Economic Case Study: Intervale Community Farm
Benefits of Irrigation in Adapting to Climate Change

FARM FACTS

Type: Certified organic vegetable farm
Location: Winooski floodplain, Burlington, VT
Size: 25 acres under cultivation in 2017
In business since 1990
Farm Manager: Andy Jones

Introduction

The Intervale Community Farm (ICF) is one of Vermont's oldest and largest community supported agriculture (CSA) farms. Established in 1990 and located along the Winooski River in Burlington, this certified organic farm has been managed by Andy Jones since 1993. The farm produces a wide variety of vegetables including cucumbers, squashes, pumpkins, melons, carrots, potatoes, sweet potatoes, spinach, lettuce, peppers, and tomatoes on 25 acres. Nearly all of this land is planted to cover crops in the winter. ICF land is leased from the Intervale Center, a non-profit which also leases to a number of smaller farming operations in the area.

Located near downtown Burlington, the largest population base in Vermont, ICF has developed strong relationships with its 600 customers. Andy Jones has built a reputation as a leading organic farm practitioner in the Northeast. As Andy explains, "On a 100-year floodplain, ICF soils have long been recognized as productive farmland, albeit subject to flooding. The irony is that much of the floodplain that ICF farms is composed of sandy soils, which drain well but need to be irrigated during dry periods." Over the past several decades, the impacts of climate change in the Northeast have meant an increase in extreme weather events including heavy downpours and extended dry, hot periods throughout the growing season.

Starting in 2001, ICF began investing in both spray and drip irrigation equipment. With the Winooski River close by and three wells on site, water supply has not been a limiting factor. While ICF's land on the flood plan looks very flat, it is actually sloping with minor surface undulations resulting in some variation in soil types and ability to retain moisture.

During extended hot dry periods in the summer months, almost all the vegetables grown on ICF's sandy soils are irrigated. Sandy soils comprise two-thirds of the acreage ICF has available. Without irrigation and access to a plentiful water supply, ICF would not be able to successfully grow lettuce, spinach, broccoli, and cucumbers. Even in an average precipitation year, vegetables such as greens, carrots, cabbage, zucchini and potatoes would suffer diminished yields and quality without supplemental water.

ICF uses raised beds on the silty soils that make up about one third of the acreage available. During intense precipitation events (or extended wet periods), raised beds help the silty soils drain and reduce saturation, which can lead to root rot and other moisture-induced diseases. In these beds ICF plants cucurbits (e.g., cucumbers, squashes, pumpkins and melons) and vine crops with similar requirements that may be prone to moisture-related diseases.

Irrigation not only enables ICF to grow a greater variety of crops on its land, but also helps to increase the yields and quality of these crops. The direct economic value of irrigation may be difficult to measure since almost all of ICF's crops are sold as fixed price CSA shares at the start of the season, which spreads the risk of any future crop failure to members. However, it is likely that higher yielding and better quality crops lead to higher customer retention from year to year and the ability to add additional members.

This case study explores the benefits and costs of adding irrigation to ICF's production practices in order to reduce the risk of lower vegetable crop yields and quality.

Methods

Andy provided actual annual vegetable revenue and irrigation-related purchase records over the past 11 years. Additional costs were estimated such as operation and maintenance, pumping (primarily diesel fuel and related labor), and waste disposal costs. The benefits of avoided crop loss due to irrigation and the costs of purchasing and using irrigation were estimated on an annual per acre basis over the 11-year period. ICF made the investments over an extended period of time, and its use of the irrigation equipment on crop acres over that time period has varied from year to year (primarily a function of the timing and amount of rainfall during the growing season). Therefore, the costs and benefits were averaged to a per acre net benefit of having irrigation for each year that was analyzed. These historic revenues and costs were then brought to constant 2016-dollar values (present values) using the USDA Producer Prices Paid Index. The results are presented in a partial budget. Sensitivity analysis was also undertaken to illustrate "what-if" conditions, and finally a break-even analysis value was calculated.

Since precipitation patterns varied from year to year, each year was classified according to the estimated number of irrigation days during the growing months. Four classifications were used: wet, average, average/dry, and dry. Cornell University's *Climate Smart Farming* (CSF) Water Deficit Calculator was used to model when plant stress was likely to occur. Andy's recollection and records of irrigation in recent summers was used to calibrate the CSF Calculator's outputs in all the summers under analysis.

The CSF Calculator provides a consistent means to predict plant stress experienced on a daily basis due to weather, soil type and crop needs. Therefore, it provides a solid model for estimating and predicting irrigation needs. Of particular note, even in a "wet" year, ICF experienced continuous dry periods at some time during the growing period, which required use of the irrigation system, albeit not to the extent of irrigation use during a "dry" summer such as 2016.

For each year, depending on the "precipitation" classification, Andy provided a percentage of avoided crop loss (Table 1). This factor was applied to annual vegetable revenues to reflect the benefit side of the analysis. These percentage factors were based on Andy's experience with variable weather at ICF throughout the growing months and ICF's use of irrigation over the past 11 years. Over time, ICF has been experiencing hotter summers and longer dry periods with the existing soil moisture evaporating and the plants transpiring more. This has driven the need for irrigation to achieve annual production goals. The CSF Calculator accounts for historic climatological data including rainfall and modelled evapotranspiration and is based on location, soil type and crop type. Results from the calculator verified Andy's experience with irrigation needs at ICF.

Table 1. Assumed vegetable yield loss due to irrigation according to average growing season precipitation.

Precipitation Classification	% avoided loss
Wet	5%
Average	15%
Avg/Dry	20%
Dry	25%

Based on the CSF Calculator outputs, it was estimated that Andy irrigated on all days of severe plant stress where wilting danger existed, and also irrigated every third day during days when plant stress was likely. This correlated well with Andy's recollection of irrigation use in recent years. However, Andy uses raised beds on some fields, which have a drying effect that the Calculator does not take into account. This may skew this calculator's estimate of irrigation days to a slightly higher level than what was actually undertaken. Table 2 shows the years 2006 to 2016 and the estimated number of days irrigated and the year's classification. For each year's classification, a percentage of avoided loss was assigned based on Andy's assessment of his potential crop loss if irrigation had not been available.

Table 2. Classification of annual growing season average precipitation and number of assumed irrigation days.

YEAR	Number of Days Irrigated	Year Classification
2006	16	AVG
2007	38	DRY
2008	14	AVG
2009	10	WET
2010	38	DRY
2011	33	DRY
2012	26	AVG/DRY
2013	10	WET
2014	15	AVG
2015	16	AVG
2016	23	AVG/DRY

It's important to note that the number of irrigation days was estimated based on the practices of ICF in recent years and then correlated and calibrated with the water deficit outputs of the CSF Calculator over historic years in the analysis. The ICF

Calculator does not recalculate any historic day-to-day change in water deficit due to water added irrigation. In other words, the days in each plant stress category would have been less if actual irrigation days were accounted for retrospectively in the ICF Calculator. Therefore the estimated irrigation days may result in overestimates during dry periods, this results in higher irrigation costs and thus lower net benefits in this case study.

For each irrigation day, operating costs were estimated based on Andy's direct experience with irrigating. Andy estimated that for each day he irrigated, he ran the tractor power take off driven pump for 6 hours, using 3 gallons of diesel per hour. Andy provided information on his investment in irrigation equipment including both old and new equipment purchased over the past 15 years, and he provided estimates of the labor required to install and manage the equipment through the season. Additional costs estimated included the equipment operation and maintenance expenses and waste disposal of plastic mulch and tubing. Although the irrigation equipment could be expected to last about 20 years, the equipment life was not amortized over a lifespan beyond 2016. This results in a more conservative estimate of net income than could otherwise be expected, i.e., the estimated net present value is based upon historical use of irrigation as opposed to total expected useful life of the irrigation equipment.

Estimated Costs and Benefits

Estimated benefits (in avoided loss terms), annual revenues and irrigation costs are documented in Table 3. Table 4 consolidates this information into a partial budget.

Table 3. Estimated per acre benefits and costs in 2016 dollars, 2006-2016.

Year	Avoided Losses	Equipment Fixed Costs	Material Yrly Cost	Labor & Diesel	Maint.	Total Costs	Net Benefits
2006	$4,642	$1,138	$348	$321	$57	$1,864	$2,778
2007	$7,695	$0	$326	$534	$0	$859	$6,836
2008	$3,792	$389	$238	$244	$19	$892	$2,900
2009	$1,140	$843	$179	$190	$42	$1,254	-$114
2010	$5,405	$130	$365	$307	$6	$808	$4,597
2011	$4,975	$132	$177	$299	$7	$615	$4,360
2012	$4,224	$61	$203	$257	$3	$523	$3,701
2013	$1,106	$153	$211	$172	$8	$543	$563
2014	$2,556	$82	$158	$164	$4	$407	$2,148
2015	$2,464	$92	$172	$153	$5	$421	$2,046
2016	$3,717	$115	$125	$165	$6	$410	$3,306
AVG	**$3,793**	**$285**	**$227**	**$255**	**$14**	**$782**	**$3,011**

Table 4. ICF Irrigation Partial Budget in 2016 dollars (average $/acre/year)

Increases in Net Income			**Decreases in Net Income**	
Average Increase in Income			**Average Increase in Cost**	
Item			**Item**	
Avoided Production Losses	$3,793		Irrigation Equipment	$285
			Annual Material (plastic, drip tape, etc.)	$227
			Annual Operation Costs (Labor & Fuel)	$269
Total Increased Net Income/Acre/year	$3,793		Total Decreased Net Income/Acre	$782
Total Net Benefit per Acre per Yr			$3,011	
Total Farm Net Benefits per acre over 11 years			$33,121	
Total Irrigation NET FARM BENEFITS (based upon all acres receiving supplemental irrigation)			$508,705	

Total Acres Irrigated	10 to 25 acres
Years of data (2006-2016)	11

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http://www.uvm.edu/~susagctr/?Page=whatwedo/projectsresearch/fcc_case_studies.html

This analysis shows that irrigation is profitable in all but one year despite on-going infrastructure costs and variable summer weather. Overall, the cumulative net benefits per irrigated acre over all years was $33,121, and total farm benefits over all irrigated acres over 11 years were just over $500,000.

This analysis illustrates the importance of analyzing supplemental irrigation costs and benefits over time as the infrastructure fixed costs varied from year to year. Therefore, when a large purchase of irrigation equipment was made, a negative net benefit could occur that single year although when averaged out over the analysis period, the overall net farm benefits for ICF were substantial. Other farms may have significantly higher fixed costs if they need to construct a new well, holding pond, buy a tractor or other irrigation pumping equipment or pay for water use.

Sensitivity Analysis

It is useful to look at the range of irrigation scenarios and net benefits in order to identify thresholds of when irrigation is needed the most and the least. Therefore, net benefits were analyzed in both extreme conditions - assuming all years had been dry with the benefits of avoided losses of each year being 25%, and conversely if all years had been wet and the benefits of avoided losses due to irrigation being 5% (Table 1). If all the years were "dry", total farm benefits due to irrigation would have exceeded $800,000 and even if all years were considered "wet", total farm benefits would have been almost $70,000. Therefore, the benefits of having irrigation exceed its costs at ICF even if every year is on average "wet" given that rainfall does not always coincide with crop production needs. The main reason is that wet years still have dry periods during critical crop growth stages when irrigation provides significant benefits.

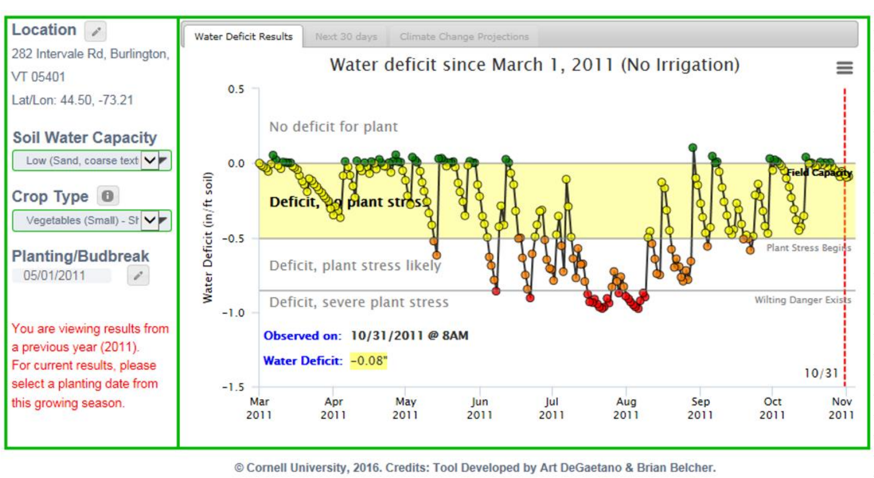
So what would be the break-even point for irrigation, that is, what percentage of revenue loss avoidance (i.e., benefit) is needed to cover the cost of irrigation? Based on ICF's investment in irrigation and the costs associated with operating the irrigation system, this percentage of revenue is 3.5%. In other words, if ICF can protect at least 3.5% of its crop revenues with irrigation, the farm will cover its costs of irrigation.

Farming in a Changing Climate

In planning ahead for irrigation on farms, it's important to revisit how the Northeast climate has already changed and how it's projected to change in the future. Between 1958 and 2010, the Northeast experienced more than a 70% increase in the amount of rain falling in very heavy events (defined as the heaviest 1% of all daily events). Between 1895 and 2011, temperatures in the Northeast increased by almost 2 °F (0.16 °F per decade), and precipitation increased by approximately five inches, or more than 10% (0.4 inches per decade).

By 2080, projected warming impacts in the Northeast will be an additional 3 to 10 degrees F depending on the level of greenhouse gases emitted. The frequency, intensity and duration of heat waves are expected to increase. The projected precipitation changes are less certain than the temperature changes. Winter and spring precipitation is projected to increase particularly in the northern part of the Northeast.

Summers are becoming hotter and longer with seasonal drought risk projected to increase in the summer and fall as higher temperatures lead to greater evaporation and earlier winter and spring snowmelt. For water management and irrigation practices, there are lessons to be learned from these trends as well as significant events in the past decade. For example, during Hurricane Irene in late August 2011, very heavy rain was recorded at three inches per hour in some locations. In contrast, earlier that same summer, ICF experienced several dry hot weeks when their crops needed to be irrigated in order to alleviate plant stress and maintain crop quality and yield. The Cornell Water Deficit Calculator graph nicely illustrates this point.



Reference: Climate Change Impacts in the US, Chapter 16 Northeast, National Climate Assessment http://nca2014.globalchange.gov/report/regions/northeast
Cornell's Climate Smart Farming Water Deficit Calculator:
http://climatesmartfarming.org/tools/csf-water-deficit-calculator/

http://www.uvm.edu/~susagctr/?Page=whatwedo/projectsresearch/fcc_case_studies.html

Conclusion

Given that the weather will continue to vary, the benefits of climate change adaptation such as supplemental irrigation will also vary from year to year. Here, the net benefits varied from -$114 to $6,836 per acre (with the average being $3,011) depending on the period of installation costs and prevailing weather during the growing season. However, the trend is clear: with overall warmer summer weather and precipitation concentrated in episodic events, the benefits for irrigation are likely to continue to increase.

ICF's decision to invest in drip and spray irrigation over the past 16 years has been sound. The benefits of reducing losses due to summer water deficits has exceeded the costs of purchasing the equipment, running the pumps, and the additional costs of labor and materials associated with managing this system. Of note is that ICF has kept their investment costs low by purchasing used equipment and using existing wells. For other farms in the Northeast, the particular net benefits will depend on their particular cost inputs and other local conditions. Each farm will have its own set of site-specific cost and benefit parameters.

Other farms may have additional considerations compared to ICF such as a restricted water supply and/or increased water access costs. In the case of the ICF, abundant water is available from both shallow wells and the adjacent river, so pumping costs are minimal. In addition to water costs, other considerations impact costs and benefits. These include both site and farm-specific factors such as soil type, crop choice, topography, cropping practices, available skilled labor, and farm management experience. Once these local differences are identified, this economic case study approach can be used to estimate irrigation benefits and costs on other similar farming operations in the Northeastern US. That said, this case study shows significant benefits of supplemental irrigation for vegetable crops is worth the investment by protecting production from variable weather.

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