University of Rhode Island

Agriculture in the State of Rhode Island

Climate Change Impact Assessment

Michael Bonilla, Alexa Bracken, Christina Montello, & Shannon Mora
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Professor Corey Lang
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Abstract

If current trends in climate change continue, the agricultural sector of Rhode Island will suffer catastrophic consequences by the year 2100. This analysis monetizes the predicted agricultural loss to the state of Rhode Island due to climate change over the 21^{st} century. Monetization is performed by estimating and then discounting losses to determine the net present value of the losses. The resulting calculated losses prove that Rhode Island's agricultural sector will be adversely affected due to climate change. Without adaptation to mitigate the effects of climate change, these losses will cause Rhode Island's gross domestic product to suffer.

1. Introduction

Farming has been a part of Rhode Island for centuries (Rhode Island Agricultural Partnership [RIAP], 2011). In colonial times farmland made up much of the state's land area, and being close to ocean and trade routes made commercial agriculture a significant part of the economy. As with much of New England, Rhode Island's economy shifted from farm-based to manufacturing-based, and by the end of the 20^{th} century, farmland decreased by approximately 80 percent from the beginning of the century. This led to "land being available for development, which…resulted in many farms being converted to residential or commercial use" (RIAP, 2011). During the 1980s, farmers began to shift from "dairy, wholesale marketing and mono-cropping towards a retail focus… include[ing] emphasis on diversification and value-added products and venues, and initiatives such as farmers markets, roadside stands, cooperative marketing and other local buying initiatives and efforts" (RIAP, 2011). Along with the local food movement, this caused a revival of farming in Rhode Island.

Even though the number of farms in Rhode Island increased from 750 in 1997 to 1,240 in 2016, with approximately 70,000 acres dedicated to farmland, agriculture makes up a very small portion of the state's economy (United States Department of Agriculture National Agricultural Statistics Service [USDANASS], 2017). Agriculture, forestry, fishing, and hunting combined only contributed $106 million, less than one percent of Rhode Island's gross domestic product of approximately $51 billion (United States Bureau of Economic Analysis, 2012). Although agriculture does not make up a significant portion of Rhode Island's economy, one study suggests agriculture provided 1,792 jobs directly and 542 jobs indirectly in 2012, contributing $170,650,704 directly to the economy, with an additional $97,452,764 of indirect revenue, totaling $268,103,468 (Sproul and Elsner, 2013). Farmland and buildings in Rhode Island were valued at $966 million in 2015 (United States Department of Agriculture [USDA], 2016).

Rhode Island farms produce a wide variety of products. In 2012 the "green" industry, which includes nurseries, greenhouse, floriculture and sod, was the largest agricultural sector. Sod production and nursery stock crops were the two largest contributors to this sector, with sales of $12,625,310 and $10,610,296, respectively (United States Department of Agriculture Census of Agriculture [USDACoA], 2012). Floriculture crops, including cut flowers and florist greens, bedding crops and plants, garden and foliage plants, and potted flowering plants, generated $8,670,523 in sales (USDACoA, 2012). Also included in the "green" industry are vegetables and fresh cut herbs grown in greenhouses, which contributed $639,502 in sales (USDACoA, 2012). Vegetables (including melons, potatoes and sweet potatoes), fruit (including tree nuts and berries), milk from cows, and poultry (including eggs) were the other top four agricultural products sold (USDACoA, 2012). Altogether, these top five products accounted for 87.6 percent of total sales. See Table 1 for a comprehensive list of products. Specific sales values were not available for the other four top agricultural products; however, the value of agriculture is not only monetary.

The local food movement is thriving in Rhode Island, as is evident from their Get Fresh Buy Local campaign. The campaign boosts the benefits of eating locally grown food, such as ensuring food security by supporting local farmers, reducing greenhouse gas emissions and costs by minimizing food transportation, as well as the consumer knowing exactly where their food comes from (Rhode Island Dept. of Environmental Management [RIDEM], 2017). Rhode Island is taking the lead in food-system planning and innovation (RIDEM, 2017). "[I]t is the only U.S. state in the which every school district serves local foods" (Rhode Island Food Policy Council, 2011). In 2016 Governor Gina Raimondo hired a director of food strategy, the first position of its kind in the state and the nation (RIDEM Relish Rhody, 2017). Agriculture's economic output may be small, but it is part of Rhode Island's culture and plan for a better future.

Table 1. Market value of agricultural products sold in Rhode Island.
Source: Census of Agriculture, National Agriculture Statistics Service (2017a)

Item	Sales ($1000)	Percent of Total Sales
Total sales	59,652	100.0
Nursery, greenhouse, floriculture and sod	32,831	55.0
Vegetables, melons, potatoes and sweet potatoes	9,331	15.6
Fruits, tree nuts and berries	4,131	6.9
Milk from cows	3,902	6.5
Poultry and eggs	2,177	3.6
Aquaculture	1,917	3.2
Other crops and hay	1,401	2.3
Cattle and calves	1,180	2.0
Grains, oilseeds, dry beans and dry peas	848	1.4
Hogs and pigs	601	1.0
Cut Christmas trees and short rotation woody crops	439	0.7
Horses, ponies, mules, burros and donkeys	382	0.6
Sheep, goats, wool, mohair and milk	257	0.4
Other animals and other animal products	256	0.4

2. Background on Climate Change

2.1 Basics of Climate Change

Climate change is a normal part of Earth's history, as seen in Figure 1; however, anthropogenic climate change is a cause for concern. Climate refers to regional or global changes in weather on a larger timescale, from years to decades to centuries, whereas weather refers to local changes on a short timescale, from minutes to weeks (United States National Aeronautical and Space Administration [NASA], 2017). Life on Earth is possible because of the greenhouse effect of our atmosphere. "The Earth absorbs radiation from the Sun, mainly at the surface," and "[t]his energy is then redistributed…and radiated to space" (Intergovernmental Panel on Climate Change [IPCC], 1995). Greenhouse gases keep some of this energy close to the surface by trapping it in the atmosphere, allowing the planet to stay warm (NASA, 2017). One such greenhouse gas is CO_2. Since the industrial revolution CO_2 concentration has increased from approximately 280 ppm (IPCC 1995) to just over 400 ppm in 2017 (NASA, 2017), due to increased use of fossil fuels (Figure 2). Alterations or redistribution of the energy can affect climate.

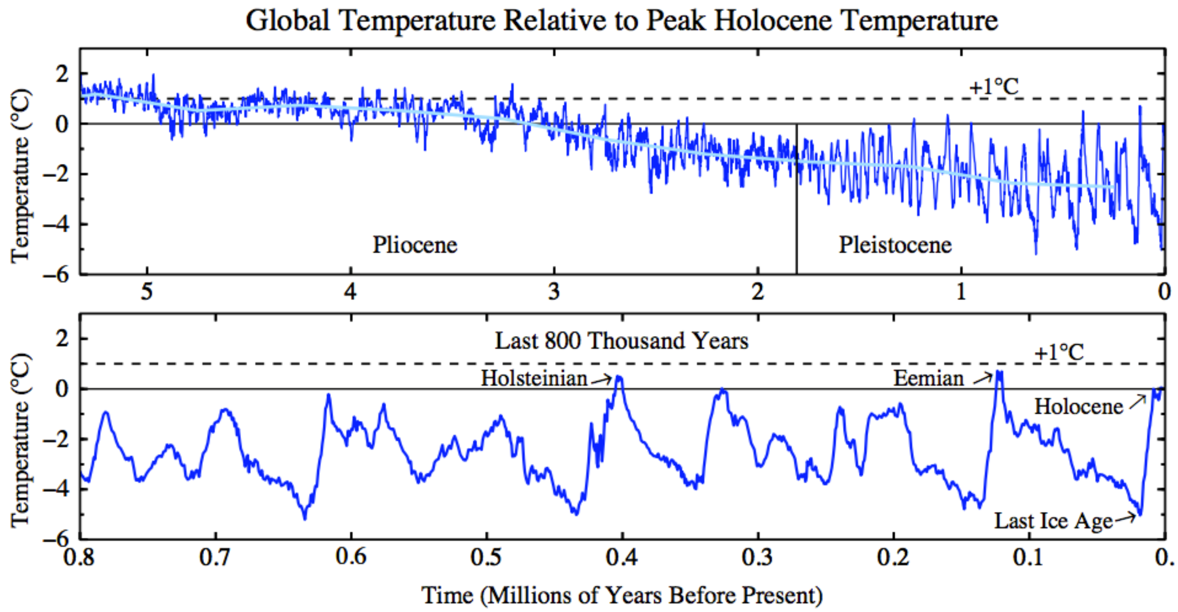

Figure 1. Global temper relative to peak Holocene temperature based on ice cores.
Source: NASA, Goddard Institute for Space Studies

The increased concentration of greenhouse gases traps more energy in the atmosphere, causing global temperature to rise, which greatly affects climate (NASA, 2017). Global surface temperature is predicted to increase by 0.3°C to 1.7°C, relative to 1986-2005, by the end of the 21st century (IPCC, 2014). Increased temperatures are causing Antarctic and Greenland ice sheets to melt, and Arctic sea-ice extent to decrease (IPCC, 2014). Melting ice and thermal expansion of the ocean is causing sea level to rise. Since 1880, global sea level has risen eight inches and is projected to rise an additional one to four feet by the end of the century, posing a threat to coastal communities around the world (NASA, 2017). Extreme events such as drought, heat waves, heavy precipitation and stronger, more frequent hurricanes are more likely to occur as a result of anthropogenic climate change (NASA, 2017). These events will not only effect humans but also ecosystems, threatening biodiversity and increasing risk of species extinction (United States Global Change Research Program, 2014).

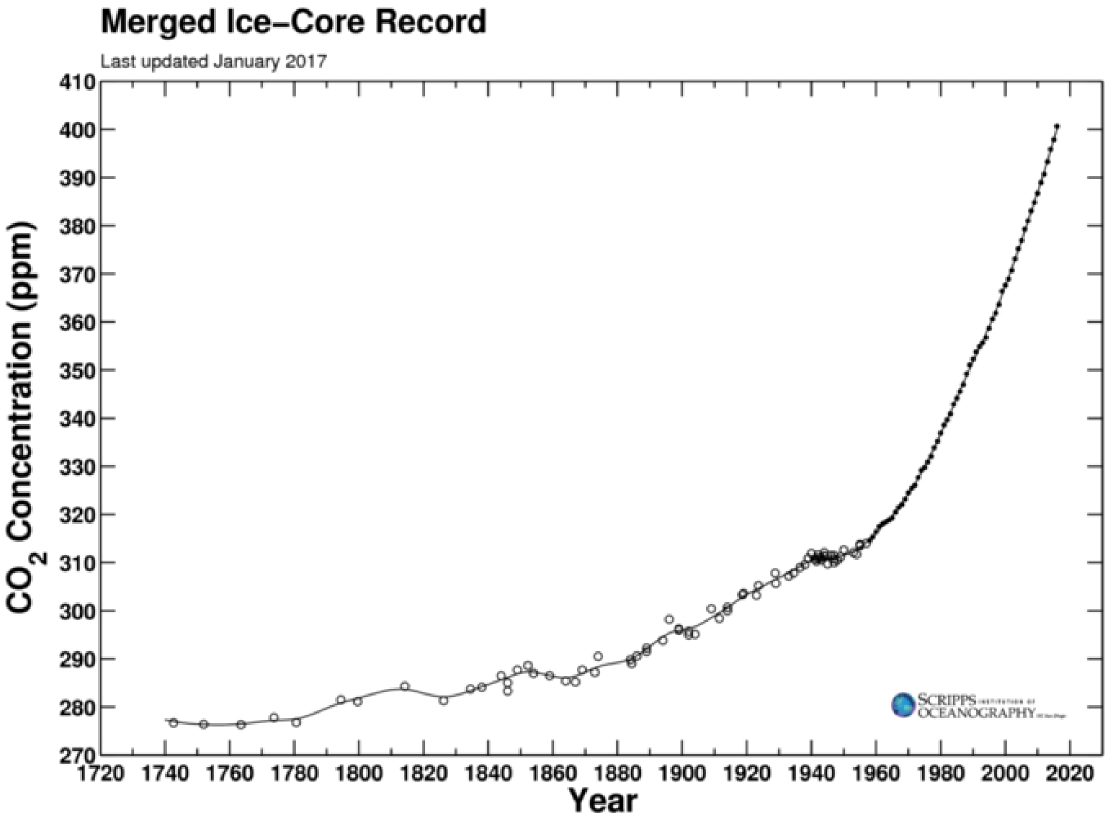

Figure 2. Atmospheric CO_2 concentrations based on merged ice core before 1958 and yearly averages of direct observations. Source: Scripps Institution of Oceanography

2.2 Climate Change and Rhode Island

Rhode Island is the smallest state in area in the nation, with a land area of 1,045 miles and 384 miles of shoreline (Rhode Island, 2017). With so many miles of shoreline, sea level rise due to climate change is a concern. According to the University of Rhode Island Climate Change Cooperative, sea level has increased eight inches in Newport since 1930, and continued sea level rise could lead to loss of waterfront property and beaches. Temperatures across the United States have risen over the last century, but Rhode Island has warmed twice as much as the rest of the country with a 3°F increase since 1900 as of August 2016 (United States Environmental Protection Agency [EPA], 2016). Weather patterns have already changed in the Northeast with less severe winters, spring arriving earlier with more precipitation, hotter and drier summers, and heavy, more frequent rainstorms (EPA, 2016). In the future, Rhode Island can expect earlier snowmelt due to rising temperatures, causing more intense floods in the winter and spring, as well as droughts and increased evaporation, causing the soil to dry in the summer and fall (EPA, 2016).

2.3 Climate Change and Agriculture

Agriculture is directly affected by climate change because production is sensitive to weather (USDA, 2013). "Beyond a certain point, higher air temperatures adversely affect plant growth, pollination and reproductive processes" (USDA, 2013), which can reduce agricultural yields. As temperatures increase so does the water requirement for agriculture, and with increased droughts and drier summer and fall seasons, the challenges of water delivery to crops through irrigation and other water management practices will need to be faced (USDA, 2013). Plants use atmospheric CO_2 for photosynthesis, and the increased CO_2 concentration actually stimulates plant growth (USDA, 2013). Although plant growth for crops increases, it uncertain whether this can compensate for the negative growth impacts of warmer temperatures and water stresses (USDA, 2013).

There are also indirect impacts of climate change on agriculture. Increased atmospheric CO_2 also increases weed growth. The increase of weeds due to the changing climate also changes interactions between crops and weeds "and the growth patterns of the entire plant community" (USDA, 2013). Warmer air temperatures are beneficial to insects and can speed up an insect's life cycle, meaning greater damage to crops from insect pests (USDA, 2013). Pathogens are also affected by climate change in the same way, and increased pathogens can affect not only crop production but also livestock production (USDA, 2013). The issues faced by crops are the same issues livestock rangeland, grain, and hay production will face (USDA, 2013).

3. Monetization of Climate Change Impacts on Select Agricultural Products

The biggest concern regarding climate change and agriculture is food security, and climate change impact analyses typically focus on food crops. Because of this the "green" industry, the largest contributor to the agriculture sector of Rhode Island's economy, will not be discussed. The monetary impacts of climate change on dairy, potatoes, and apples will be calculated.

3.1 Discount Rate Used and Assumptions

For the monetization calculations, the decreased value or production of each product due to climate change was determined for the year 2100. A linear change in value or production from present day to the year 2100 was assumed for potatoes and apples, and a piecewise linear change was used for dairy. A decaying discount rate was used, starting at 3% and slowly decaying to approximately 1%. The baseline year is the year in which the most recent value or production of each product was found. Discounting calculations started with the year after the baseline year. Only the years from 2017 to 2100 were summed for the net present value of losses.

$$Decaying\ Discount\ Rate = 0.01 + 0.02(0.95^{(Future\ Year - Baseline\ Year)})$$

For the data that was found, the following assumptions were made for all calculations: the only climate change factor considered is temperature, the value of the product in 2100 would be the same as the most current baseline value for the product and the change in product value is proportional to change in product yield. The year of the most current value statistics for each product was used as the baseline year. If actual temperatures are higher than predicted, the estimated losses in this study would be lower than actual losses, and vice versa if actual temperatures are lower than predicted. Additionally, if the value of the product goes up over time, due to inflation, then the estimated losses will be lower than the actual losses.

3.2 Dairy

In a USDA Economic Research Service report, the percentage reduction in milk production from 2010 to 2030 was predicted for 26 states using four different climate models (Key et al., 2014). Rhode Island is not included as one of the states, and the predictions do not extend to 2100, as was needed for this assessment. The assessment did include predictions for New York, Virginia, and Georgia. The Union of Concerned Scientists (2017) predict that by 2039 the summers in Rhode Island will feel like that of the current summers in New Jersey, by 2069 they will feel like that of Virginia, and by 2099 they will feel like that of the current summers in Georgia under a higher emissions scenario (Figure 3).

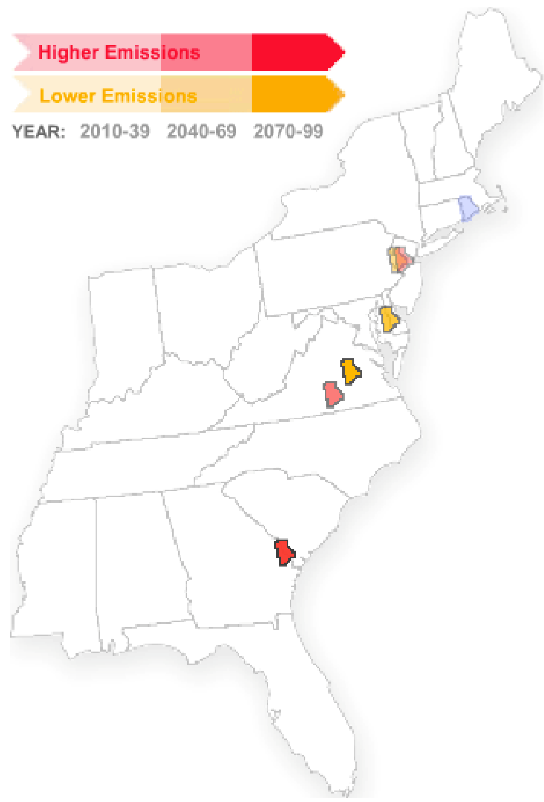

Figure 3. What Rhode Island summers could feel like under two different emissions scenarios. Source: Union of Concerned Scientists (2017).

Based on this information, and assuming the climate in New Jersey is like that of New York, the percentage reduction in milk production for Rhode Island was estimated. Milk production is predicted to decrease from 2010 to 2030 by approximately 0.25-0.5 percent for New York, 0.8-1.3 percent for Virginia, and 1.5-2.7 percent for Georgia (Key, et al. 2014). To estimate the percentage reduction in milk production for Rhode Island from 2016 to 2040, the percent decrease for New York was multiplied by 1.25, from 2041 to 2070 the percent decrease for Virginia was multiplied by 1.5, and from 2071 to 2100 the percent decrease for Georgia was multiplied by 1.5, using the least conservative estimation. The multipliers were calculated by dividing the number of years for each time period by the time span of the estimation (20 years). Assuming the change in milk production is linear for each time period, the result is a piecewise linear change (Figure 4).

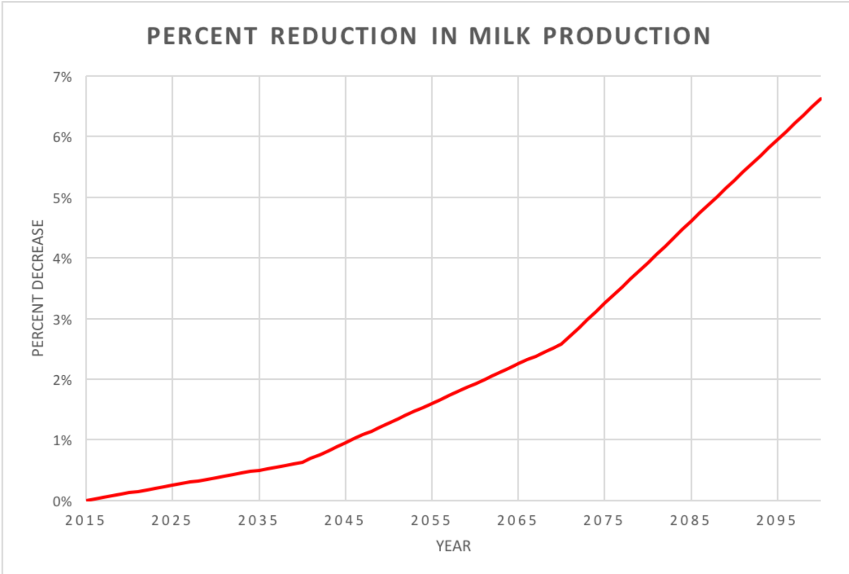

Figure 4. Estimated percent reduction in milk production for Rhode Island.

The value of milk in 2015 was approximately $3 million (USDANASS, 2016a). The predicted value of milk produced in 2100 will be approximately $2.72 million. The present value of lost dairy production due to climate change from 2017 to 2100 is approximately $2.91 million (Figure 5).

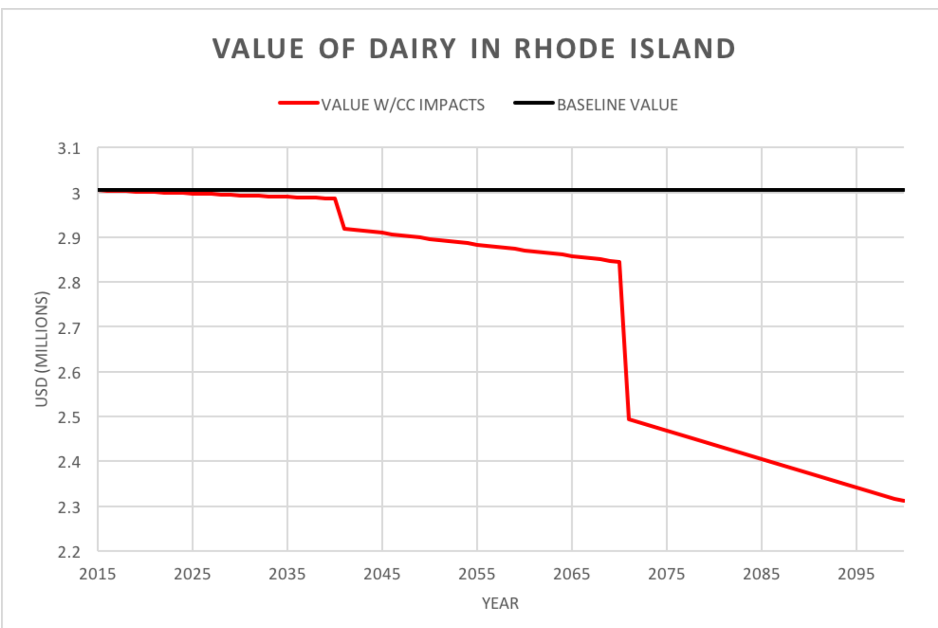

Figure 5. Value of dairy in Rhode Island, baseline and with climate change.

3.3 Potatoes and Apples

A climate change impact assessment conducted for Washington state used four different climate models to estimate the yield change for various crops, including potatoes and apples, for adaption and no adaptation. They also ran scenarios "with…or without…the effects of elevated CO_2 concentration on plant growth" (Stöckle et al., 2010). The predictions only extended out to the year 2080, and for these calculations the predictions for 2080 were used for the year 2100. It was also assumed that the climate in Rhode Island is, and will be, similar enough to that of Washington for the purpose of these calculations, as seen in Figure 6 (United States Geological Survey Climate Research and Development Program, 2017).

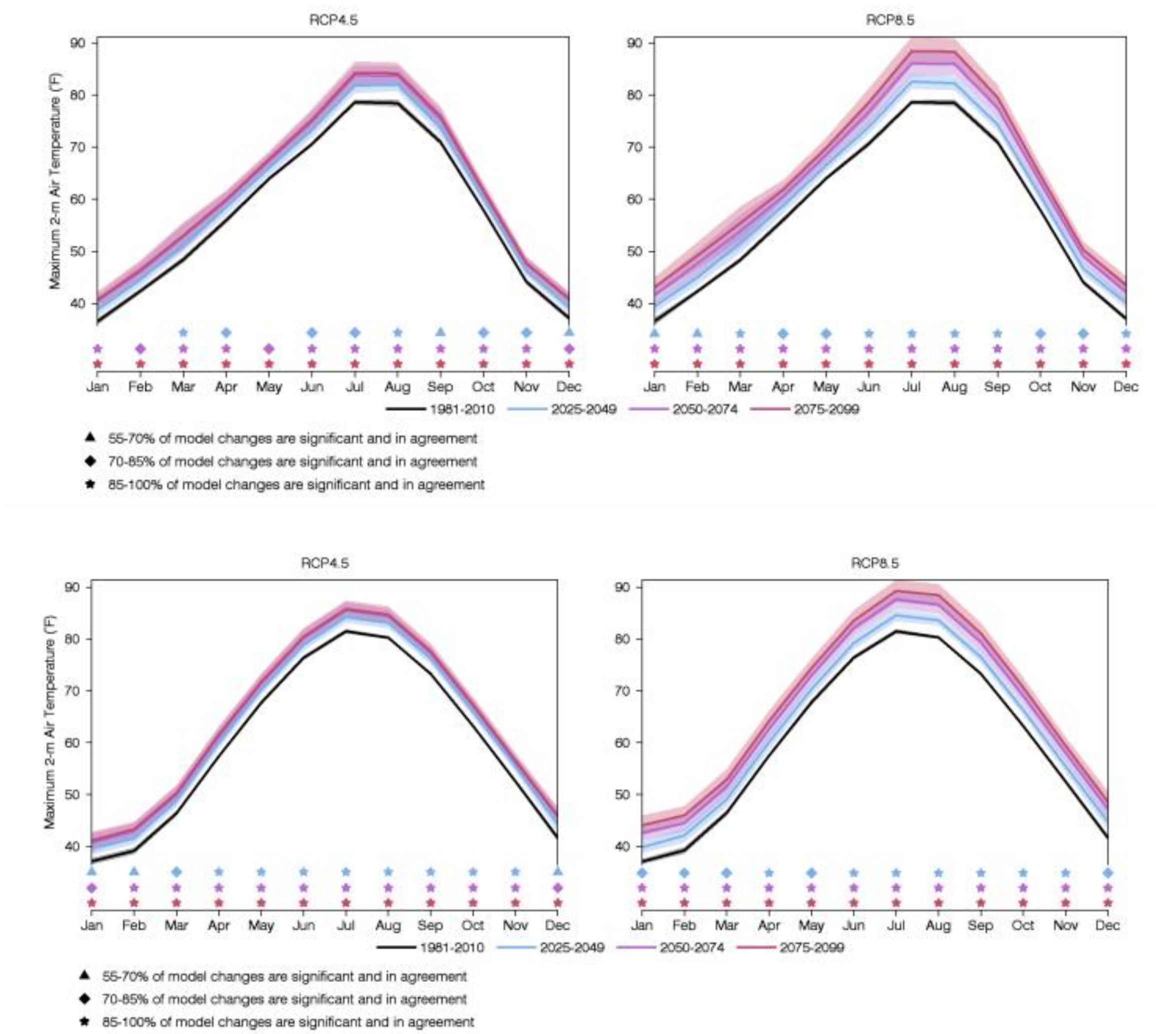

Figure 6. Monthly average maximum temperatures for Washington (top) and Rhode Island (bottom) for four time periods for two different climate model simulations, RCP4.5 (left) and RCP 8.5 (right). Source: United States Geological Survey, Climate Research and Development Program (2017).

The predicted ratio of future to baseline yield for the year 2080 was estimated based on the average yield predicted for each of the four different climate models. The estimated ratio was 0.778 for potatoes and 0.96 for apples (Stöckle et al., 2010). The value of sales in 2015 was approximately $888,000 for potatoes (USDANASS, 2016b) and approximately $1.83 million for apples (USDANASS, 2016c). In 2100, the predicted value of potatoes is $690,864, and the predicted value of apples is $1.75 million (Figure 7 and Figure 8). The net present value of lost yields due to climate change is approximately $3.48 million for potatoes and $1.29 million for apples.

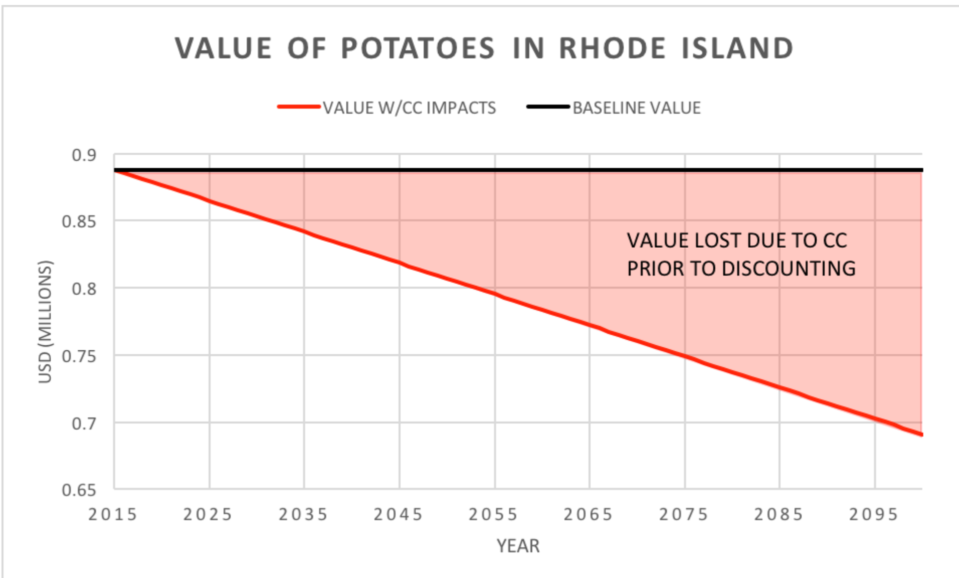

Figure 7. Value of potatoes in Rhode Island, baseline and with climate change.

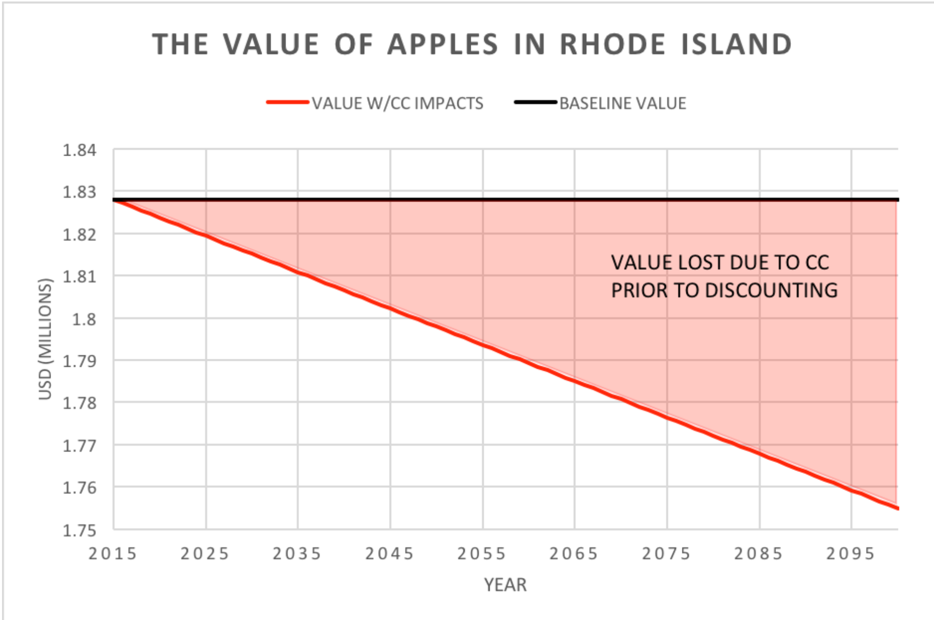

Figure 8. Value of apples in Rhode Island, baseline and with climate change.

3.4 Estimated Overall Impact

Quantifiable climate change impact data was not available for the products accounting for the majority of Rhode Island's agricultural sales such as sod, floriculture, and nursery and greenhouse products. However, even with the limited data available, increasing temperatures due to climate change will adversely affect the agricultural sector if action is not taken to adapt agricultural practices. Dairy, potatoes, and apples make up only a small percentage of total agricultural sales (USDACoA, 2017), yet their potential losses due to climate change by 2100 is estimated to be approximately $7.68 million dollars (Table 2).

Table 2. Impacts of climate change on select agricultural products including yield, undiscounted value and discounted net present value lost. All values are presented in millions of USD.

Product	Change in Yield Due to CC	Baseline Value	Estimated Value in 2100	Estimated NPV Loss
Dairy	Variable	$3.00	$2.72	$2.91
Potatoes	22.2%	$0.89	$0.69	$3.48
Apples	4%	$1.83	$1.76	$1.29
			Total Loss	$7.68

4. Minimizing the Costs of Climate Change

The monetization calculations did not account for adaption in order to show the consequences of inaction. However, climate change is a slow process, and with the help of climate models it is something that can be planned for. Because agroecosystems are controlled by humans, the severity of climate change impacts is largely dependent on the steps taken by humans to minimize those impacts (USDA, 2013). Action must be taken by Rhode Island farmers and policymakers to develop and implement adaption strategies in order to minimize the cost of climate change for the agricultural sector. Specific adaptation strategies are dependent upon the scale and stresses being placed on the system (USDA, 2013).

4.1 Resistance Strategies

Resistance strategies are used to maintain the current conditions by improving ecosystem defenses through intensive management intervention (Millar et al., 2007). Resistance management practices include "adjustments in cultivar selection and the timing of field operations, increased use of pesticides to control higher pest pressures, and the purchase of crop insurance" (USDA, 2013). Although this strategy can be effective in the short-term, it is limited because the implementation does not improve the ecosystem's ability to adapt (USDA, 2013), changing climate conditions require increased management efforts, increasing the costs, and these efforts will likely fail as the effects of climate change accelerate (Millar et al., 2007).

For the dairy industry, resistance strategies include the selection of heat tolerant cattle breeds (McManus et al., 2009), feed and water rationing adjustments, and housing and facility adjustments (Chase, 2006). The latter strategy is a relatively low cost way to minimize the effects of heat stress on cattle, one of the major consequences of climate change implications that impacts dairy production (Chase, 2006). For potatoes, planting dates will need to be altered to adapt to the changing growing season (Stöckle et al., 2010). However, even with an increased growing season, adjustments will need to be made based on water availability and extreme heat events (Stöckle et al., 2010). For apples, management strategies need to be adapted to control increased insect and weed populations, and possibly replace cultivars as temperatures increase (Stöckle et al., 2010).

4.2 Resilience Strategies

Resilience strategies increase the ecosystem's capacity to adapt. The ecosystem is encouraged to gradually adapt to the changing climate, either with minimal management intervention or naturally (Millar, et al., 2007). Managing pest populations through varying crop rotations, using more than one cultivar within a monoculture crop, "integrating livestock with crop production systems to manage resource cycles," and improving soil quality are adjustments that can be made to existing management practices (USDA, 2013). These practices prevent agricultural losses, and are already associated with sustainable agriculture (USDA, 2013).

4.3 Transformation Strategies

Transformation strategies facilitate the shift of existing ecosystem to a new ecosystem that is able to function better and maintain production in spite of the quickly changing climate (USDA, 2013). These types of adaptations include shifting production systems northward, or to higher elevations, and shifting "cultivated row crops into forest, perennial grasslands, or wetlands" (USDA, 2013). It is likely some agricultural systems will have to undergo transformation in order to maintain productivity and profitability (USDA, 2013), such as apples. As temperatures rise, orchards at lower elevations are experiencing lower productivity, and land at higher elevations is becoming more suitable for orchards (Rahimzadeh, 2017). Such transformations with fruit tree crops will require a significant initial investment of time and money to shift production from one crop to another.

This analysis discussed the impacts of climate change on agriculture, including economic impacts through monetization of losses. To minimize Rhode Island's economic losses, agricultural practices need to be adapted to the changing climate. "Climate change is no longer some far-off problem; it is happening here, it is happening now" (Barack Obama).

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