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Cost of Supplemental Irrigation for Potato Production in Maine

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The authors are grateful for the patience and support of these contributors, which has been essential for the development of this cost update and assessment. Finally, we would like to acknowledge the support of the United States Department of Agriculture and the Maine Agricultural and Forest Experiment Station for their financial support and for the technical and financial data that were used in compiling this update.

Cover photo reference: Center pivot spray irrigation apparatus assembled and ready to provide supplemental moisture to row crops (potatoes in Aroostook County, Maine).

INTRODUCTION

This report presents estimated irrigation costs for potato production in Maine, which includes updated data originally published in Section 7 of the *Maine Irrigation Guide* (Dalton 2004). The variability of the weather in Maine (particularly precipitation) has a large influence on crop yields and overall farm profitability. The use of supplemental irrigation on high-value agricultural crops can improve the economic situation of farmers who use this equipment efficiently.

Although some growing seasons in Maine have total rainfall quantity that might provide ideal growing conditions for plants, weekly rainfall is highly variable. Therefore, supplemental irrigation may be profitable for producers. This report provides a summary of the costs of irrigation depending on the type of equipment used and the size of the application areas typically found in Maine. Supplemental irrigation reduces variability of crop yields due to inconsistent rainfall and can improve the quality and quantity of the potato harvest.

Historically, naturally occurring rainfall is not distributed evenly through the growing season. A University of Maine Cooperative Extension study found that "in most seasons the potato crop in Maine suffers by varying degrees from drought stress…. In trials over many seasons at the Aroostook Research Farm in Presque Isle, plots receiving supplemental irrigation have shown an average yield increase of 49 cwt per acre over non-irrigated plots" (Sexton et al. 2008: 1).

This section summarizes the costs of irrigation systems currently used in potato production in Aroostook County, Maine. We have incorporated water-development costs, which were not fully included in the *Maine Irrigation Guide,* into this report. To evaluate the economics of the investment, we use a standard budget approach, where costs are calculated on an annual basis, and we determined annual capital costs with the amortization method. This method spreads out the total investment cost over the life of the equipment, including an interest charge (less any salvage value).

Costs considered in this report include

- Capital Costs (equipment, interest)
- Water Development (pond construction, permitting, engineering)
- Operating and Maintenance Costs (labor, power, repair)

Costs of the irrigation systems considered in this study are evaluated using budget tables. Tables 3A and 4A incorporate water-development costs, and Tables 3B and 4B assess annual cost without water-development expenses.

Currently, regulatory requirements of the Maine Department of Environmental Protection (DEP) encourage farmers who decide to irrigate to withdraw water from non-regulated, or less-regulated, groundwater wells or from constructed water-impoundment ponds. Direct withdrawal from rivers, streams, brooks, wetlands, Great Ponds, and other water resources is discouraged, as these natural areas may be considered protected under state and/or federal law (please refer to the State of Maine Natural Resources Protection Act, 38 MRSA, § 480-A, *et seq.*, and the U.S. federal Clean Water Act, 40 CFR).

Constructing production wells or surface-water irrigation reservoirs, to the extent they occur in regulated natural-resource areas, may require permitting under state and/or federal law. Construction of ponds in, or alteration of, protected natural resources may require mitigation costs. The cost of developing water sources adds additional fixed costs to providing supplemental irrigation. The Maine Department of Agriculture, Food and Rural Resources offers grants to partially offset the cost of developing water sources. These grants may provide partial relief of the cost for farmers with an approved water-source-development plan created in conformance with U.S. Department of Agriculture (USDA) and Maine regulations. The budget analysis without water-development cost (Tables 3B and 4B) shows the estimated irrigation cost for farmers who already have a well, pond, or other water source, but who want to increase their acreage with supplemental irrigation.

Different irrigation systems have varying capital costs and operational requirements. This study evaluates two types of systems typically used in northern Maine: the hose reel traveler and the center-pivot system. Costs for each system are analyzed for three field sizes.[1]

We determined the investment cost of each system through interviews with equipment dealers, farmers, and others. Then we annualized the total capital cost over the life of the equipment to give a uniform annual capital cost payment. Finally, we calculated the annual operating costs for each field size for each system and then added the annualized capital cost. The results are presented in Tables 3 and 4.

The current irrigation systems used in potato production have different operating costs. Center-pivot systems cost more to buy but have lower operating costs compared to the hose reel traveler, which requires more labor to operate. Also, the differences in technical operating characteristics of these systems affect fuel consumption and therefore maintenance costs. The center pivot requires a fuel-operated motor that moves the center-pivot laterals around the field.

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[1] 50-, 100-, and 200-acre fields, except for hose reel traveler systems, which are generally not used on fields larger than 100 acres because they have limited application capacity. The hand-line large-gun system is no longer typically installed in Aroostook County; it is being phased out and is not included in this update.

Currently many farmers are installing center-pivot systems because they save water, allow more control over application rates and the total water applied to the land, and they have an overall reduced cost per acre irrigated because of economies of size. With a center-pivot system it is possible to apply small amounts of water, and it is easy to adjust for changing weather conditions during the spraying period (typically 6 hours per day). Therefore, farmers can optimize irrigation timing and duration to provide crops with the best growing conditions. Another notable advantage is the reduction of crop damage from harvest by applying a small amount of water (just enough to wet a dry field to facilitate harvesting and reduce bruising of the crop).

CAPITAL COSTS

We determined capital investment costs through interviews with irrigation engineers, equipment dealers, farmers, regulators, and others familiar with the production conditions of northern Maine. For each system and field size, we calculated investment costs over five cost budget components: (1) permitting and development of water source; (2) the pumping system; (3) the mainline delivery system; (4) the water-application system; and (5) miscellaneous and system-specific costs. We calculated the total investment cost for each system based upon representative conditions facing growers in this region, including a water source that is approximately one-half to one mile from the fields, with a moderate change in elevation, and an estimate cost of up to $275,000 for water-source development.[2] All remaining components are sized to ensure that 1 inch of water per week can be applied to the fields. It should be noted that the cost of pipe (mainline to and within fields) is highly variable and depends on the location and size of the system. Per unit (linear foot) cost of pipe is broken down between cost of the pipe itself and cost of burying the pipe.

To convert initial capital investment costs to annual costs, we used an amortization technique that derives equal annual payments to cover both costs and interest. We added tax[3] and insurance charges to get the total annual capital costs for each component. Then we added together the amortized annual costs for each item (component), and the resulting total is the annual breakdown of capital-cost payments for the one-time investment cost of the irrigation equipment.

[2]According to farmers and irrigators who have already constructed ponds, the cost of water-source development varies between $200,000 and $300,000. This cost includes permitting and engineering studies and construction of the pond.

[3]Maine farmers are exempt from state tax on capital equipment purchases, but towns may charge their own tax.

Tables 1 and 2 summarize the capital cost of hose reel and center-pivot systems. The investment costs for center-pivot-irrigation systems are 5% to 10% more than those for the hose reel traveler; however, the former provides more flexibility in irrigating and has lower operating costs. Table 1 summarizes the cost of items associated with the hose reel traveler system applied on 50-, and 100-acre field sizes. Note, the total cost associated with irrigation on a 50-acre application using the hose reel traveler system is $384,250, whereas the cost estimate is $411,500 for a 100-acre application.

Table 2 summarizes the costs associated with the center-pivot-irrigation systems on 50-, 100-, and 200-acre field sizes. Note, using a center-pivot system, the total cost associated for a 50-acre application is $403,250, whereas the estimated costs are $448,500 and $512,000, respectively, for a 100- and 200-acre application.

COSTS OF WATER-SOURCE DEVELOPMENT

One of the greatest sources of uncertainty facing potato producers is the significant cost of developing a water source to meet irrigation demands. State and federal authorities with jurisdiction over permitting are discouraging growers who currently use natural rivers and streams for irrigating from continuing to do so. Such activity will likely be more regulated in the future. The costs of water-source development include engineering and environmental assessment, physical construction of the pond, and wetland mitigation costs if the construction disrupts wetland areas.

Currently, environmental practices encourage the development of upland ponds rather than ponds in low-lying areas where they may affect wetlands. Both alternatives require significant development investment, but upland ponds may be more expensive because conditions are conducive to leakage. Upland ponds often need an artificial impermeable layer to help them to retain water. On the other hand, if a pond is created in a lowland, the producer may be required to mitigate any damage to the surrounding lowland or wetland ecology. Most experts believe that the $15,000 to $25,000 previously spent to develop a water source will only cover basic environmental engineering and permitting application costs. Water-source-development costs will substantially increase the cost of irrigating.

Due to the new rules on diversion of water from protected water resources, almost all farmers who have been irrigating are required to develop a water-management plan by August 14, 2012. Otherwise, according to Maine's DEP, they may face wetland-mitigation costs. The cost of water-source development ranges between $200,000 and $300,000. The Maine Department of Agriculture,

Table 1. Breakdown of capital costs by the two field sizes with hose reel traveler systems.

Hose Reel Traveler	Capital Cost 50 acre ($/field)			Capital Cost 100 acre ($/field)		
Item	Qty (ft.)	Price per unit ($)	Total Purchase price($)	Qty (ft.)	Price per unit ($)	Total Purchase price($)
Water Source						
Well/Pond		250,000	250,000		250,000	250,000
Permitting and water management plan		25,000	25,000		25,000	25,000
Irrigation System Pump						
Engine* and pump* and mobility/trailer		25,000	25,000		28,000	28,000
Suction, discharge, primer, check valve assembly		3,500	3,500		3,500	3,500
Mainline	(6" PVC)			(8" PVC)		
Mainline to and within field	3000	4.25	12,750	4000	6.75	27,000
Application System						
Hose reel system (gun included)			38,000			38,000
Total Fittings and Fixtures (end plugs, 90 degree elbow fittings etc)			6,000			8,000
Miscellaneous						
Installation/set up charges	3000	8	24,000	4000	8	32,000
Total Charges			**384,250**			**411,500**

*100-HP Engine, 400-GPM Pump and 135-HP, 600-GPM for 50 acres and 100 acres, respectively.

Table 2. Breakdown of capital costs by the three field sizes using center-pivot systems.

Center-Pivot System	Capital Cost 50 acres ($/field)			Capital Cost 100 acres ($/field)			Capital Cost 200 acres ($/field)		
Item	Qty (ft.)	Price per unit ($)	Total Purchase price ($)	Qty (No.)	Price per unit ($)	Total Purchase price ($)	Qty (ft.)	Price per unit ($)	Total Purchase price($)
Water Source									
Pond		250,000	250,000		250,000	250,000		250,000	250,000
Permitting and water management plan		25,000	25,000		25,000	25,000		25,000	25,000
Irrigation System Pump									
Engine* and Pump* and mobility/ trailer		25,000	25,000		28,000	28,000		33,000	33,000
Suction, discharge, primer, check valve assembly		3,500	3,500		3,500	3,500		3,500	3,500
Mainline		(6″ PVC)			(8″ PVC)			(10″ PVC)	
Mainline to and within field (feet)	3000	4.25	12,750	4000	6.75	27,000	5000	9.5	47,500
Application System									
Total Sprinkler System			75,000			100,000			135,000
Total Fittings and Fixtures (end plugs, 90 degree elbow fittings, etc.)			6,000			6,000			6,000
Miscellaneous									
Installation/set up charges			6,000			9,000			12,000
Total Charges	**403,250**					**448,500**			**512,000**

*100 HP Engine, 400 GPM Pump and 135 HP, 600 GPM, 175 HP, 900 GPM for 50 acres and 100 acres and 200 acres respectively.

Food and Rural Resources Water Source Development Cost Share program currently provides up to 75% of cost of the construction of new or expanded water source, or up to $80,000 per project, whichever is less. The cost of developing a water source is a key factor in the decision to invest in irrigation. The new regulations will result in additional costs for development of an irrigation system and will have an impact on the area to be irrigated. At an average cost of $275,000 for water development, most farmers will not choose to irrigate small plots (less than 50 acres).

OPERATING EXPENSES

Annual operating expenses associated with irrigation include labor costs, power costs, repair and maintenance costs, and interest charges associated with operating expenses accrued during the season.

Labor Costs

There are two primary labor costs associated with irrigation: (1) initial setup and end-of-season take-down of the system, and (2) variable labor usage per irrigation. For each acreage category (50, 100, and 200) in each system (hose reel and center pivot), we multiplied the average total number of work hours by total number of laborers required during the whole season. We then applied an adverse-effects wage rate of $9.70[4] (in 2008 dollars) inflation adjusted to $10.20 current dollars to the calculation to give the total wage bill for the whole season. Since managerial labor is not included in the calculation, we calculated a constant cost-per-acre labor charge for the two different systems.

Power Costs

We calculated power costs by determining the number of hours that the pumping unit operates to apply the required amount of irrigation water. We adjusted total pumping time for flushing, system testing, and calibration, which is about 10% of the total cost. Then we multiplied total pumping time by hourly fuel-consumption rates of the different diesel motors and then by a representative per gallon price of diesel fuel ($3[5]). Average fuel costs decline as acreage increases, reflecting economies of size in motor pumping. For example, per acre power cost declines from $130 in 50-acre fields to $72 in 100-acre fields using the hose reel traveler system.

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[4]U.S. Congress publication prepared in 2008 dollars, adjusted to current dollars using Consumer Price Index (CPI).

[5]http://www.mainegasprices.com/retail_price_chart.aspx

Repair and Maintenance Costs

We calculated repair and maintenance costs as a generic $1,000 expense for hose reel travelers in 50- and 100-acre field sizes. For center-pivot systems, maintenance expense are generally lower, ranging from $320 to $390 (refer to budget tables). We derived these costs from interviews with equipment dealers, and they represent an average charge incurred over the life of the irrigation component. It has been suggested that maintenance and repair coefficients can be used as a percentage of the total purchase price of the equipment; however, for the purpose of this analysis, we used a fixed range of repair and maintenance costs for the systems across the field sizes. We found these figures to be comparable to the maintenance and repair costs estimated from the coefficient approach.

Interest Charge

The final component of the operating budget is an interest charge on working capital used during the production season. The interest charge represents the financial cost of a short-term operating loan or the opportunity cost of producer capital used in irrigation. A 5% interest rate used by Agricultural Marketing Loan Fund[6] of Maine is applied over a six-month crop-growing period (e.g., May through October) on the balance of labor, fuel, and maintenance charges.

OPERATING COSTS, IRRIGATION AND RAINFALL ANALYSIS

Uncertainty in the estimates for costs arises from not knowing precisely how much irrigation water will be required during the season. Since the quantity required to optimize crop yield for that season is not known with certainty, the underlying cost functions also are not known with certainty. Fuel costs are dependent upon the size of the pumping unit and the number of hours that the system is operated. Repair and maintenance costs are related to usage and the capital cost of the systems.

Optimal potato production requires 1.0 inch of water per week or roughly 14 inches of water for the crop over the months of June, July, and August. This amount of water can be in the form of irrigation water or natural rainfall. The decision to irrigate is determined by the amount of natural rainfall and the amount of residual soil moisture remaining for optimal potato production. Nearly 90% of potato production in Maine occurs in the northernmost county of the state. As such, this study evaluates the cost of irrigation systems located within this geographical area and in the context of the historical weather patterns in the heart of the growing region. Over the 30-year period

[6]http://www.maine.gov/agriculture/mpd/business/amlf/index.html

from 1980 to 2009 (see Figure 1), total rainfall during June through August was normally distributed with a mean of 11.2 inches and a variance of 5.5 inches (a standard deviation of 2.4 inches), an observed minimum of 5.6 inches and maximum of 18.9.

Nonetheless, the probability of receiving 1 inch of rainfall per week, to ensure proper crop development, is highly variable. During the early part of the season, the probability of receiving 1 inch of rainfall per week is less than 20%, and during the critical stages of tuber bulking in August and early September, it is less than 30%. The decision to irrigate is contingent upon a 1-inch shortfall in natural rain to prevent infrequent and costly short irrigations. Based upon these characteristics, we calculated net returns to irrigated and non-irrigated production and compared these results to determine the mean benefit and the risk-reduction effects.

Figure 1 shows the total monthly rainfall for Aroostook County, Maine, during summer (primary growing season) months for the period from 1980 to 2009. Note the periods of severe drought conditions in 1995 (June) and 2002 (August) and excess rainfall in 1981 (August) and 1992 (August). These figures reflect conditions at the particular rain-gauge station. Individual farm operations may not experience these precipitation events and may find localized

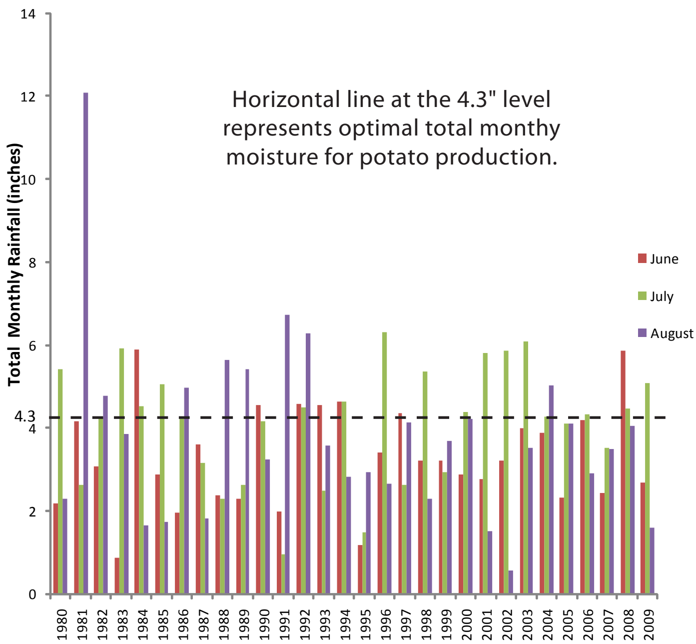

Figure 1. Thirty years of total monthly rainfall for June, July, and August, 1980–2009, in Aroostook County, Maine.

conditions varied significantly from these data. The variability of precipitation can have significant impact on localized farming conditions and crop yields. In addition, it is likely that weekly average rainfall, on which the irrigation decisions are made, are even more highly variable. The dashed horizontal line in the graph represents 4.3 inches of monthly rainfall typically required for a good potato-growing season. We observe from the graph that most of the monthly rainfall in the past 30 years has been below that optimal level. This is a good indication that supplemental irrigation can enhance revenue for potato production in Maine during the majority of the time.

PARTIAL BUDGET RESULTS

Based upon the expected demand for irrigation water, cost budgets for the two systems over three typically sized fields are presented in the following tables. We calculated these cost budgets based upon the expected value of the types of irrigation system setups. Several trends merit discussion:

1. In the category of annual operating costs, per acre power costs decline as acreage increases due to the power efficiencies of larger diesel engines.
2. Capital costs (per acre) also decline as acreage increases. Despite higher initial capital costs, average cost per acre decreases as production increases due to a larger output. Since tax and insurance charges are fixed costs and are based upon the replacement cost of the system, they decrease as farm size (acres) increases.

According to the budget results in Tables 3 and 4, comparisons between all of the typical acreage sizes used in this evaluation indicate significant economies of size (decreasing average cost per acre) when using any of the irrigation systems. Doubling acreage from 50 to 100 acres decreases the average total annual cost of irrigation by 46% for hose reel traveler systems and by 44% for the center-pivot system. Doubling field size again, from 100 to 200 acres, decreases average total annual cost by 42% for the center-pivot systems. Overall, this analysis indicates that size economies are still available for many farmers at the typical acreage found in Aroostook County and may also exist for field sizes above the three levels used in this report.

Direct comparison of the costs found in Aroostook County, Maine, with potato production in other parts of the country is not possible because the procedures and the assumptions made in estimating the cost of irrigation are different. Most of the production in the western U.S. is undertaken on a larger scale, thereby making economies of scale more apparent in the western U.S. than in Maine. In addition, irrigation is more commonly used and critical in agricultural production because of the lower average rainfall probability

Table 3. Hose reel traveler system: Expected annual irrigation cost budgets ($/field).

A) With Water Development Cost	50 Acres	100 Acres	200 Acres
Annual Operating Costs			
Labor	$ 3,672	$ 4,080	-
Power	6,480	7,200	-
Repair and Maintenance	1,000	1,000	-
Interest	508	564	-
Total Operating Costs	**$11,660**	**$12,844**	**-**
Annual Ownership Costs			
Depreciation and Interest	26,426	28,284	-
Insurance	367	393	-
Total Ownership Costs	**26, 793**	**28,677**	**-**
Total Annual Cost	**$38,453.00**	**$41,521.00**	**-**
Per Acre Annual Total Cost	**$769**	**$415**	
Percentage decline in per acre cost		**46%**	

B) Without Water Development Cost	50 Acres	100 Acres	200 Acres
Annual Operating Costs			
Labor	$ 3,672	$ 4,080	-
Power	6,480	7,200	-
Repair and Maintenance	1,000	1,000	-
Interest	508	564	-
Total Operating Costs	**$11,660**	**$12,844**	**-**
Annual Ownership Costs			
Depreciation and Interest	8,411	10,270	-
Insurance	116	143	-
Total Ownership Costs	**$ 8,528**	**10,413**	**-**
Total Annual Cost	**$20,188.00**	**$23,257.00**	**-**
Per Acre Annual Total Cost	**$403.76**	**$232.57**	
Percentage decline in per acre cost		**43%**	

Table 4. Center-pivot system: Expected annual irrigation cost budgets ($/field).

A) With Water Development Cost	50 Acres	100 Acres	200 Acres
Annual Operating Costs			
Labor	$184	$184	$184
Power	6,480	7,200	8,640
Repair and Maintenance	320	350	390
Interest	350	387	461
Total Operating Costs	**$7,334**	**$8,121**	**$9,675**
Annual Ownership Costs			
Depreciation and Interest	$28,590	$ 32,183	$ 37,207
Insurance	394	448	517
Total Ownership Costs	**$28,984**	**$ 32,631**	**$ 37, 724**
Total Annual Cost	**$36,318**	**$40,752**	**$47,399**
Per Acre Annual Total Cost	**$726.36**	**$407.52**	**$237**
Percentage decline in per acre cost		**44%**	**42%**

B) Without Water Development Cost	50 Acres	100 Acres	200 Acres
Annual Operating Costs			
Labor	$184	$184	$184
Power	6,480	7,200	8,640
Repair and Maintenance	320	350	390
Interest	350	387	461
Total Operating Costs	$7,334	$8,121	$9,675
Annual Ownership Costs			
Depreciation and Interest	$10,576	$ 14,169	$19,193
Tax and Insurance	147	197	267
Total Ownership Costs	**$10,723**	**$ 14,366**	**$ 19,460**
Total Annual Cost	**$18,057**	**$22,487**	**$29,135**
Per Acre Annual Total Cost	**$361.14**	**$224.87**	**$145.68**
Percentage decline in per acre cost		**38%**	**35%**

compared to Maine (for example, around 12 inches a year in Idaho vs 44 inches in Maine). Per acre costs may be lower in Idaho due to economies of scale, while yield per acre was 415 hundredweight (cwt) in Idaho and 275 cwt in Maine in 2009 (NASS 2010).

RISK-MANAGEMENT ATTRIBUTES OF IRRIGATION SYSTEMS

Given that demand for irrigation water is dependent upon rainfall, cost estimates have a variable component reflecting the demand for irrigation water. While operating costs increase with increasing amounts of irrigation applied, average cost (inches per acre) declines. When this expense is compared to the analysis of nonirrigated crop production, total annual cost of production is greater with the added cost of irrigation.

The added cost should be offset by additional revenue derived from the higher expected crop yield and quality. However, annual net profit varies according to total annual rainfall along with how it is distributed over the growing season.

CONCLUSION

Supplemental irrigation has often been described as an "insurance policy" for farmers. Due to the high investment costs associated with irrigation, size economies are an important component of the overall economic feasibility of such an expense. State and federal farm policy promotes development of water supplies for irrigation, but these policies discourage use of, or impacts to, water resources that are defined as, or included within, protected or regulated natural resources and encourage the development of subsurface water resources (production wells) or manmade surface-water impoundments. Farmers also have reported improved crop quality when using supplemental irrigation on potato crop land because of the ability to "soften" the soil during dry weather, which reduces bruising of the tubers during harvesting operations. This information is important for farmers who are seeking to use irrigation on their land, to reduce variation and risk inherent in potato yield and quality, and to maintain overall sustainability of agriculture in Maine. Finally, it is worth noting that the cost figures in this study are estimates reflecting the prices that existed in summer and fall of 2010. Certain price components of this equipment have been increasing at a 3% to 5% annual rate and may affect the conditions and conclusions observed and reflected in this study.

LITERATURE CITED

Dalton, T. 2004. Introduction to irrigation costs and returns. *Maine Irrigation Guide,* Section 7. Central Aroostook Soil and Water Conservation District, Presque Isle, ME. pp 7:1–14. http://www.caswcd.org/Irrigation%20guide/Sec7.pdf

National Agricultural Statistics Service (NASS). 2010. Fall potatoes. Agricultural Review 30(9): 2–5.

Sexton, P., G. Porter, and S.B. Johnson. 2008. Irrigating potatoes in Maine. University of Maine Cooperative Extension Bulletin 2439. http://umaine.edu/publications/2439e/

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