system is more than two times the time expended with seep systems. This extra management requirement, in addition to the relatively higher fixed and variable costs, is likely to deter adoption of sub-drip in the absence of substantial cost savings for other inputs or increased yields.

A Benefit/Cost Analysis of Automated Irrigation Systems

Private Benefit/Cost Analysis

The benefits of the adoption of automated seep or sub-drip systems can be measured at private and public levels. The budget analysis and examination of the net returns for the three irrigation systems presented in Section three form the basis for estimating the private benefit/cost

[5]Cotton, Bill, personal communication. President, Florida Potato Exchange.

ratio. The benefit is the savings in electrical costs associated with pumping water. This benefit is a tradeoff for the extra fixed and variable costs associated with the automated systems. We assume that no potato yield or quality differences exist between the irrigation systems and that all growers face the same prices. Thus, the benefit is measured in terms of costs/savings associated with automated seep and sub-drip systems.

In the case of the automated seep system, the incremental annual fixed cost of automation is approximately $12/acre over the manual seep system. The estimated benefit in saved electricity costs from the conversion to an automated seep system is about $19/acre per year, yielding a benefit/cost ratio of about 1.6 for irrigation system conversion. In the case of the automated sub-drip system, the benefit/cost ratio from conversion is only .08.

A general rule of thumb in making an investment decision is to have a benefit/cost ratio of 2 to take into account the uncertainty regarding the beneficial effects of the investment. In this case, growers might be hesitant to invest in automating their seep systems and certainly would not invest in the sub-drip system without some other cost savings.

Table 15 indicates the prices and/or yield levels that would be necessary for a grower to recoup a capital investment for any of the three irrigation systems. The payback period on any piece of capital equipment is budgeted over the life of that equipment. For example, the payback period for the drip line is the same as its estimated life expectancy (five years). The level of annual fixed costs reflects the amount the grower needs to recoup for a given life expectancy. Thus, any level of net revenue that is positive in table 15 reflects the price and yield conditions under which growers recoup their capital investments.

Public Benefit/Cost Analysis

A public benefit associated with the conversion to either an automated seep or a drip system also exists. That benefit is embodied in the conservation of water resources for both irrigation and drainage. The determination of the monetary value of the conservation benefit, given the fact that there is no market price for water entering or leaving the field, can present problems.

Irrigation

For irrigation the cost of water to the grower is simply the cost of pumping. One could assume that it is appropriate to use the unit price of water for household consumption in the production area, but it is questionable whether or not this would truly reflect the public benefit of increased water conservation.

The estimated amounts of water used by automated seep and sub-drip systems for the 1996 production year are 16.5 inches/acre and 10 inches/acre, respectively (Smajstrla et al., 1996). In comparison, the average amount of water used by 29 growers in St. Johns County in 1996 was estimated at 15.27 inches/acre (St. Johns River Water Management District, 1996). The water used is sensitive to crop age and to planting and harvesting dates. Because of several differences in production practices between the research site and growers' fields, Smajstrla et al. (1996) indicate that water use is not directly comparable. For example, the grower who is adjacent to the research area used only 9 inches/acre, primarily as a result of earlier planting and harvesting dates.

Thus, if one considers the average grower's use of water in 1996, an estimated savings of about 5.25 inches/acre exists from converting to a sub-drip system. An average area of 20,000 acres of potatoes are produced in St. Johns County; this represents a savings of about 105,000 acre-inches per year. The value of this savings in monetary terms depends on the other potential and competing uses that exist and the relative scarcity of water. This valuation question is a topic that requires further research.

Conflicts may arise between the public benefits associated with *water* conservation and *soil* conservation. As mentioned previously, potato growers practice sub-soiling about every five years to avoid soil compaction. The following are three benefits of sub-soiling: (1) It conserves the soil resource base; (2) it allows for better infiltration of irrigation water; and (3) it subsequently helps maintain and/or increase crop yield. The problem with sub-soiling is that drip lines that have been laid beneath the ground will be ripped up every five years. Normally, the life span of drip tubing would be about 10 years. The replacement of drip tubing every five years essentially raises the annual fixed cost of the investment and discourages the use of sub-drip irrigation. Thus, water conservation goals compete with strategies to protect the soil from degradation.

Drainage

The quality of drainage water will be important in determining the benefit/cost ratio of automated seep and/or sub-drip irrigation. As already known, these systems can decrease the amount of drainage flow and thus the amount of nutrients that are carried off the field and into the drainage waterways. If a value can be assigned to the decreased rate of drainage and/or nutrient loss, then the new systems would be viewed as more beneficial from the public standpoint.

Even if water quality problems are identified, there will still be little incentive for growers to cut water usage (and hence drainage) by using sub-drip irrigation. The reason is that they cannot capture the benefits associated with cleaner drainage in the absence of some kind of market mechanism. Until water quality from drainage is measured, however, and a means is found to valuate the cleaner runoff, this public benefit cannot be evaluated. Both topics require further research.

Factors Affecting Water Use, Yield, and Net Revenue: A Regression Analysis

Water use and yield data were gathered at the research site. Ten yield samples were collected from each of six beds in three locations for a sample size of 180. Water use and yield data were combined with estimates of production costs and net revenue to create a data set for a regression analysis. The objective of the regression analysis was to determine which factors significantly affect water usage, yield, and net revenue. Table 17 gives the descriptive statistics for the dependent and independent variables, and table 18 shows the results and significance levels of the various regression analyses for the three dependent variables.

Table 17. Descriptive Statistics for Water Use, Yield, and Net Revenue for Irrigated Potatoes, Hastings Research Center, Florida, 1996.

Variable	Mean	Standard Deviation	Minimum	Maximum
Water Use (acre/inches)	13	3.6	8	17
Crop Yield (cwt/acre)	315	28.9	238.8	397.8
Net Revenue ($/acre)	2,243.00	257.00	1,480.00	2,860.00

Table 18. Regression Analysis Results: Factors Affecting Water Use, Yield, and Net Revenue for Irrigated Potatoes, Hastings Research Center, Florida, 1996.

Dependent Variable	Explanatory Variable	Parameter Estimate	Standard Error	Significance Level
Irrigation Water Use (inches)	Intercept	13.25	.46	.0001
	Replication 2	-1.0	.65	.13
	Replication 3	.25	.65	.70
	Irrigation System	7.0	0.12	.0001
Crop Yield (cwt/acre)	Intercept	318.76	4.0	.0001
	Replication 2	-7.39	5.27	.16
	Replication 3	-6.25	5.27	.24
	Central	-14.10	4.90	.004
	South	12.19	4.90	.013
	Irrigation System	6.19	4.00	.12
Net Revenue ($/acre)	Intercept	2172.72	35.50	.0001
	Central	-85.75	43.48	.05
	South	104.18	43.48	.02
	Irrigation System	-128.72	35.50	.0004

Water Use

Water use is measured in terms of inches per acre and varies across the three automated seep and sub-drip replications (six observations). It was hypothesized that replication and irrigation system type (automated seep and drip) could affect water usage. Replication is a proxy for any differences that result from location (slope, soil type) within the field. Three replications of each system were used with replication 1 containing Seep 1 and Drip 1, and so forth. Irrigation system was defined as a 0,1 dummy variable with zero signifying sub-drip irrigation and one signifying automated seep irrigation.

The results in table 18 reflect no significant difference in water use between replications, meaning that, on average, soil and slope characteristics of the various locations did not affect water use across the three replications. The sign on Replication 2 indicates that slightly less water was used as compared to Replication 1; it was almost significant at the .12 level. The sign on Replication 3 shows a slight increase in water use over Replication 1, but it is not at all significant.

As expected, the irrigation system type had a significant effect on the amount of water used for growing the potato crop. The parameter estimate of 7.0 indicates the number of acre-inches saved by converting from an automated seepage system to an automated sub-drip system. In other words, the amount of water used by the automated sub-surface drip system across all replications was, on average, 7 acre-inches less than the automated seep system, and this savings was statistically significant.

Yield

Yield was estimated from both crop cuttings and fruit samples at three positions in each of the six bed rows for a total of 18 sites. Ten samples were drawn at each site for a total sample size of 180. The 180 yield estimates were converted to cwt/acre. Across all systems, yield averaged about 315 cwt/acre. The three row positions (North, Central, South) correspond to the head, middle, and tail of the irrigation system, respectively, and were modeled as dummy variables. It was hypothesized that replication, position within the bed row, and irrigation system type could affect yield.

Table 18 shows that replication is not a significant factor in explaining the variance in yields within the field. The position in the bed row at which the yield sample was taken, however, is significant. Yield levels are positively related to the head and tail of the bed row and are negatively affected in the middle position. For example, about a 12 cwt/acre increase in yield was associated with the tail (South) position, and about a 14 cwt/acre decrease in yield was associated with the middle (Central) position.

The type of irrigation system used was not significant in explaining the variance in yields, supporting earlier evidence from Smajstrla et al. (1995a) that there is no important yield difference between automated seep and sub-drip systems. This finding, combined with no decrease in other production costs from the use of sub-drip irrigation, would discourage the adoption of the more expensive sub-drip irrigation system.

Net Revenue

Net revenue was calculated by subtracting total costs from total revenue. Total revenue was estimated by multiplying each of the 180 yield samples by the average 12-year (1982-94) price of $9/cwt. Total costs for automated seep were taken from table 12 ($1,834/acre), and total costs for automated sub-drip were extracted from table 13 ($1,957/acre). Net revenue averaged $2,243/acre, but the estimated range was quite large, having a minimum of $1,480/acre to a maximum of $2,860/acre (table 17).

The factors affecting net revenue were hypothesized to include the position within the bed row (since it affected yield) and the irrigation system type. Both variables were significant to at least the .05 level. The Central bed position was associated with a decrease in net revenue of $85.75/acre, while the South bed position (the tail of the system) resulted in an increase in net revenue of about $104/acre.

The parameter estimate for the effect of irrigation system type on net revenue is about -$129. This means that conversion from an automated seep irrigation system to an automated sub-drip system results in a net loss in revenue of about $129/acre, given the potato prices and yields used in this analysis. The decrease in revenue is primarily due to the higher sub-drip costs associated with the drip lines and system maintenance.

Summary

The overall results of the regression analyses applied to data from the experimental site offer some interesting insights. First, water use is not significantly affected by physical conditions in the field, most likely because slope, soil type, and other physical characteristics are homogeneous in nature. Previous research carried out over a larger geographical area has shown that soil type is a significant factor in explaining agricultural water use (Trippensee et al., 1995).

Position in the row affects yield and therefore also affects net revenue. Significant yield differences at the tail and middle of the bed-row compromise one important objective of growers—to have uniform production throughout a field. The cause of the variance in yields at different positions in the bed rows requires further research.

Finally, while the type of irrigation system had no significant effect on yield, it was very important in explaining the variance in net revenue. The increase in net revenue from conversion to an automated seep system is associated with the lower total costs of automated seep as compared to sub-drip irrigation.

Conclusions and Recommendations for Further Research

The primary purpose of this report was to investigate the willingness of potato growers to invest in automated seep or sub-drip irrigation and the conditions under which they would do so. The tools of this investigation were comprised of cost estimates, financial budgeting, discussion of private and social benefit/cost ratios, and regression analysis.

The cost analysis shows that an incremental conversion from manual to automated seep resulted in a net savings of about $7/acre. This estimate, however, does not include the extra time it takes to manage the automated system. Incremental conversion to sub-drip irrigation requires a net increase in annual costs of $178/acre. The increase in net costs is primarily a result of the fixed costs of the drip tubing and the variable costs associated with its maintenance.

Net revenue is determined by cost levels, yields, and prices. Assuming that there is no product price or yield difference amongst the three systems, net returns are higher for the automated seep system. One result of the regression analysis is that there is no significant difference in yield levels between the automated seep and sub-drip systems (table 18); however, because this result was obtained for a limited, homogeneous area at a research station, further research should be carried out across different soil types to see if the interaction between soil type and irrigation system makes a difference in yield levels and therefore in net revenue.

Net revenue is sensitive to yield and price level and the variety marketed. Evidence of substantial price variation, both within a year (table 16) and between years (figure 1), suggests that investment in an expensive irrigation system such as sub-drip would be extremely risky. With no evidence of other positive benefits associated with the use of automated sub-drip (that is, increased yields or reduced costs for other production inputs) growers' adoption of sub-drip systems is highly unlikely.

The regression analysis had two additional and important results. First, for both automated seep and sub-drip systems, yields varied significantly between the head and tail of the system. This is discouraging to growers who seek uniform growth in a given area. The difference in yields may be explained by the location of the automation unit in relation to the underground water table. The second result is that irrigation system type did not affect yield, but it did affect net revenue. Conversion from an automated manual seep irrigation system to an automated sub-drip system results in a decrease in net revenue of about $129/acre.

The social benefits of automated seep and sub-drip systems are associated with lower amounts of water for irrigation (conservation) and decreased drainage flows (environmental protection); however, insufficient information is available to quantify these public benefits, and further research is needed. Specifically, there is a need to identify and select existing method(s) for valuing conserved water and estimating drainage costs in terms of environmental damages from runoff. Once these methods have been identified, then valuation studies of the benefits of conserved water and decreased environmental damage from drainage can proceed, and a more complete benefit/cost analysis can be conducted. The private, individual-level investment in automated sub-drip irrigation is not profitable relative to other existing irrigation systems. This conclusion may or may not be the same at the public level and depends upon obtaining the aforementioned information.

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