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Farmer Resiliency in a Changing Climate: A Comparative Study of Massachusetts and Vermont Farmers

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Abstract

Farmers throughout New England are facing the increasingly difficult task of adapting to the effects of climate change, which include warming temperatures, increased precipitation and storms, and new pest and disease challenges. Farmers must adapt their farming practices in order to become more resilient. Resilience is the ability of a system to absorb change while still maintaining basic structure and function. In Vermont, there there has been research done on farmer perception of climate change and practiced adaptations. In Massachusetts, there is very little research on this topic. For this study, interviews were conducted that included questions about the causes and effects of climate change, agricultural adaptations to manage risks posed to farmers (both climate-related and not), and what the future of New England agriculture will look like. The interview data was then compared between the two sites. I found that Vermont farmers appear to be more educated about climate change causes and effects, while Massachusetts farmers maintain optimism and strong community involvement in the face of climate change. Further research in Massachusetts would likely help farmers gain access to more information regarding climate change and effective agricultural adaptations, and further research in Vermont would refine existing information.

Keywords: resilience, climate change, farmers, adaptation, New England, Vermont, Massachusetts, community, diversification

Acknowledgements

What a road this has been. I owe so much to so many, but here is an attempt at keeping it brief. Thank you to my team of thesis advisors, Ernesto Mendez, Amy Seidl, and Kit Anderson. I could never have arrived at this final destination had it not been for your guidance. I want to particularly thank Kit for putting in tireless hours of thoughtful grading and comments on my disastrous preliminary thesis work that helped eventually lead me to this project. Your dedication to helping Environmental Studies students survive the thesis process is appreciated and recognized by so many floundering, lost souls, myself included.

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Thank you to my parents, family, and friends. Mom and Dad, you've somehow managed to instill in me the values and skills that have led me here, and that is something incomparable. Thank you for your unconditional love, support, and infallible belief that I will succeed. Thank you for allowing me to pursue my goals and passions, even if they weren't what you were expecting them to be. Thank you for giving me the opportunity to study at the most amazing place, with the most amazing people, and learn truly amazing things that I will carry with me for the rest of my days.

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Table of Contents

Table of Figures

Introduction

Food provides energy for human life. It is vital. The act of growing and preparing food is sacred and emotional. Since the Industrial Revolution, when food production began to transition to factory farms and industrial plants, humans have begun to lose their connection with the land and the food it provides. Food is becoming less and less sacred. Many people no longer know where their food comes from or what it consists of.

Growing up, I knew where much of my food came from. My mother frequented farmer's markets and farm stands, enjoying the freshness and quality of the products she found there. Having grown up herself with a father who was an avid gardener, she instilled in me the same sense of awareness surrounding food and its production and quality that he passed on to her.

What I never realized until I came to the University of Vermont and began studying the environment and food systems was that so many people do not have that same awareness. Unfortunately, ignorance concerning the food system in this country is widespread, and people often do not consider the source of a product or the potential implications, environmental or social, of its production and transportation to their shopping cart.

Once this realization became clear, I started to increasingly investigate food systems, especially the Vermont food system. In this state, people are generally much more aware of what they are eating and where it comes from. This is likely due to the availability of local, fresh, quality food products in Vermont and the more environmentally concerned mindset of the population. Vermonters are proud of this "locavore" food culture, and many enjoy its proliferating success and the increasing awareness of the importance of eating food closer to home. It stimulates local business and is consistently a healthier option, both for environmental and human health.

The effects of global climate change are increasingly threatening the food system. Climate change is arguably the most substantial threat to human livelihood in the future, and awareness of its effects, particularly on our food system, must increase. Here in New England, farmers are currently experiencing these effects. Increasing temperatures are affecting crop growth and livestock productivity, increased precipitation, and disruptive weather patterns are already affecting farmers throughout the region. It is apparent that agriculture will continue to be affected in these ways, and likely with more intensity, in the future, and as a result, adaptation is necessary (Fairbank et al., 2011; Faulkner, 2014).

Initially, this project was going to focus on Vermont farmers and their opinions about and adaptations to climate change. Being so intrigued and enamored with Vermont's food culture, this seemed like an obvious choice. Upon further thought, I realized, it was too obvious. Vermont farmers are relatively thoroughly studied, and frequently interviewed. After some discussion with my primary advisor, Dr. Ernesto Mendez, and PhD candidate Rachel Schattman, we found a niche for my thesis in their project concerning Vermont farmer resilience in the face of a changing climate. I would conduct interviews with farmers from my home state of Massachusetts. Farmers there are not nearly as highly sought after for research, and the local food scene in my hometown of Medfield, despite farms in the area, pales in comparison to Burlington, and even Vermont as a whole. How interesting it could be to observe the differing experiences, knowledge, and risk management surrounding climate change of farmers from both states. Thus, my thesis project was born.

To accomplish my project, the first step was to consult with experienced researchers at the University of Vermont who have studied in my chosen field and have an understanding of the up-to-date research. After speaking with Dr. Ernesto Mendez and Rachel Schattman, it was revealed that there was a niche for my thesis within their three-year research project aiming to develop a "Resilient Farmer Typology" through interviewing Vermont farmers and identifying themes or patterns in the data collected from the interview transcriptions. It was determined that I could interview Massachusetts farmers using the same interview guide that would be used for Vermont farmers, and could compare data from the two states. Additionally, the data from my interviews could be used in Dr. Mendez's project to establish a larger, broader picture of the resilient farmer by expanding the implications of the study to the Northeast region of the United States, instead of being limited exclusively to Vermont. Please note that, for the purpose of this study, whenever Massachusetts is referred to in this paper, it is referring to eastern Massachusetts and mainly the Greater Boston Area.

This process gave me the chance to talk to some truly amazing farmers who are doing everything they can to be successful and remain viable, despite the challenges they face. This project could not have existed without them, but more importantly, the food system cannot exist without them. Farmers feed the world. Their success is humanity's health, sustenance, and prosperity. In order for them to succeed, they need to understand the effects of climate change,

and I hope, through this thesis, to contribute to how a farmer can most effectively progress toward farmer resilience, which will be elaborated on later in this paper.

Literature Review

Introduction

This literature review will present existing information surrounding the relationship between climate change and agriculture. It will outline the effects of climate change that are present and projected in Vermont and Massachusetts, and what that could mean for New England agriculture in the future. Additionally, it introduces the idea of resilient agriculture, and puts the agricultural industry and its significance in context in both states. Lastly, it examines the existing research and literature surrounding farmer adaptation to climate change and resilience-building approaches that are present in Vermont and Massachusetts, as well as globally.

Climate Change and Agriculture

Globally, agriculture utilizes more land area than any other industry. As of 2013, 44.3 percent of the land area in the United States was devoted to agricultural activities (The World Bank, 2013). Globally, people have converted almost 3.8 billion hectares of land, which is a third of the entire landmass on Earth, to agriculture and urban areas. Roughly 85 percent of the land dedicated to agriculture contains areas of soil degraded by rising salt in groundwater, excessive compaction, and erosion. In the past three centuries, 300 million tons of topsoil have been lost each year. In just the last fifty years, that rate has more than doubled to 760 million tons per year, and some estimates say that this soil degradation has decreased global agricultural productivity by about 15 percent (Walker & Salt, 2006).

Agriculture is an incredibly resource-intensive industry, and has been proven to be a large contributor to degrading environmental health as well as climate change (Foley et al., 2005). Land use for agricultural purposes has increased atmospheric carbon due to immense deforestation, biomass burning, soil cultivation, draining of wetlands, and overall conversion of natural ecosystems to agricultural systems. Soil cultivation releases stored carbon in the soil and depletes the ability of the soil to sequester carbon from the air (Lal, 2004). Agricultural practices impact water quality through increasing erosion, leeching of nutrients into soil and groundwater, as well as chemical runoff. Agriculture is the largest contributor of excess nitrogen and phosphorous to coastal areas. Another lesser-known impact of agriculture is an increase in the spreading of infectious diseases through modification of natural habitats as well as increasing the

proximity of humans and livestock (Foley et al., 2005). Due to the irreversible nature of current climate change trends, farmers must now find ways to adapt to these changes.

Agriculture is a hugely important industry, having social, economic, and ecological components that contribute largely to societies all over the world. Its widespread nature means that agriculture exists in multiple different forms with various adaptations depending on local climate and other specific characteristics of any given area (Howden et al., 2007). Therefore, as the climate changes worldwide, it is vital that agriculture adapt to these changes. There is already more attention being paid to climate risk management in agriculture, and tools are becoming publicly available that assist farmers in this process (Southeast Climate Consortium, 2015).

Climate change is directly impacting agriculture through its physical effects on both plants and animals. For example, research shows that increased carbon dioxide levels in the atmosphere, which have risen past 400 parts per million, as of 2013, for the first time in recorded history (NASA, 2016). While this can increase plant productivity through increased photosynthesis and decreased water transpiration, it is likely this will not occur due to interactions with other effects of climate change such as water shortage (Sardans & Penuelas, 2012). However, this has not been definitively proven, so the potential of increased crop growth due to increased carbon dioxide fertilization is considered by some researchers to still be a valid topic for further exploration (Helling et al., 2015). Crop success will also be affected by multiple effects of climate change that act on varying time horizons. For instance, changes to soil chemistry will affects plants much longer than newly emergent pests and diseases that could inhabit new areas due to alterations in climate. Climate change, due its volatile nature, could result in previously unseen combinations of changes to multiple factors of agriculture that include climatic, biotic, and soil-related components (Rotter & van de Geijn, 1999). In animals, heat stress induced from consistent warming due to climate change has a myriad of negative effects, including decreases in milk production, reproduction capabilities, and meat quality in dairy cattle, and mass deaths in housed poultry (Rotter & van de Geijn, 1999). All of these can potentially result in a plummeting market in animal agriculture.

Resilient Agriculture

Resilience is becoming an increasingly important topic to consider in agriculture because of the necessity to adapt to unpredictable conditions climate change is causing. “Resilience is the

capacity of [a] system to absorb change and disturbances, and still retain its basic structure and function—its identity" (Walker & Salt, 2006). The resilience of agricultural systems is vital in order to thrive in a changing climate. Agricultural resilience is a facet of overall agricultural sustainability. Currently, the focus within agricultural sustainability is to develop technology or methods of farming that do not harm the environment, are easy to implement, are effective for farmers, and that increase food productivity as well as enhance the surrounding environment and ecosystems (Pretty, 2008). Combined with these goals, resilient food systems also aim to "…1) absorb or withstand external stresses or shocks, and 2) [are] able to adapt to and recover from the effects of these stressors or shocks" (Scarborough, Mendez, & Bisson, 2014). Resilient agriculture should enhance productivity of the land as well as promote environmental health in the face of climate change-related challenges that impact soil and water quality as well as general agriculture due to weather uncertainty (United States Department of Agricuture, 2014). It is thought that localizing food systems can increase resilience as well as make food production more sustainable, as growing practices of smaller, local farms are consistently more ecologically sound than those used on large, conventional farms (Feenstra, 1997).

Resilient agriculture received substantial attention in Vermont following tropical storm Irene in 2011. Irene caused devastating effects all over the state, especially in farmland. The large majority of Vermont cities and towns were affected by the storm (National Association of Development Organizations, 2012), and the flooding across the state was massive. It was the worst flooding Vermonters have seen since the 1920's (Dolak, Katrangjian, & Forber, 2011). A massive total of almost 9,100 acres of farmland was reported to have received damage from Irene, and almost 500 farms reported impacts. Due to contact with contaminated floodwater, a staggering two million dollars' worth of vegetable crops were rendered unsellable, resulting in devastating financial losses for farmers (Grubinger et al., 2012). Following the storm, Vermont farmers, some of whom were facing millions dollars' worth of damage to their farms, were heavily reliant on volunteers to help clean up the effects of the storm. Communities coming together and working with a common goal of restoring their towns' infrastructures became a source of resilience for these farmers, and some Vermont farmers believe their farms would have never recovered if it were not for the help of kind strangers (Shulins, 2014).

Food Security

With a population that is currently standing around 7.2 billion and is projected to increase by another billion in the next twelve years and even reach 9.6 billion by 2050, the human population will have no choice but to alter the food system in order to feed that many people (United Nations, 2013). More people means more competition for resources such as land, water, and energy, and along with a changing climate, this will undoubtedly affect food production abilities (Godfray et al., 2010). It is estimated that global grain production will need to increase by 40 percent in order to meet global food demand in 2020. To make matters more difficult, the average growth rate of annual cereal production in developing countries has decreased from 2.5 to 1 percent per year over the past 35 years, and water scarcity and degradation of land could reduce yields on 16 percent of land used for agriculture (Walker & Salt, 2006).

Importance of Agriculture in Vermont and Massachusetts

In Vermont, the agricultural sector is a pivotal part of the economy. The agricultural industry employs roughly 10,500 Vermont residents (Dunnington, 2010). Climate change could result in a marked decline for the dairy industry, which accounts for 70-80% of Vermont's annual agricultural sales (Dunnington, 2010) due to decreased milk production when cattle are subject to high temperatures (Rotter & van de Geijn, 1999). Additionally, agricultural activities in Vermont provide substantial high-quality, locally-grown food options (Wolfe et al., 2008). In 2012, agricultural products accounted for almost $700 million in cash receipts, almost $600 million of which was from dairy products (United States Department of Agriculture (USDA), Economic Research Service, 2012).

Agriculture is also central to the Massachusetts' economy. There were about 7,800 farms in Massachusetts as of 2015, with a net income of almost $40 million annually (United States Department of Agriculture (USDA), 2015). Agritourism is a large sector of the agricultural industry in Massachusetts, and there is concern about the unpredictable weather climate change will continue to bring and how that could affect its popularity. Additionally, cranberries, while they may not experience as severe an impact from climate change (which will be discussed further later), are potentially at risk of insufficient bog drainage if salt water from rising sea levels infiltrates groundwater (Fairbank et al., 2011). Massachusetts is the second highest

producer in the nation of cranberries, so even a slight interference with production could result in a substantial effect felt around the country (USDA, 2015).

Climate Change Effects in Vermont and Massachusetts

Vermont's agriculture will be extremely vulnerable to the changes climate change will bring. Soil erosion and nutrient loss will increase, as will the need for irrigation and pest, disease, and weed management, because new species will inhabit Vermont in its warming climate (Galford, Hadnott, & Betts, 2015). The cool season crops will suffer lower yields and quality due to warmer winters. Additionally, overly wet soils due to increased flooding will result in lower yields and affect timing of necessary field operations, such as plowing (Faulkner, 2014).

Massachusetts is predicted to experience an increase in pest and disease risks as well as drought in summer and increased unexpected precipitation events (Grund & Walberg, 2013). Winter precipitation, mostly in rain and not snow, is expected to increase by 12 to 30 percent, which will reduce snowpack, affecting the dormancy cycles of plants. Additionally, days reaching above 90 degrees Fahrenheit is projected to increase, from the current five to 20 days annually, to 30 to 60 days annually, increasing the likelihood of heat stress in crops and livestock (Fairbank et al., 2011). These changes will undeniably impact agriculture.

Similar to the large majority of Americans, who largely understand that climate change will continue to affect the earth in several ways (Leiserowitz et al., 2010), it is now generally accepted that agriculture in New England is experiencing great change due to climate change impacts, and that this will continue to in the future. With its historically hot summers and cold winters, crops grown in this region tend to be well adapted to the weather pattern. Vermont and Massachusetts, while both in New England, will likely experience climate change effects on agriculture differently, and some similarly. For example, climate change is predicted to affect apple production both negatively and positively by reducing the number of winter chill days necessary for adequate winter dormancy to set in for some apple varieties, but also extending the growing season for other varieties (Grund & Walberg, 2013). The two states will both experience these changes in apple production.

However, staple products in both states (maple syrup in Vermont and cranberries in Massachusetts) will experience different effects. Cranberry production still has promise to continue successfully, despite climate change due to the ability of cranberries to grow in warmer,

wetter climates (Grund & Walberg, 2013). In contrast, maple sap production is projected to decrease seven days per year by the middle of the century, due to climate change effects (Faulkner, 2014).

Existing Research on Farmers and Climate Change

Farmers in Vermont are aware of the changes that are happening and how they could put their livelihoods in peril. When asked what they consider to be the most pressing, most concerning potential problems related to climate change in Vermont agriculture, farmers reported, in 2011, that they are most concerned with the "economic impacts of climate change and rainfall levels/flooding", which is in part due to the agricultural flooding disaster that was Tropical Storm Irene that year. They also believe that climate adaptation approaches in agriculture is the topic that requires the most attention and improvement. Additionally, they emphasize the need to maximize both short- and long-term benefits for both the farmers and the environment through innovative methods and alterations to Vermont agriculture (Schattman, Mendez, & Westdjik, 2012).

In a recent study, it was found that Vermont farmers are using, at least, three best management practices (BMPs) to mitigate climate change effects: diversification, soil health improvement and water management, and new cropping systems. Farmers surveyed in this study reported diversifying markets, products, sources of household income, and land-base to better mitigate agricultural unpredictability (crop failure, income loss, decreased productivity, etc.) associated with climate change (Schattman et al., 2015).

Vermont farmers recognize soil health improvement and water management as one of the most important adaptation steps to take. They are highly concerned about the levels of organic matter in their soil (Schattman et al., 2015). According to soil scientists, for each one percent of organic matter content, soil can hold 16,500 gallons of water per acre of land down to one foot deep (Gould, 2012). They are also worried about increased erosion from flooding, and say that green manure and cover cropping are strategies they often implement to not only increase soil organic matter but also mitigate erosion. In seasons where cover cropping is not an option, farmers use buffer strips and river reconstruction to help slow flood waters (Schattman et al., 2015).

While Vermont is relatively progressive in terms of addressing climate change in agriculture, farmers still believe that certain resources are lacking. In a 2012 study, farmers stated that they believe lack of information, lack of funding, and lack of political will are the top three barriers to more effective climate change adaptation. Additionally, farmers generally think that climate change is an immense subject, and emphasize that there is no universal approach to tackling climate change from an agricultural perspective. Because of this, it is often hard to know where to start or what is worth investing in (Schattman, Mendez, & Westdjick, 2012).

In Massachusetts, farmer concerns and feelings about climate change have been researched less than in Vermont. There is research on climate change adaptation in general in Massachusetts (Fairbank et al., 2011), and there is some literature surrounding potential farmer adaptations in this research. Farmer training programs exist for beginning farmers, and the goal of building a resilient food system is addressed in these programs. However, specific discussion of climate change effects on agriculture and how farmers can work towards becoming resilient to these effects is seemingly absent from these resources (New Entry Sustainable Farming Project, 2015). This indicates a lack of knowledge pertaining to what farmers specifically need in order to build resiliency. It is important to note, though, that there is some information available to farmers through organizations that can inform them of individual resilience-building strategies, such as increasing absorption capacity of soil to assist in maintaining farms during extreme heat and unexpected precipitation events (Northeast Organic Farming Association, 2014).

Vermont has substantial resources surrounding the topic of agricultural adaptation and resilience to climate change. The Agroecology and Rural Livelihoods Group at UVM has a long-term initiative called Vermont Agricultural Resilience in a Changing Climate, which focuses on helping farmers gain access to effective adaptation or mitigation strategies and practices (Agroecology and Rural Livelihoods Group, 2016). Vermont Land Trust has its Affordable Farmland initiative, which seeks to help beginning farmers gain access to quality, financially feasible land on which to start farming, which is often the hardest part of starting a farm (Vermont Land Trust, 2016). UVM Extension has its Center for Sustainable Agriculture, which has a branch dedicated to farming and climate change with multiple research publications on building agricultural resilience to climate change and how to adapt (UVM Extension, 2016).

Massachusetts has existing resources for beginning farmers as well, such as the Northeast Organic Farmers Association of Massachusetts (NOFA/Mass) Beginner Farmer Program and the

Beginning Farmer Network of Massachusetts (NOFA/Mass, 2016; Beginning Farmer Network of Massachusetts).

Interestingly, there is more significant research available on farmer understanding of and adaptations to climate change in eastern countries, such as Africa, than there is on the topic in the United States. In Southern Africa, it has been found that farmer adaptation strategies include increasing diversification in crops and production activities, and adopting strategic planting strategies that avoid planting crops during times in which they are likely to experience climatic stress (Nhemachena & Hassan, 2007). In a case study in the Limpopo River Basin of South Africa, it was found that almost all (91%) of farmers correctly perceived long-term increases in temperature. Based on data trends, it was determined that education about climate change or access to extension, in addition to experience farming, increases a farmer's likelihood to correctly perceive a long-term change in temperature. Main adaptations include planting different crops, irrigating more, changing planting dates, and increasing diversification (Gbetibouo, 2009).

Methods

The tables presented below show farm characteristics of the farms included in this study. Table 1 presents the number of years of farming experience farmers have, while Table 2 shows the types of farms examined in both states.

<10	0
11-20	4
21-30	3
31-40	1
41-50	1
50+	1

Table 1: Number of years farming, n=10

Orchard	1
Diversified Vegetable	5
Diversified Vegetable and Meat	4

Table 2: Types of farms, n=10

Methods

The goal of this research was to do a comparative study of five farmers from both Vermont and Massachusetts to contribute to the larger study on developing a Resilient Farmer Typology. I first identified the farmers I wanted to interview. Growing up in Massachusetts, I was familiar with several farms in the Greater Boston Area, as I grew up frequenting them. They all have notable community involvement. Upon speaking with several community members in my hometown of Medfield and surrounding towns, my inclination to interview at the farms I knew was echoed. Many people expressed that these farms are integrated into the cultures of the communities of which they are a part. It was my belief that these farms, as are all others, are undoubtedly experiencing the effects of climate change, and community members expressed this belief as well. It is through this process that I formed my list of interviewees, which initially consisted of ten farmers.

Following this, I contacted the farmers through e-mail or telephone. Out of the ten I contacted, five were both responsive and willing to participate, and I then established times I could meet with them. All of the five farmers that I managed to make a connection with opted to have the interviews take place in farm structures, like greenhouses or an office, or in their homes, which were on the farms. I conducted these interviews while I was in Massachusetts for winter school vacation. I recorded the interviews with permission using a recording device, and I then downloaded the audio files onto my computer. The farmers were given an Institutional Review Board (IRB) information sheet prior to the interview that informed them of the approval of this research and explained that it would not expose them to excessive risk. My project was granted umbrella exemption under the larger project being performed by the ARLG. During the interviews, I used the interview guide developed largely by the Agroecology and Rural Livelihoods Group (ARLG) at the University of Vermont, which Dr. Mendez leads and of which

Ms. Schattman is a member, for their larger study concerning Vermont farmer resiliency. The interview guide can be found in the Appendix. I contributed to the editing process of the guide by offering feedback or suggestions on the way the questions were formatted, worded, and ordered. The same interview guide was used both for the interviews I conducted in Massachusetts and the interviews ARLG conducted in Vermont for consistency, and so patterns could more easily be detected in the responses. Since the same conversation was essentially being had with each farmer, it allowed for more direct comparison of responses. The Vermont farmers were selected for the ARLG project by connecting with key contacts at agricultural organizations and asking for recommendations of farmers with a wide range of experiences and beliefs about climate change.

The farms used in this study were all diversified vegetable/fruit operations, some of which also produced and/or sold meat. The Massachusetts farms were all located in areas relatively free of excessive risk, for example none of them were directly near a body of water or were located in a floodplain, or were on very sloping terrain.

One Vermont farm in this study is located on a substantial slope, and another farm has very dense, clay-like soil. Additionally, the majority of the Vermont farmers have previously farmed in areas that are floodplains or in close proximity to bodies of water, and they experienced the effects of these risks in the past. These factors are important to keep in mind when considering the results of this study.

Using the HyperTRANSCRIBE software, I then transcribed my interviews. I also transcribed five Vermont interviews conducted by ARLG members, which were the five interviews I used to compare to the Massachusetts farmer interviews. Following the completion of the transcriptions, I utilized the HyperRESEARCH software to analyze my interviews using a coding method. In order to do this, I read through the interview transcriptions and identified which questions on the interview guide elicited the most interesting responses (e.g. widely diverse responses, unanimous responses) and developed overarching, yet explicit, code groups that represented the topics that farmers talked about, which were most interesting or significant in terms of my study. In general, questions concerning critical infrastructure, management of risks, extreme weather, causes and effects of climate change globally and regionally in New England, and the future of agriculture in New England yielded the most significant responses in both states. Then, I used HyperRESEARCH to compartmentalize quotations from the

transcriptions into their corresponding code groups. I compiled two code books (one for Massachusetts and one for Vermont), which represented the central themes and patterns that emerged in the interviews from each state. The codes were grouped into six broader categories: 1) adaptations/risk management, 2) risks, 3) perceived climate change causes, 4) perceived climate change effects, 5) experienced climate change effects, and 6) future of agriculture in New England. Within these groups, each state had its own set of codes that were determined from interview data. Some of the codes were the same between states, while some differed.

After coding the transcriptions and collecting my data, I began my analysis. I examined existing literature and studies surrounding climate change and agriculture, particularly in New England, and noted where my data had any discrepancies with the existing data or if it reinforced it. Additionally, I compared the data I collected from Massachusetts and Vermont interviews and searched for similarities and differences in the data sets. Following this analysis, I developed a general picture of the resilient New England farmer that included characteristics or practices that appear, based on the interview data, to be the most effective in building farmer resiliency to climate change. I additionally created tables that organized some demographic information I gathered from the farmers, as well as some information gathered from farmer responses, and included a map that visually represents the approximate locations of the farms in both states.

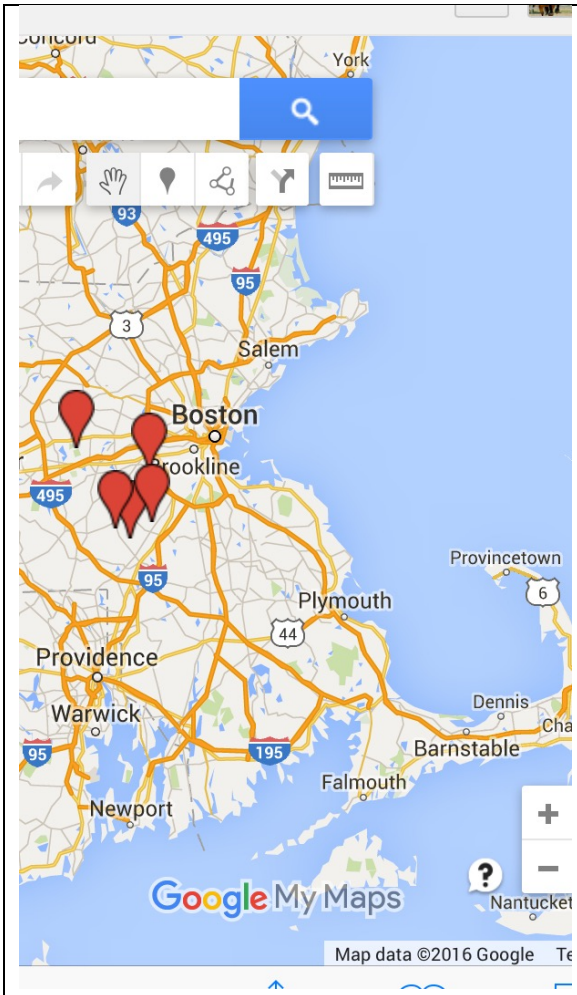

Figure 1: A map of Massachusetts farms interviewed for this study

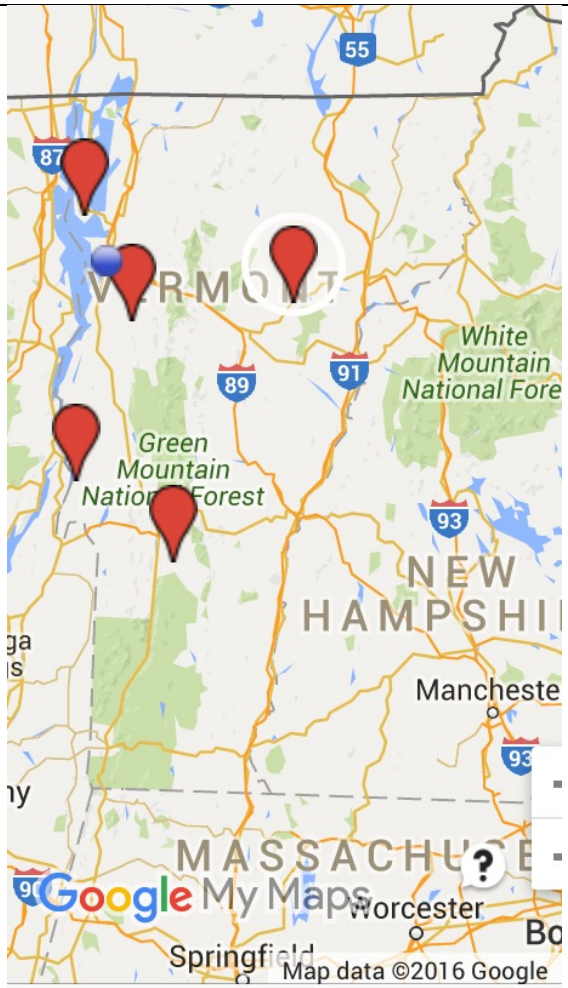

Figure 2: A map of Vermont farms interviewed for this study

Limitations of the Study

There are some factors that potentially limit the scope of this study. The sample size of farmers from both states is quite small, at only five farms per state, and therefore the data does not effectively represent the entire population of farmers in either state. The farm selection process also had the limitation that it did not allow for a complete representation of farmers within the two states. Additionally, the Massachusetts interviews were performed by an undergraduate student with limited interviewing and research experience, while the Vermont interviews were performed by more experienced interviewers and researchers. This could have

influenced the amount of discussion that occurred in the interviews, as more experienced interviewers are more familiar with the style of questions that are effective to ask to elicit interesting interview responses.

Results

Climate Change Causes and Effects

In general, Vermont farmers seem to have more knowledge about and a more thorough understanding of climate change than Massachusetts farmers. Farmers from Vermont cite scientifically accurate information about the causes of climate change, mainly reporting fossil fuel combustion and human activities as the central factors exacerbating climate change today. Massachusetts farmers, while expressing awareness of climate change and its effects as well as confidence in their ability to adapt to changes it might bring, cited more simplistic causes for climate change, such as vehicles, and offered less explanation and less overall discussion of details surrounding climate change causes (see Table 3). Along similar lines, Massachusetts farmers consistently reported that they do not get information on climate change from any one reliable source. They mainly hear about it on the news, but note that they do not perceive this information as credible. One farmer said he appreciated information published by universities and colleges on this topic, and that is a source he trusts. Otherwise, most farmers reported that they do not truly receive information on climate change from anywhere. Contrarily, in Vermont, farmers reported using personally chosen and trusted news sources as well as Extension for main sources of climate change information.

Massachusetts	Vermont
"…I see all these millions of cars, I think they got to be doing something… so what is that, carbon dioxide from cars, is it?"	"…human carbon dioxide…methane inputs into the atmosphere. Industrialization worldwide."
"…the growth of the population across the globe is stressing the natural resources of the planet out… Do I know the specific gases and things? No."	"…carbon dioxide is the big one that we associate because of heating and vehicles, but methane gas is much worse."
"…carbon fuel emissions… I'm not a scientist but I know that much."	"Fossil fuel use. And agriculture."

Table 3: Perceived causes of climate change

Notably, Vermont farmers mentioned eight distinctive categories of effects they believe climate change will bring, while Massachusetts farmers' responses fell into four categories (see Table 4). Vermont response categories are also more specific and are of a wider variety than Massachusetts response categories, all of which are generally well-known potential implications of climate change on agriculture. However, they are also accurate, Vermonters simply mentioned more potential effects.

Massachusetts	Vermont
Extreme Weather	Extreme Weather
Sea Level Rise	Sea Level Rise
New Crop Varieties	Warming
Warming	Mass Human Migration
	Longer Growing Season
	Increased Pests/Disease
	Drought
	Increased Precipitation

Table 4: Perceived effects of climate change

Farmers in Vermont mentioned effects of climate change that they have experienced firsthand, during their experiences farming, more frequently than Massachusetts farmers did. Interestingly, Vermont farmers also mentioned some events that they associated with climate change that were never brought up in the Massachusetts interviews, such as tick-borne illness and lack of sufficient pollinators. These concepts are also less widely associated with climate change by the general public than, for instance, increasing global temperature. Additionally, all five Vermont farmers mentioned tropical storm Irene and its effects, especially rainfall, winds, and flooding that eroded soil, damaged infrastructure, and rendered crops unsellable. No Massachusetts famers mentioned Irene in their interviews, likely because its impact there was far less than in Vermont.

Risks

Massachusetts farmers cited fewer risks that they believe they face on their farms as opposed to Vermont farmers. While Vermonters mentioned ten categories of risk, Massachusetts

mentioned only five (see Table 5). Additionally, the only climate-related risks Massachusetts farmers cited were unpredictable weather and frost, the latter of which was only mentioned by one farmer. Out of the ten categories Vermont risks fell into, three of them were climate- or ecologically-based, and included erosion, unpredictable weather, and soil quality. In both states, farmers mentioned the risk of unpredictable weather with the most frequency, and financial instability as the second most frequent. The code of 'unpredictable weather' included farmer comments related to droughts, freezes, wind, storms and precipitation, and hail. Concerns about precipitations and flooding were more prominent in Vermont than in Massachusetts, which could be due to experience with tropical storm Irene.

Massachusetts	Vermont
Financial Instability	Erosion
Frost	Failure
Market Shifts	Financial Instability
Neighbor Issues	Market Shifts
Unpredictable Weather	Neighbor Issues
	Physical Injury
	Power Outage
	Quality of Labor
	Soil Quality
	Unpredictable Weather

Table 5: Farmer reported risks

Farmers in both states mentioned several other risks that were not related to climate or ecology, such as quality of labor, physical injury, market shifts, failure of their business, and neighbor issues. Since this study was originally intended to explore farmers' experiences with climate change and the risks they experience in that context, the extent to which farmers from both states cited non-ecological risks that they feel they face on their farms was unexpected and intriguing. Additionally, farmers from both states tended to discuss more about these socially-based risks, and in general, spoke more passionately and personally about them through personal stories and specific examples. They stress about how they seek to provide the products and services that their community desires, and how constantly adjusting to local market shifts is vital to the maintained viability of their businesses.

Adaptations

Both Massachusetts and Vermont farmers discussed several adaptations they have developed on their farms to manage their risks, both climate change-related and not. Vermont farmers talked about thirteen categories of adaptations, and Massachusetts farmers discussed ten categories (see Table 6). In both states, farmers most frequently cited diversification as a key adaptation on their farms. Many farmers emphasized how diversification allows for financial stability because if one particular crop or market has a low revenue year, other aspects of their farm will likely be successful enough to keep the farm financially viable.

Massachusetts	Vermont
Community Involvement	Alternative Income Sources
CSA	Community Relations
Diversification	Cover Cropping
Efficient Energy Systems	CSA
Growing Under Cover	Diversification
Irrigation	Drainage
Life Experience	Farm Location
Retail	Growing Under Cover
Storage	Insurance
Strategic Planting	Irrigation
	Soil Building
	Storage
	Strategic Planting

Table 6: Farmer reported adaptations

Vermont farmers discussed strategic planting adaptations with the second highest frequency, and mentioned community relations and growing under cover with the next highest frequency. Massachusetts farmers talked about community relations and growing under cover with the second highest frequencies. This reflects parallels between the states concerning what farmers believe to be the most critical adaptations or risk management practices on their farms. Diversification is pivotal for all of the farmers interviewed, regardless of location, and

community relations and growing in covered structures are both critical adaptations as well. It is interesting that strategic planting was so prominently mentioned in Vermont interviews, with ten mentions out of a total of 67 (14.9%) instances of adaptation discussion, and in Massachusetts it was only spoken about twice out of 40 mentions (5%) of adaptations.

Three adaptations that were mentioned with moderate frequency (three to seven mentions) in Vermont interviews were cover cropping, soil building, and drainage. None of these adaptations were discussed in Massachusetts interviews, with the exception of cover cropping, which was indirectly mentioned by one farmer who alluded to the necessity of increasing the farm's land base to allow fields to have a rotational planting schedule that allows some fields to be out of production for a certain amount of time. All three of these adaptations involve manipulating or influencing the land in some way in order to improve the growth and production of crops. This does not mean Massachusetts farmers are not utilizing these adaptation strategies as well, they just were not mentioned in the context of climate change, during the five interviews done for this study.

Several farmers from both states stressed the general capability of farmers to adapt to climate change, as that is what they have always had to do. Working outdoors inherently involves constantly being at the whim of the weather, so historically farmers have had no choice but to adapt. Farmers today believe that this will not change, and climate change could enhance the amplitude of these changes, however they generally feel that they will go on adapting to the elements as farmers consistently have.

Future of New England Agriculture

Table 7 below presents information regarding what farmers in both states believe the future of New England Agriculture will involve and what will be most prominent.

Massachusetts	Vermont
Increased Diversification	Covered Structures
Increased Pests/Disease	Decrease in Agricultural Land Base
Increased Success	Disruptive Weather
Localized Food Systems	Increased Success
New Crop Varieties	Localized Food Systems
Small Farms	New Crop Varieties
	Shift in Agricultural Products

Table 6: Characteristic elements of future New England agriculture reported by farmers

Farmers were asked what the future of agriculture will look like in New England and what sort of role agriculture will play in the evolution of the region considering climate change. In Vermont, the most frequently reported belief is that farmers will transition to new varieties of crops to adapt to climate change, such as crops that are more suited to warmer climates, that are drought resistant or can handle saturation, or that are in general more hardy and can remain viable through the extremes of weather. Four out of five Vermont farmers in this study reported this belief. Additionally, two out of five farmers noted that they believe one of the most significant issues New England farmers will face in the future is excessive rainfall, flooding, and saturation.

In Massachusetts, the increasing prevalence of localized food systems was most highly reported. Farmers believe that as climate change continues to progress, people will be increasingly inclined to know their food source and buy local food. Most farmers believe this will be due to the destabilizing of the nationwide food system, and credit climate change effects in main food production areas of the country, such as drought in California and sea level rise in Florida, for the likely increasing destabilization that will continue into the future. Four out of the five Massachusetts farmers cited localized food systems as a central element in the future of New England agriculture.

Interestingly, though, Massachusetts did not cite specific weather-related aspects about what they think the future holds for New England agriculture given climate change. Other potential changes were discussed in the context of climate change, like new crop varieties being grown because of increased temperatures and New England having a climate of a more southern region, but no predictions were made as to what New England weather patterns might look like

given climate change and how that would affect farmers. Vermont farmers, for instance, cited the likely perils of having too much rain in New England or too much soil exhaustion from extreme weather and, therefore, a decrease in agricultural land. Vermont farmers tended to consider a wider variety of potential climate change effects on agriculture, and, in general, Massachusetts farmers discussed in lesser detail what they think the climatic changes will be in New England and how they will specifically relate to agriculture.

Discussion

Understanding of Climate Change

According to a 2010 report, 50% of Americans understood that climate change is caused by human activities (Leiserowitz et al., 2010). In this study, four out of five Vermont farmers (80%) cited human activity as a perceived cause of climate change, and two out of five (40%) Massachusetts farmers mentioned it specifically. However, four out of five Massachusetts farmers mentioned greenhouse gases or carbon emissions as a cause of climate change, which is arguably implying human activity. Leiserowitz et al. (2010) also stated that 63% of Americans believe climate change is happening, while 19% say they do not know and the last 19% saying it is not happening. In this study, all of the farmers discussed climate change and understood that it is happening. No farmers denied it. The degree to which they believe what science says about climate change is varied between farmers, and the degree to which they are concerned about it varied, but the fact that farmers in this study were consistently aware that climate change is happening is notable. In addition, the majority of Americans understand carbon dioxide to be a major gas that is emitted from the burning of fossil fuels, and also recognize that burning fossil fuels for heat or electric power, as well as the use of vehicles, contribute to climate change (Leiserowitz et al., 2010). Similarly, the majority of farmers in this study understand this concept.

Based on the results of this study, in that Vermont farmers, in general, tended to elaborate more in their responses to climate change-related questions and consider a wider variety of climate change effects that could come to agriculture in the future compared to Massachusetts farmers. It appears that Vermont farmers have more accurate information about climate change and therefore are more educated on it. This hypothesis is strengthened by the prevalence of farmer climate change adaptation research and initiatives in Vermont, and the comparably lesser amount in the studied area of Massachusetts. Vermont has many specific initiatives and efforts aimed directly at connecting farmers with resources that can help them succeed despite climate change and assist in their effective adaptation to its effects.

In Massachusetts, resources exist that seek to help new farmers get off the ground. However, the specific efforts seeking to make information about climate change directly available to farmers, as well as information concerning what other farmers in the area are doing

and research about what more can be done, are limited. There are publications on climate change effects in Massachusetts. For instance, www.mass.gov released a Climate Change Adaptation Report in 2011 that contained information regarding areas of vulnerability to climate change effects and potential actions that can be taken to help mitigate risk. While agriculture has a section in that report which addresses vulnerabilities local agriculture might have, there is a noticeable lacking of resources readily and publicly available for farmers that inform them of adaptation strategies that could prove effective given climate change. Farmers experience climate daily, and essentially have no choice but to adapt to climate change if they wish to remain viable, but the information surrounding the probable effects it will have in specific areas appears to be scarce. Widespread awareness needs to be present if anyone seeks to help farmers adapt.

One Massachusetts farmer in this study, upon being asked how confident he is in his ability to adapt to possible changes to agriculture climate change may bring, responded, "Yeah, we could adapt to them if we knew what they were going to be". Another farmer, when asked if the risks she faces on her farm are compounded by what she knows about climate change, she responded, "Who knows?", and later stated that she is "skeptical about the science" on climate change. She indicated awareness of climate change stemming from fossil fuel combustion, and admitted to noticing higher temperatures than normal during certain points in the year, but her overall lack of specific knowledge indicates a potential scarcity of widespread information available to farmers if they want or need to find out more about climate change adaptation in agriculture. Another farmer, when asked what he believed to be the causes of climate change, responded, "…carbon fuel emissions…that kind of thing". Another responded, "…obviously the…energy…and the emissions and all that business". The relatively vague understanding that appears to be present surrounding climate change suggests insufficient resources to become informed about this topic in this specific area of the state, or insufficient knowledge that climate change is a substantial concern for the future of agriculture. This calls for a more in-depth understanding of what is causing changes and what can be done to prepare to face them.

Additional factors that could contribute to knowledge of climate change, such as age and level of education, are important to take into consideration in this study. In Vermont, one particular farmer who both graduated college and was older than the other farmers in this study did seem to be the most familiar with climate change effects on his farm and how to best mitigate them. Additionally, the majority of Vermont farmers have education past high school, while the

farmers in Massachusetts mostly had a high school education. In this sense, it is possible Vermont farmers were more educated on climate change simply because they have had a more extensive education in school. Age differences between farmers in both states did not seem to yield any significant patterns.

One Vermont farmer emphasized the difference between the terms 'climate change' and 'global warming', because the temperature changes are "different in different places". Another Vermont farmer said, regarding climate change, "…we go through big, climatic shifts over time, but we haven't seen in the…geologic record, anything as fast, and it seems to correlate with the industrial revolution". Yet another farmer articulated that a main atmospheric gas associated with climate change is "…carbon dioxide which comes from the burning of fossil fuel, but then it's also… carbon particles that end up in the atmosphere, so it's this combination of things that are creating this barrier so that heat cannot escape". This describes the greenhouse effect that results in a largely warming climate. Compared to Massachusetts responses to the same questions, Vermont farmers seem more well-versed on the topic of climate change and the science behind it. The prevalence of resources and research initiatives related to climate change and agriculture as well as agricultural adaptations is likely a contributing factor to this heightened awareness. Additionally, considering that Vermont farmers were selected from agricultural organizations and Massachusetts farmers were selected by community opinions and were largely not a part of any organizations, it is possible the Vermont farmers have easier, more immediate access to agricultural climate change adaptation resources. Furthermore, there is likely more information surrounding this topic in research and popular culture in Vermont because of the attention tropical storm Irene drew to the need to build resiliency to unanticipated impacts of climate change.

Community

As introduced in the results, it was apparent that non-climate change-related risks were prominent in farmers' lives from both states. Similarly, positive community relations were cited as one of the top three most-mentioned adaptations in Vermont and Massachusetts. Farmers spoke frequently of the importance of community integration and support, and also did so with more willingness, passion, and vigor than most other topics discussed in the interviews. This reflects a high level of community integration of farms into their communities, as well as

suggests the presence of a mutually beneficial system. One Massachusetts farmer emphasized that their customers "…tell us what they want…we know they're going to hang out here, they always do, and…how does this work into what the customer wants to do? And what do we think the customer needs to see to be able to help them better understand what we do?". Another stated, "…we get a lot of community support…people really want us to be there…and they want to support us…and that's huge…it makes all the difference in the world". This suggests a sincere investment of these farmers in their community relations and a high level of personal care and attention to their role in the community.

A similar sentiment was echoed in the Vermont interviews as well. One Vermont farmer stressed how maintaining connections within the farming community has saved her from not being able to sell crops in the past, saying, "I feel like that…tapping into that relationship…just saved us and…they buy so much stuff and she was so willing to work with us". Another Vermont farmer articulated the importance of community to farms quite effectively:

> …we do make sure we stay relevant and involved in our community, because we think a long-term farm has good community relations. And…creating those relationships on different levels with people, invites people to be a part of our farm and then it just makes it more sustainable…it comes back multifold…when we do work in the community…or we do volunteering, because the relationships we build in those experiences, those people then…are telling their friends about…who our farm is.

Community relations between farms and surrounding populations allow for a chain reaction of positive effects. Farmers who are supported by their community flourish because of the financial support and investment in their products, and because of this, they are able to continue providing the service that the community wants. They can grow more food and expand entertainment and farm activity offerings when financially stable and consistently supported by their customers. What this means in the greater context is that local farms need community support in order to be truly successful. Supporting local agriculture will stabilize local food systems.

Local food systems tend to make communities more sustainable, more equitable, allow for a food system that aims to be economically viable for both producer and consumer, and use

practices that are consistently more ecologically sound than industrial agricultural practices (Feenstra, 1997). Five out of five Massachusetts farmers believe that the future of New England agriculture will be largely localized food systems and/or small farms. Interestingly, only one out of five Vermont farmers noted localized food systems as a significant part of the future of New England agriculture. Vermont farmers, in contrast, cited characteristics like increased disruptive weather patterns, the necessity to plant new varieties of crops, or an increase in growing in covered structures being prominent in the region's future. While disruptive weather was mentioned by only two farmers, both spoke of it in the context of excessive rainfall and soil saturation. These effects are predicted scientifically to occur in the future of Vermont due to climate change (Dunnington, 2010; Faulkner, 2014). While Massachusetts is similarly predicted to experience an increase in precipitation, particularly as winter rain, as well as increased unexpected precipitation events (Grund & Walberg, 2013), the farmers in this study did not cite increased precipitation as a notable aspect of future regional agriculture. This can likely be attributed to Vermont farmers' experience with tropical storm Irene, and the dramatic flooding that occurred because of the roughly 11 inches of rain the state experienced. Because Massachusetts farmers did not experience Irene's devastation to as great of a degree as Vermont farmers did, precipitation does not stand out in their minds as prominently as a risk of climate change. Vermonters still talk about the trauma farms faced because of Irene, and are still feeling the repercussions today (Grubinger et. al., 2012). This firsthand experience makes the fear of what is to come in the future stronger, and likely results in farmers thinking about resilience and adaptation more. Therefore, investing their time, effort, and money into techniques and strategies that can help them be better prepared for the next storm like Irene seems worthwhile. Climate change can easily remain a relatively abstract idea if people do not directly experience its effects, which appears to be the case for Massachusetts farmers.

Risks

As previously stated, farmers from Massachusetts and Vermont cited unpredictable weather and financial instability most frequently when asked about pressing risks they face on their farms. What was found through closer examination of the interview transcripts was that these two categories of risk often overlapped with one another. In other words, unpredictable weather would often lead to an event that resulted in financial losses, thus destabilizing the

farmer's livelihood. These findings are consistent with a 2012 study done in Vermont, which found that while farmers are interested in soil building, water management, and other practices that can help mitigate the effects of climate change on farms, and while they believe these are important, their main concerns are the economic impacts associated with climate change effects like crop losses, soil erosion, and livestock heat stress (Schattman, Mendez, & Westdjik, 2012). Though this topic in Massachusetts remains infrequently researched, it is likely that Massachusetts farmers share this sentiment of the interconnectivity of unpredictable weather and financial instability due to the relative consistencies of the sentiments regarding these risks in the interviews. All farmers expressed, at some point in their interview, how unpredictable weather has caused them financial losses on their farms. As one Massachusetts farmer said of those in the business, "we live and die by the weather".

All five Vermont farmers mentioned tropical storm Irene and its destructive effects on Vermont agriculture at least once during their interviews, while zero Massachusetts farmers did. The reason for this is fairly obvious, as Vermont experienced far more effects from the storm than eastern Massachusetts did. Out of Vermont's 251 towns, 223 were affected, causing President Obama to sign a disaster declaration after the storm's completion (National Association of Development Organizations, 2012). It is possible that because Vermont farmers experienced such devastating effects from an extreme weather event, their awareness of climate change and how it has potential to bring more storms like Irene to the region more frequently has increased. This has potentially resulted in them being more proactive and taking initiative more quickly in terms of adopting adaptation technology to combat this and other similar effects of climate change in the future.

It is possible that Vermont farmers cited more risks faced on their farms than Massachusetts farmers because of the types of farms incorporated into this study from both states. The Massachusetts farms, as previously stated, generally have less geographical proclivity to climate-related risks than the Vermont farms in this study. All five Massachusetts farms were located on relatively flat terrain, not in a floodplain or near a body of water subjecting them to frequent flooding risks, and none of the farmers reported notable issues with their soils. One Vermont farmer reported the risks of growing on clay soil, the denseness of which makes it difficult for the soil to handle excessive rainfall. As a result, the farm occasionally suffers from poor crop growth due to the suffocation of the plants and a lack of proper soil drainage. Another

is located on a substantial slope, making increased precipitation a problem due to erosion risks and soil loss. Because of this, Vermont farmers could have reported more risks and more awareness of how to mitigate them because they have directly experienced the effects. Massachusetts farmers might not have reported certain risks, such as excessive precipitation, as frequently because they are not directly affected by these factors on their farms due to geographic location or farm topography.

Adaptations/Risk Management

Because of the inescapable nature of the elements and their volatility, adaptation is necessary for farmers. Farmers from both states stress the importance of diversification in maintaining the farm financially, as it is easier to absorb impacts from temporary limited success of one facet of the farm business when there are other aspects that can make up for that loss. A farmer from Massachusetts effectively summarized this idea:

> …every component of the things that we do has a place. The horse boarding, I don't make a lot of money from that, but there's a check here in January that I don't get at another time. The CSA allows us to finance ourselves before the season. The big entertainment stuff at the end [of the growing season] usually can make up for a lot of ups and downs during the season as far as variability. You're not tied to trying to make all your money on a dozen ears of corn, you know what I mean?

For this farmer, the CSA program, or community-supported agriculture, is considered part of his diversification, but he also cited the CSA separately as its own adaptation because it allows him to get money upfront, stabilizing his business. Notice, once again, the trend of investing in a particular practice or adaptation at least partially due to economic impacts. As with any business, a farm can only remain viable if it is economically stable.

Vermont farmers brought up ecologically-based farm adaptations in their interviews such as cover cropping, soil building, and drainage systems, none of which were cited in Massachusetts interviews. As mentioned in the results, that does not necessarily mean these practices are nonexistent on farms in Massachusetts, they simply were not mentioned in the farmer interviews done for this study. However, it could also suggest a wider knowledge of these adaptation strategies and how to effectively implement them in Vermont. The likelihood of this possibility is strengthened by the research focus and publications on how farmers can most effectively adapt and build resilience to climate change in Vermont (Schattman et al., 2015; Schattman, Aitken, Mendez, & Caswell, 2014; Scarborough, Mendez, & Bisson, 2014; Schattman, Mendez, and Westdijk, 2012), and the lack thereof in Massachusetts. Without research and the spreading of education on this topic, Massachusetts farmers will likely continue using strategies to adapt to climate change that have proven effective through experience, but widespread education and understanding of how to build resilience to incoming, more unpredictable changes will remain lacking.

An adaptation that was discussed by two Vermont farmers that was not discussed by Massachusetts farmers is having alternative sources of income besides the farm. This differs from farm diversification, and is usually termed *livelihood* diversification (Ellis, 2000) because the source of income in this case comes from another job, not another aspect of the farm business. One Vermont farmer stated that having an alternative source of income is one of the best forms of protection for her farm and livelihood. A 2015 study suggests that this is true for many Vermont farmers, determining that diversification of multiple aspects of the farm, including household income, is a key strategy for mitigating risks associated with climate change (Schattman, et. al., 2015). To again reference the impact of tropical storm Irene on this state, it is possible that the immense destabilization of farms that occurred due to Irene has encouraged Vermont farmers to have a source of income to fall back on, just in case disaster strikes again. However, it is possible that this is not necessarily related to climate change, and is simply a form

of resilience that farmers use to maintain financial stability regardless of climate change effects.

It is worth noting that the majority of farmers in this study have been farming for more than 15 years (see Table 1), giving them substantial experience and years of trial and error when it comes to risk management and adaptation strategies. As for the differences between Massachusetts and Vermont, the variation in farmer experience is relatively consistent. There was at least one farmer in both states who had been farming the same land for his or her whole life. There were also a number of young farmers in both states who have farmed at other locations previous to settling at their current farms. While the lifelong farmers possess a greater knowledge and familiarity with their land, it did not generally appear to be a notable factor considering climate change resilience or adaptations on the farms. Regardless of the length of time a farmer had been on their current land, or had been farming in general, challenges and unexpected circumstances have arisen and continue to arise for all farmers in both states. This is possibly because this era of climate change is unique, and the rapid change that is happening now is unprecedented in the lives of any of these farmers. Therefore, past knowledge or experience in farming, or a lack thereof, might not substantially affect a farmer's ability to adapt to changes now.

Parallels Between States

Vermonters cited diversification, strategic planting, growing under cover, and community relations most frequently in interviews, while Massachusetts farmers cited diversification, community relations, and growing under cover most frequently. The overlapping of most of these top-identified adaptations is significant in reflecting parallels between Vermont and Massachusetts regarding what sort of risk management practices are most effective in building resiliency to climate change on farms. Diversification, growing in covered structures, and maintaining positive, substantial community relations were cited with substantial frequency in both states. In Vermont, out of 67 instances of discussion of various adaptations, diversification was cited 12 times (17.9% of adaptation mentions), and growing under cover and community relations were cited 9 times each (13.4%). In Massachusetts, out of 40 instances of discussion of farm adaptations, diversification was cited 10 times (25%), and community relations and growing under cover were cited 6 times each (15%). The similarities among the most highly

discussed adaptations imply that these adaptations are effective and significant for farmers in the New England region, attempting to manage risks posed to them by climate change.

Schattman et. al. (2015) found in a study that, according to a survey of Vermont farmers, diversification of markets, income, land base, and production, in addition to sustainable soil management and innovative cropping systems, are most effective in mitigating risks associated with climate change. The findings from the Vermont interviews are relatively consistent with this data, as strategic planting, the way it was discussed by farmers in this study, could effectively be included under 'innovative cropping systems', and diversification of multiple elements of the farm was the most consistent adaptation. Soil building was mentioned three times by two Vermont farmers, so it was not as prominently reported in this study as in the 2015 study, but it is still present. Community relations, which was significant for both states in this study, was not present in the 2015 study because the survey examined risk management, resilience-building strategies for climate change-related risks, and prominent community relations are not necessarily valuable for directly mitigating climatic risks. They do build resilience of a farm by stabilizing it financially with consistent business, but they do not immediately assist in managing ecological problems caused by the effects of climate change. This signifies an important difference between climate change adaptation and resilience. Actions responding to climate change are often perceived as ecological or biophysical. Resilience involves several factors that allow an entity (e. g. person, household, business) to respond to impacts and remain viable despite changes. Therefore, resilience can heavily involve non-ecological factors such as community relationships, and the prevalence of these factors in this study is significant.

Because Massachusetts does not have comparable studies on the topic of farmer adaptation to climate change and resilience-building to its effects, it is difficult to compare the data collected from Massachusetts interviews in this study with other information. Instead, it will be compared here to the data from Schattman et. al. (2015), as the Vermont interview data was. These data sets reflect one another less so. Diversification was the top-mentioned adaptation in Massachusetts, which parallels the 2015 study, but soil building and innovative cropping systems were not significant adaptations cited in Massachusetts farmer interviews. While, again, this study allowed for more discussion of non-ecological adaptations, and the 2015 study focused more specifically on risk management related to climate change effects such as warming, increased precipitation and extreme weather, and drought on farms, it is significant that

ecological adaptations were mentioned with so little frequency in Massachusetts interviews. In fact, irrigation, strategic planting, growing under cover, and certain discussions of diversification were the only ecologically-based adaptations that were cited by Massachusetts farmers, and irrigation and strategic planting were both mentioned with low frequency (two mentions each out of 40, or 5%). Out of 10 total categories of adaptations, not even four (because diversification mentions were partially ecologically-based, partially not) were ecological adaptations. This indicates a stronger focus for Massachusetts farmers on other elements of adaptation or farm resilience, such as community involvement and financial stability through strategies like CSA development, rather than on practices such as soil building or improved drainage for saturated soils, which appear to have more prevalence in Vermont.

Conclusion

A significant gap in this study was the lack of accessibility to literature and research surrounding this topic in eastern Massachusetts. Particularly compared to the relatively significant amount of research being done on farmer adaptation to climate change in Vermont, my area of Massachusetts seemed lacking. That said, a more comprehensive state-wide search may reveal more studies, but this was beyond the scope of my project. However, the amount of and type of climate change and agriculture research in Vermont seems to be of relevance to farmers, and this could be a good model to replicate in Massachusetts. This could significantly spread awareness of climate change and its effects on agriculture, as well as to make information surrounding effective adaptation strategies more available to farmers. While there are valuable resources available currently for new incoming farmers in Massachusetts, resources for existing farmers as to how to build resiliency to climate change are noticeably lesser in the Greater Boston Area than in Vermont. In order to make this information available, more research could be done to determine what adaptation strategies are, or would be, most effective on Massachusetts farms. Although climate change impacts up until now may have been less severe in Massachusetts than in Vermont, and it is difficult to be aware of a topic with which there is little firsthand experience, awareness surrounding this topic needs to be present if farmers are to be assisted in the resilience-building process. Research on this topic being done in Vermont by organizations such as the ARLG could be used as a guideline, as there are parallels between the two states in farmer approaches to this issue, as evidenced by this study.

Overall, Vermont farmers displayed more scientifically accurate and detailed knowledge of climate change and its effects, specifically on agriculture, than Massachusetts farmers. Based on their responses to questions about what sort of effects they believe climate change will bring, Vermont farmers are aware of a wider variety of lesser-known effects, such as a decline in bee population and therefore insufficient pollinators to fertilize plants, as well as an increase in the prominence of tick-borne illnesses due to rising temperatures and tick populations. Additionally, Vermont farmers elaborated more than Massachusetts farmers on the causes of climate change, and tended to offer more discussion on the details of these causes. Vermont farmers also cite more risks that they face on their farms, as well as more adaptations strategies, particularly those that are ecologically-based, than those from Massachusetts. This indicates a larger present awareness as to the degree to which agriculture will be affected by climate change and the

immediate threat it poses. It also suggests that Vermont farmers are more equipped to become resilient despite this threat, as they are making more fundamental changes to how their farms operate in hopes of increasing their adaptive capacity. All of these conclusions make logical sense because of the impacts of climate change, namely topical storm Irene, that Vermont farmers have experienced firsthand, and therefore can grasp climate change as a more concrete idea. They consider large-scale changes to their farms worth investing in, financially and in terms of time and effort, if they are going to increase the resilience of the farm to future climate change effects. It could better prepare them for the next storm like Irene, which would allow them to avoid being devastated in the same way again. Despite the lacking of the same level of firsthand experience, it is important to note that Massachusetts farmers feel confident in their ability to successfully remain in the agriculture industry despite the challenges climate change will bring. Mainly noting the importance of diversification in this confidence, they believe that they will prevail and that climate change will not bring an end to their farming livelihoods.

Based on the results found in this study, it appears that the general picture of the resilient New England farmer includes substantial farm diversification in terms of markets, sources of income, and services offered, positive community relations, the ability to plant strategically and innovate cropping systems that can withstand certain weather, and the option to grow in covered structures such as greenhouses, high tunnels, or hoop houses. Including information from previous research, this could also include effective soil building and water management practices, both of which were cited, albeit with lesser frequency than the aforementioned adaptations, in Vermont interviews. Community relations, in particular, seem to be important in developing resiliency, as the support farmers receive from invested community members can be significant enough to allow farms to continue in operation even in times of struggle.

While more research is required in Massachusetts, as well as in Vermont and various other places around the country, it appears that farmers can effectively become resilient to climate change with enough strategy and adaptation. Community relationships and substantial community integration, while not directly mitigating climate change effects, is a key aspect in farmer resilience. Although climate change is unpredictable, farmers can be certain that alterations to practices suited to their current or past climate will be necessary in the near future. In an industry that is rooted in the outdoors, exposed to the elements, resilience is pivotal for farmers in the face of climate change.

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Appendix

Interview guide

Agricultural Resilience in a Changing Climate: Towards a Resilient Farmer Typology

Prior to beginning the interview, give recipient IRB Info Sheet, and have compensation form ready.

Part 1: Questions related to your farm and your management decisions – 30 min

The following questions are open-ended:

1. What is your farm name, type (dairy, vegetable, etc), and what are your primary markets? **RS/BW**
2. How many acres do you farm (lease vs owned)? **RS/BW**
3. How long have you been farming, at this farm and at other operations? **RS/BW**
4. Please briefly describe the farm infrastructure that you consider most critical in your farm operation. (E.g. high tunnels, irrigation systems, barns or outbuildings, cold storage, other crop storage, ponds or other surface water management like dams or constructed channels.) **RS**
5. What are the risks you face on your farm? **RS**
    a. When did you first become aware of those risks and how?
    b. What have been the impacts of these risks to your farm?
    c. Which, of these risks do you think you have the capacity or ability to do anything about?
    d. Are these compounded by what you know about climate change or not?
    e. Economic, ecological, social (buckets) For each type of risk:
        i. What management choices have you made to deal with these risks?
        ii. How long did it take you to put those management practices into use?
        iii. If you could, what management decisions do you think would BETTER protect you?
        iv. What keeps you from putting these management practices into use?
        v. At what point would this risk become necessary for you to address? (Ecological, economic, or social thresholds.)

6. What is the most recent extreme weather event you remember? Describe this event and any impact it had on your farm.

7. In general, how confident are you in your ability to adapt to the possible risks and/or problems posed by climate change? Indicate your level of confidence below.

   - Very confident
   - Somewhat confident
   - Unsure
   - Somewhat pessimistic
   - Very pessimistic

For the next section of questions, I am going to ask you identical questions that relate to ecological, economic, and social planning. If a question is not relevant to you, we can skip it.

8. When you think about the ecology or natural systems of your farm (e.g. insect populations, soil building, etc.), what is the time horizon you use for planning? **RS**

   Interviewer, do not read this text, but check the appropriate box.

- Daily
- Weekly
- Monthly
- Seasonally
- Yearly
- 5 years ahead
- 10 years ahead
- Other
- Don't know

If something unexpected comes up, how quickly can you change course? Give an example.

9. When you think about the economics or financial aspects of your farm, what is the time horizon you use for planning? **RS**

   Interviewer, do not read this text, but check the appropriate box.

   - Daily
   - Weekly
   - Monthly
   - Seasonally
   - Yearly
   - 5 years ahead
   - 10 years ahead
   - Other
   - Don't know

   If something unexpected comes up, how quickly can you change course? Give an example.

10. When you think about the social aspects of your farm (e.g. family, social networks, community), what is the time horizon you use for planning? (Farm succession plans? Retirement?) **RS**

    Interviewer, do not read this text, but check the appropriate box.

    - Daily
    - Weekly
    - Monthly
    - Seasonally
    - Yearly
    - 5 years ahead
    - 10 years ahead
    - Other
    - Don't know

If something unexpected comes up, how quickly can you change course? Give an example.

11. Do you have a farm succession plan for after you retire?

☐ Yes ☐ No ☐ Don't know

Interviewer, if the answer is yes, ask the following questions:

a. Does your succession plan involve your spouse or children who will maintain a career in agriculture?
b. Does your succession plan involve other relatives who will maintain a career in agriculture?
c. Does your succession plan involve the use of conservation easements?

Part 2: Questions about your perception of climate change

12. Based on your current understanding, what are the causes of climate change?

13. Based on your current understanding, what are the main atmospheric gases associated with climate change, and where do they come from?

14. Tell me what you understand to be the potential impacts of climate change on a global scale?

15. Tell me what you understand to be the potential impacts of climate change in the northeastern United States?

16. Indicate your level of agreement with the following statements

	Strongly agree	Agree somewhat	Neutral	Disagree somewhat	Strongly disagree	Don't know
The global climate is changing.						
Average global temperatures are increasing.						
Human activities such as fossil fuel combustion are an important cause of climate change.						
Climate change poses risks to agriculture globally.						
Climate change presents opportunities for agriculture globally						
Climate change presents more risks than benefits to agriculture globally.						
Climate change presents more risks than benefits to agriculture in the northeastern United States.						
Most scientists think that global climate change is happening.						
I am worried about climate change.						
Climate change is already harming people in the US.						
Climate change will harm me personally.						
Climate change will benefit me personally.						
Climate change will harm people in the US.						
Climate change will benefit people in the US.						
Climate change will harm people in developing countries.						

Climate change will benefit people in developing countries.						
Climate change will harm future generations.						
Climate change will benefit future generations.						

The following questions are open-ended.

17. What are your biggest concerns about the potential impacts of storms and floods on your farm, and why? **BW**

18. How do your current concerns about possible impacts of storms and flooding compare to the concerns you held about flooding impacts when you first acquired the land? What changed? **BW**

19. What is the future of agriculture in New England given climate change and the risks you described above? **BW**
    a. If climate change worsens, what agricultural activities will take place in New England?
    b. How do you envision the region evolving in the future, and what is the role of agriculture in that evolution?

20. How bad would climate change or the risks alluded to above have to get for you to consider leaving agriculture? **BW**
    c. What would a transition out of agriculture look like for you? What steps would you take? What would you do?

21. How important is climate change to you when you make farm management decisions now?

    - Very important
    - Somewhat important
    - Neutral
    - Somewhat unimportant
    - Very Unimportant

22. How important do you think climate change will be to you when you make farm management decisions in the future?

- Very important
- Somewhat important
- Neutral
- Somewhat unimportant
- Very Unimportant

23. Where do you get information about climate change?

	1 = most trustworthy, 5 = least trustworthy				
	1	2	3	4	5
Peers					
Family and friends					
News					
Online (describe)					
Peer reviewed journals					
Conferences					
Scientists					
Extension					
Policy makers/government					
Other (describe)					

Part 3: final demographics

24. Age (approximate)
25. Education level