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SMALL-SCALE MAINE FARMERS' PERCEPTIONS AND ADAPTATIONS TO
CLIMATE CHANGE

by

Shireen Luick

A Thesis Submitted in Partial Fulfillment
of the Requirements for a Degree with Honors
(Ecology and Environmental Sciences)

The Honors College

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ABSTRACT

Climate change is affecting agricultural practices in Maine and all over the world, and this research aims to highlight the effects of climate change on small-scale Maine farmers. Maine has a highly variable climate as well as a strong tradition in agriculture and thus it is important to understand how the different changes may affect farmers statewide. Ten interviews were conducted with small-scale farmers in western Maine. We ask what farmers are perceiving in terms of climatic changes and how they may be adapting to those ongoing changes. Several adaptations resulted from both shifting temperature and precipitation patterns. This research may be used by other small-scale farmers in Maine as a way to understand what climatic changes fellow farmers are experiencing and what practices they are utilizing as adaptation, to enhance their own farming practices to be more resilient to climate change. Stakeholders who support the farming community in Maine also benefit from such research as it allows them to understand exactly what farmers are experiencing and how they are adapting, ultimately allowing them to provide more effective targeted support strategies.

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INTRODUCTION

The effects of climate change can be seen across the globe at multiple scales. Due to increasing levels of carbon dioxide and the resulting greenhouse gas effect, global temperatures are rising and weather patterns are disrupted. Research has shown that the global “tipping point” for atmospheric carbon was 350 ppm (Hansen et al., 2008). In 2013, at the Mauna Loa Observatory in Hawaii, atmospheric carbon levels were recorded above at above 400 ppm (Blunden, 2014). This has increased global average temperatures approximately 0.8°C since 1900, with continued warming projected due to increasingly high levels of greenhouse gas emissions (Brown et al., 2015). While many aspects of world ecosystems and economies will be affected by the resulting changes in climate, this paper specifically focuses on small-scale farmers in Maine. This paper contributes to the understanding of climate change impacts and adaptation on agriculture in the United States.

It is important to understand how climate change will affect small-scale agriculture in Maine, and the United States, because it is how human and livestock populations are fed. Agriculture also plays a significant role in the rural and national economy. Impacts to agriculture would affect people not just through changes to the environment, but also might potentially disrupt social and economic systems. The agricultural and food sectors of the United States account for over \$750 billion of national gross domestic product (USGCRP, 2014). The agricultural industry is vulnerable to unpredictable, and therefore it is important to understand the impacts of increased levels of atmospheric CO₂ and resulting temperature increases will have on current and future crop production.

How individual crops are affected is highly dependent on the particular crop's optimal temperature range and regional variances (USGCRP, 2014). While higher temperatures may provide some opportunity for increased crop yields, many of the dominant crops, such as corn, have already reached their optimal temperature range and therefore may see diminished yields as temperatures continue to rise (Romero-Lankao et al., 2014). However, there are many regional differences in how changing temperatures may affect a given crop, and these differences can also vary by climate model, based on differing levels of adaptation.

Precipitation levels and extreme weather events also play a significant role in agricultural production. In northern regions of the United States, for example, soil erosion is expected to worsen with projected increases in total rainfall and heightened intensity of those rainfall events (Hatfield et al., 2014). It is dependent on the region, but projections show extreme conditions of severe rainfall, drought, and heat across many parts of the United States. With the absence of conservation practices, soil processes like compaction, acidification and particularly erosion will intensify soil degradation (Kunkel et al., 2013). It is important to both agriculture and the atmosphere to maintain soil health due to the many ecosystem services it provides such as food production, carbon sequestration and flood mitigation (Hatfield et al., 2014). Negative impacts to the soil results in negative productivity which can in turn lead to food insecurity. The Northeastern and Southeastern United States produce much of the country's grain. These regions have been labeled as vulnerability "hot spots" due to projections that extreme heat, drought, and intense storm events will continue to increase through 2045 (Romero-Lankao et al., 2014).

Weeds, diseases, and pests have the potential to have even greater detrimental direct and indirect impacts to crop yield due to increased stress from climate change. Crops are most threatened by weeds, secondly by pests, and lastly by disease, but regardless all three will play an even larger role as the climate changes throughout the United States (Oerke, 2006). Warming temperatures and increased rainfall across much of the agricultural U.S. improves conditions for an abundance of pests and pathogens. Damp conditions allow pathogens to spread more easily, and yet again depend on the region and the given pathogen (Hatfield et al., 2014). Insects—both beneficial and detrimental—are also directly affected by temperature. Higher summer temperatures allow for pests to regenerate more times throughout the growing season, making management more difficult (Hatfield et al., 2014). Another concern is the northern spread of invasive weed species, and the associated management costs. Increased levels of CO₂ allow weeds to thrive, and thus create further competition between weeds and the desired crop. Many of the concerning species of weeds actually thrive in higher levels of CO₂, while many of the crops do not (Ziska, 2001). The costs associated with the pesticides used in conventional agricultural will therefore rise as weed populations increase. The pesticides required will cost more as farmers feel the need to increase their usage of them. This could result in economic burdens and greater environmental costs due to toxic runoff and other environmental issues associated with the use of chemical pesticides (Hatfield et al., 2014).

These multifaceted threats and unpredictability have increased the need for farmers to innovate and adapt to climatic changes to maintain their livelihoods, and to keep our food and economic systems stable. Farmers have always adapted to their

environment by shifting cultivation, harvest, irrigation, tillage, but long-term the current adaptive strategies will not be sufficient to maintain necessary yields in the long term (Malcom et al., 2012). There is a need for new, improved institutions and technologies to support and inform producers in the face of climate change. Further challenges arise in the costs necessary to implement such technologies or programs, and there is little research or understanding of what short- and long-term costs there will be (Walthall et al., 2012). Land inputs, such as water, also play a role in the unpredictability of adaptation, as it is not known beyond climate model projections exactly how availability of resources will increase or decrease in different regions (Hatfield et al., 2014). Other adaptation strategies that farmers currently employ are changing crop selection, increased use of pesticides, diversified crop rotation, and integrating crop-livestock systems. All contribute to climate change resilience, but it will be important for future research to improve and expand upon these practices, particularly for large-scale agriculture (Easterling, 2010).

This brings us to small-scale agriculture, which will be defined based on USDA delineations in a later section. All of the participating farms in this study were small-scale farms whose primary focus was on growing diversified vegetable crops. The aim was to discuss temperature and precipitation changes with farmers directly relying on those conditions, versus for example someone raising livestock whose farm may be less directly affected by such climatic changes. All the participating farms were either already organically certified or used organic agricultural practices as their primary method of farming. Small-scale organic agriculture will have to undergo far fewer transformative measures compared to large-scale conventional operations, as many of these adaptive

practices are already inherent to organic agriculture management (Easterling, 2010). Though fewer, small-scale family farms will still face necessary changes, and associated challenges. Many smaller family farms lack the capital necessary to adopt new technologies (Hatfield et al., 2014). Climate change resilience of our agricultural system requires increased research on adaptive strategies for both large-scale and small-scale operations. We ask farmers what climatic and environmental changes they are perceiving and what adaptations they are utilizing in order to adapt to those changes. Farmers possess unique ecological knowledge of their regional ecosystems, and for successful innovation, adaptation, and education, researchers must include farmers, policy makers, extension agents, and others in the conversation. In the context of extreme regional weather variability, it becomes even more important for effective communication with farmers, so that policy makers and institutions can provide necessary regional support. The objectives of this research are to identify and understand farmers' perceptions of climatic changes, how they may be adapting to those changes, and ultimately use this understanding to support stakeholders and other farmers in Maine with current and future adaptation strategies as the climate continues to shift.

Climate change is threatening both the livelihoods of the producers as well as the security of our food system as a whole. Food security entails access, utilization, and stability (FAO, 2001). The food system is highly complex, and as a result climate change will affect food security in multiple ways. Changing temperatures and weather patterns affect both agricultural yield as well as the general distribution of food and the distribution of food-borne diseases (NRC, 2007). Both the agricultural system and the food system must adapt in order to limit the effects of climate change. Adaptations such

as policies ensuring food access for disadvantaged populations, reducing food waste, and sourcing food locally, are all methods among many others that will aid in fostering a more resilient and secure food system (Walthall et al., 2012). Agricultural systems adapting more sustainable or organic practices will be key to attaining resilience, due to the environmental benefits of those practices (Scialabba & Müller-Lindenlauf, 2010). Adoption of sustainable agriculture is in the interest of humans and the environment. It is more adaptive to climate change as it reduces GHG emissions, increases water and land use efficiency, maintains ecosystem services, and ultimately increases productivity in a way that is within both ecosystems and humanity's "safe operating space" (Beddington et al., 2012).

BACKGROUND

Maine Climate Background

Maine is unique in its varied climate, large variety of ecosystems in close proximity, and high reliance on natural resources (Griffin et al., 2009). Therefore, it is necessary to understand how past, current, and projected changes will affect the state's ecosystems, human populations, and economy. All of the following information has been referenced from *Maine's Climate Future (MCF): An Initial Assessment* and *Maine's Climate Future: 2015 Update*. First I provide a general overview of Maine's climate followed by a more specific look into how those described changes in climate will affect agriculture in the state. It is also important to acknowledge, as is stated in the publication, that projections for future changes and effects are highly variable as they are based on differing emission scenarios. The summation of changes in Maine over the next century are as follows: "a 2-6°C increase in average annual temperatures, a longer growing season, a 2-14% increase in precipitation, less snow, more rain, and highly variable precipitation"(Griffin et al., 2009, p. 9). The results of these climate projections should be considered as guidelines for the broad direction and range of changes likely to occur with temperature and precipitation. *Maine's Climate Future* is based on the Intergovernmental Panel on Climate Change (IPCC) 2007 report using emission scenario A2, that considers both natural and human climate factors. In this scenario there is continued delayed development and use of renewable energy at a global scale (Griffin et al., 2009).

Maine is divided into 3 climate divisions, Northern, Southern Interior, and Coastal. The climate gradient seen in just 3 degrees of latitude in Maine occurs over 20 degrees of latitude in Europe. These divisions are useful for making long-term

predictions of climate over a century or more. Due to these climate divisions and multiple microclimate divisions within each, predicting short-term changes is highly variable and therefore quite difficult. All three Maine climate divisions are now warmer than they were 30 years ago. This matches the global trend of warming due to atmospheric pollution as a result of the greenhouse gases emitted from burning fossil fuels. Specifically, temperatures have warmed by 1.7°C since 1895, and although warming is the trend, past climate data and future projections signal that Maine will undergo significant fluctuation from year to year. Between now and 2050, Maine is projected to warm further as annual temperature increases by 1.1-1.7°C. These temperature changes will affect the “relative length and character of each season” (Fernandez et al., 2015, p. 3). For example, Maine’s warm season has already extended two weeks later since the early 1900s, and it may shift an additional two weeks within the next fifty years. As a result of these warm season increases, the number of days where heat exceeds 35°C will also increase, constituting an extreme warm day. In the 2000s, Augusta, Maine experienced 3.4 extreme warm days on average, and by 2050 is projected to experience up to 13.5. Global trends have also affected precipitation changes in Maine and will continue to do so. Total annual precipitation has increased by 13%, and the increases are most visible in the late summer and fall. Between now and 2050 the IPCC models utilized in the MCF predict continued increases of 5-10% in the Northeast United States. The distribution of that precipitation is uncertain between the climate divisions. Precipitation has primarily been most visibly increasing on the coast, but future projections show increases in the interior of the state. *Maine’s Climate Future* defines extreme weather events as those “in which two or more inches (five or more centimeters)

of precipitation falls within a 24-hour period” (Fernandez et al., 2015, p. 9). Extreme weather events have been witnessed at an increasing rate across Maine. Overall, Maine is expected to be warmer and wetter than it ever previously has been, and more specifically expecting the amount of rainfall in the early summer to decrease (Griffin et al., 2009).

Increased temperatures, length of warm season, and extreme weather events are all factors of high concern to Maine agriculture, as it relies on consistent rainfall and steady temperatures. As a result of warming, USDA hardiness zones have shifted by one half zone to the north, impacting Maine growing conditions and agriculture. Maine has approximately 40 inches of precipitation and is unique at a global scale as the precipitation is typically distributed fairly evenly throughout the year as opposed to being concentrated to specific seasons. In the future, with high variability, the distribution may become more seasonally sporadic. While more rain may seem beneficial for sectors like agriculture, it may not occur during the desired timeframe for agricultural practices in the state, as early summer precipitation is expected to decrease. Both temperature and precipitation significantly affect the growing season. Old diaries kept by farmers show evidence that growing seasons were much shorter than they are now, as there were later spring frosts and earlier fall frosts. A lengthened growing season may provide increased opportunities for farmers regarding the possibility for planting new varieties and increasing total yield. However, reduced early summer rain may counteract those benefits for certain species such as potatoes and blueberries, that rely on that early summer rainfall to set their fall yields. Farmers statewide should be considering the need for increased irrigation methods due to evaporation and transpiration from the soil. Again, the effects of warming will depend on the region as well as the given species, as different

crops have different optimal ranges in which they grow. For crops like blueberries and potatoes, there is concern that increasing temperatures will push them past their optimal zone, whereas things like tomatoes, pumpkins and corn would be moving further into their optimal zone (Griffin et al., 2009).

Warmer temperatures also raise concern for new pests and weeds, increases in existing pests, and the spread of pathogens. Weeds may also gain an advantage over desired crops due to increasing concentrations of CO₂. Pests that are inherent to southern regions of the country will arrive with warming temperatures. Southern pests that typically migrate to Maine will either be able to arrive sooner in the growing season, or even possibly over-winter as winter temperature extremes are reduced. Aphids are an example of pest like this that typically arrives with southern summer storm fronts, but may begin to stay year-round. Pests like aphids are a concern for the plant diseases and pathogens they carry, and projected warm, wet conditions will lend well to pathogens upheaval of crops. In addition to new pests, existing pests such as the Colorado potato beetle (*Leptinotarsa decemlineata*) are raising concern. They are an example of a pest that will be able to regenerate more times throughout the growing season as it extends, when they typically are only present for one generation during Maine's warm season. Multiple generations of pests like the Colorado potato beetle are already seen in states south of Maine like Massachusetts and Connecticut. With both pests and weeds there is also the possibility of numbers of beneficial species increasing with temperature changes as well, although traditional agricultural practice implies increased use of pesticides as the main response. These changes clearly provide challenges to the agricultural community of Maine, but also room for opportunity as new beneficial and or profitable

species may be able to grow and thrive in the new climatic conditions (Griffin et al., 2009).

Conceptual Model and Framework Background

This study was with small-scale farmers in western Maine, and as there are a number of ways to define small-scale farms in the United States, it is important to clarify my use of the term. The United States Department of Agriculture (USDA) Economic Research Service (ERS) defines small-scale farms as those with a gross cash farm income (GCFI) below \$250,000. They also note that approximately 60% of the farms within this delineation are even smaller, generating a GCFI under \$10,000, and 20% of those farmers make less than \$1,000. When pooled together with all farm scales, small-scale operations make up 90% of all farms in the United States, yet only account for 23% percent of agricultural production (Hoppe et al., 2010). It is important to note that small farm production varies, and USDA statistics are based on broad definitions of farming.

The ERS developed a small farm classification system including definitions and statistics resulting in eight mutually-exclusive homogeneous categories. Those relevant to this study are as follows; rural-residence retirement farms are those run by operators who are retired, rural-residential lifestyle farms are small farms with operators reporting another major occupation other than farming, and intermediate family-farming-occupation farms are those operated by people who report farming as their primary occupation. Each are classified as either low-sales, grossing less than \$100,000, or high-sales, grossing between \$100,000-249,999. Farms must also exceed \$2,000 GCFI in order to be classified as small-scale (“USDA Small Farm Definitions,” 2013). For the purpose

of this study, I focused on only those classified as low-sales during the research process. As mid-size crop farm numbers are declining, the numbers of large-scale and small-scale crop farms are increasing (MacDonald et al., 2013). While small farms only account for a relatively small fraction agricultural production, their numbers continue to increase. Due to the role they may play in resilience to climate change it is important to understand how the farmers operating these growing numbers of small farms are experiencing changes in climate today. This allows other farmers to learn and stakeholders to better understand how to provide effective adaptation and support strategies as farmers adapt to ongoing and projected changes.

Many global climate change research institutions have defined adaptation to climate change. The IPCC defines it as, “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (“Climate Change Adaptation Definitions,” n.d). The United Nations Framework Convention on Climate Change (UNFCCC) defines it as “Actions taken to help communities and ecosystems cope with changing climate conditions” (“Climate Change Adaptation Definitions,” n.d). While definitions differ, the overall aim of each is to highlight adaptation as any change an ecosystem or human society must undergo due to climate change. Research regarding how individual communities of farmers worldwide adapt should be rooted in local knowledge in order to comprise a more accurate picture of perceived effects of climate change, and provide relevant support for adaptation. The Food and Agriculture Organization (FAO) of the United Nations defines local knowledge as the main asset people have to produce food, survive, and achieve control over their lives. It is developed as well as adapted

continuously to a changing environment. For these reasons, local farmer knowledge is extremely important to highlight and understand regarding agriculture, use of natural resources, and community development in terms of climate change (FAO, 2004).

There are many existing studies that focus on farmer knowledge, perceptions, and adaptations to climate change. Understanding the strengths and weaknesses of these studies, as well as their contribution to climate change and agricultural research will be important as the climate continues to change and the need for adaptation increases. It is also beneficial to our own study of farmers to understand how similar research has been conducted, in order to strengthen our methods and conclusions. In a study conducted in Sub-Saharan Africa (SSA), researchers studied adaptation strategies for small-scale farmers using survey, experimental, and modeled data. They chose to highlight populations in SSA who rely on semi-subsistence agriculture in order to survive, as SSA is projected by the IPCC to experience significant negative impacts due to climate change. The purpose of their study was to highlight those often forgotten in existing studies in SSA, which typically only focus on larger scale crop operations, or that have utilized statistical analysis that does not provide strategies for site-specific adaptations. Focusing on smaller scale agriculture and how those farmers are affected by climate change as opposed to just highlighting the experiences of “big ag,” is something that is mimicked in our research as we highlight a specific population of small-scale farmers in Maine. In the SSA study they employed the Tradeoff Analysis for Multi-Dimensional Impact Assessment Model (TOA-MD), and used several types of data—survey, experimental, modeled, and expert—in order to integrate socio-economic and biophysical data from farmers in a way that simulates how the impacts of the adoption of alternative

systems and management strategies will affect farmers in terms of climate change under differing socio-economic scenarios (Classens et al., 2012). Essentially, they describe the TOA-MD as a “generic model for analysis of technology adoption, impact assessment, and ecosystem service analysis” (Classens et al., 2012, p. 6).

The strength of the Classens et al. (2012) study is that it took all of the complex factors into account regarding how farmers specifically in SSA will adapt to climate change. It highlights the importance of having a holistic view of the social and economic factors affecting farmers, while still focusing upon the interactions between the farmers and their individual environment. Their approach was highly statistical and involved fewer face-to-face interactions with the farmers studied. They statistically simulated the impact that climate change will have on this specific group farmers without adaptation strategies, or the impacts if they chose to adopt alternative systems and strategies in order to adapt (Classens et al., 2012). A statistical approach was logical for the SSA study due to their methodological approach and larger sample size. A highly statistical methodology did not make sense for the small sample size of Maine farmers in our study, but it is still useful to understand the role statistics can play in similar studies. Using statistics, they were able to combine farmer perception, current adaptation strategies, and socioeconomic factors in terms of the need for further adaptation in order to continue and or survive. Their study is relevant as it highlights the importance of considering multiple inputs on farmers’ decision-making process, and exemplifies the importance of understanding the impacts of climate change on agriculture at all scales. Our study was necessary to do the same for Maine and small-scale Maine farmers.

In comparison to the highly statistical based research done in the SSA study, the Danangou watershed in China was the study site of another relevant study highlighting the importance of understanding farmers' perceptions of climate change and adaptations to those changes (Hageback et al., 2005). The aim was to show how climate variability affected farmers' perceptions of climate and how resulting adaptations affected land-use change in the given watershed. The research sought to fill a gap in existing research on agriculture in China, that had previously only focused on large scale agricultural production using model simulations and, therefore, provided no assistance to farming at the local scale in regards to adaptation to climate variability. This is similar to both the research conducted in the SSA study, as well as the research conducted for our study of farmers in Maine. In all cases the researchers identified the need for local studies to fill a gap in regional climate and agricultural science, and in order to support local farmers.

The research questions for the Danangou Watershed were as follows: What are the local and regional precipitation and temperature trends and variability, and do farmers perceive climate variability? What are possible responses and hence adaptations to climate variability and is there any impact on their farming? Are there other changes causing farmers to change their land use (Hageback et al., 2005)? Our study used similar questions to evaluate what environmental effects farmers were perceiving, and ultimately which perceptions led to which adaptations. They used climate data records from the local Ansai weather station in Shaanxi and compared it with the perceived changes relayed by the farmers during interviews. In this study, the SSA study, and our own it is important to obtain and understand climate data for the given region in order to properly comprehend the effects experienced by the respective farmers. They conducted several

interviews with key participants as well as utilizing focus group discussions to obtain their data. This differs from the SSA study in that their main source of data was qualitative and interview based, as opposed to primarily quantitative. Our study is therefore more similar to the Chinese study in that all of our data aside from demographics is qualitative. Targeted interview questions such as “Do you feel any changes in the weather now compared to 20 years ago?” allowed us to compare respondents answers with the actual climate data to establish if what the farmers were perceiving was actually what was happening with the climate, something that we also aimed to do in our own study. Overall they established that much of the farmer perception of climate was accurate to the climate data. The result of the experienced changes in climate indeed had an effect on farmers’ adaptation and land use, but the researchers found that economics and policy also played a significant role. In order to cope with the variability farmers employed diversification, more drought resistant crops, and seeking out non-farm income sources. Much of their adaptation to climate variability resulted in economic adaptations, like changes in their main crops and ultimately less reliance on crops as a sole income source (Hageback et al., 2005).

This study examines the various factors influencing farmers adaptation, and highlights that while climate plays a role it may not be the only driving factor. Interviews allowed the researchers to obtain a more holistic and accurate understanding of the livelihoods of the farmers, instead of solely relying on statistics. The interviews we conducted with farmers had a similar aim by asking a wide range of questions from market viability to the role of new pests. They employed qualitative and quantitative data in order to conduct their research in a way that considered multiple inputs. The study

could have been improved by providing more non-economic adaptation strategies for farmers in the Danangou Watershed who perhaps did not have the means to shift to non-farm sources of income, as that seemed to be their main claim for adaptation. In our study, while economic adaptations do play a role, the focus is more on ecological adaptations surrounding irrigation, pest control, and variety selection.

Our study also utilized the benefits of a qualitative research approach to farmers experiencing climate change by conducting interviews. In order to formulate interview questions, we employed two theoretical models were employed for our study on small-scale western Maine farmers' perceptions and adaptations to climate change. The primary model used was taken from Turner and Berkes (2006) called *The Ecological Understanding Model* (EUM). This model was useful for several reasons. The EUM allows researchers to identify mechanisms that farmers utilize to build their ecological understanding, surrounding sustainable and conservation practices, and therefore provide a pathway for further development of that knowledge. Ultimately this allows researchers and policy makers to provide improved recommendations and support. The EUM refers to “coming to ecological understanding through incremental learning from careful observation, knowledge exchange, and development of a conserving belief system and worldview that guides peoples' collective actions towards other species” (Berkes and Turner, 2006). The model was initially develop to highlight how indigenous and small-scale rural communities have developed conservation practice and knowledge, without experiencing a catastrophic ecological event depleting resources. It was therefore useful to this research as small-scale farmers in Maine have not necessarily experienced a catastrophic event that has led to their ecological knowledge or practice, yet the farmers

have unique ecological knowledge of their land and its resources. The model may be applied to a varying range of natural resource users as the mechanisms used to develop conservation knowledge are shared (Collum, 2016). The following table is developed by Turner and Berkes (2006) and lists the attributes of ecological understanding.

Table 1: Attributes of Ecological Understanding (From Turner and Berkes 2006).

Incremental learning of individuals and groups and elaboration of environmental knowledge as a result of detailed observation and experience of variations in nature and leading to a sophisticated understanding of the ecosystem in which they dwell.
Development of concomitant belief systems that help avert serious resource depletion and promote conserving approaches.
Creating and perpetuating ways of encoding, communicating and disseminating both the practical aspects of such incremental learning and adaptive response and the ideologies and belief systems associated it.
Development of institutions that consolidate environmental knowledge and practice, or development of rules by which members of a society deal with their environment and resources.

As stated previously, small-scale organic farmers have a vast ecological knowledge base due to their constant, direct interaction with nature and therefore use that knowledge to improve practices on their farm to ultimately make it more sustainable. This knowledge will prove to be invaluable as the climate continues to change, particularly in Maine due to the highly varied climate. Farmers in close proximity to one

another can use this type of knowledge to support and share each other's climate adaptations unique to their area.

Incremental learning from personal experience or through the experience of others is an important mechanism for building ecological understanding. The following table highlights the mechanisms that resource users use to acquire knowledge and then how that knowledge results in lessons that ultimately assist them in developing ecological understanding and therefore more sustainable conservation practices. We have adapted their framework to use examples relevant to small-scale Maine farmers. As the climate changes, understanding the knowledge farmers currently possess will be key for current adaptation and ultimately necessary for future adaptation and climate change resiliency efforts. This may also assist government or institutions like Cooperative Extension in supporting farmers and allow them to create more opportunities for farmer-to-farmer knowledge exchange (Collum, 2016). This knowledge exchange helps farmers secure their own livelihoods, and therefore strengthens the small-scale farmer communities ultimately making the state more resilient to climate change.

Table 2: EUM Adapted to Small-Scale Maine Farmers

Mechanism	Example from Text	Examples for Small-Scale Maine Farmers
Lessons from the past	Stories of positive and negative experiences, embedded in individual or institutional memory, and transmitted through oral and written history	Memories of abundance from early farming years The intensity of New England winters in the past
Lessons from other places	Technologies, products, names, and ideas relating to conservation and environmental stewardship passed through communication	Information via Facebook Books written by small

	networks	farmers for small farmers Exposure to climate change ideas early on Learning from other farmers
Learning from animals/insects/disease	Observations of animal foraging strategies, populations, browsing and predation, behaviors that might engender understandings of kinship and reciprocity	Noticing any types of pest, prevalence of one particular species The emergence of new pest/disease that threatens crops Predictions for increased/pest disease
Monitoring - Building on Experiences and Expectations	Routine observations of seasonal changes and plant and animal life cycles, bringing recognition of expected patterns and ability to detect variation from the norm	Changes in growing season Precipitation changes Temperature changes Extreme weather events
Observing Ecosystem Cycles and Disturbance Events	Relative abundance, diversity, and productivity of plants and animals in particular circumstances, both spatial and temporal, guiding peoples' land and resource management strategies	The ability to produce the same yield as easily as previous years Knowing the best times to plant/harvest how that may have changed
Trial and Error Experimentation and Incremental Modification	Observing the results—both positive and negative, intentional or incidental, short and long-term—of people's activities	Changing methods based on what they want to grow Adaptations they have been using for many years as a

		<p>way to be resilient</p> <p>Rotation of crops, identifying what works best</p> <p>Where to grow certain things</p>
Learning by Association, Extension, and Extrapolation	Applying observations and knowledge—positive or negative— from one place, time, or context, to another (e.g., a different field, crop, season, or community)	<p>Knowing what works well for one crop and applying it to others</p> <p>What association they belong to</p> <p>Using other local farmers’ knowledge</p>
Elaborating and Building Sophistication	Combining the lessons and understandings gained from all of these pathways, and building up knowledge, practices, and beliefs into complex systems of land and resource management	<p>Are their “adaptations” just normal practice, as they have begun their farming during this climate change era/period</p> <p>What have they been doing to adapt to the climate long term</p> <p>What will they have to do in the future to further adapt</p>

The EUM provides comprehensive mechanisms through which farmers gain the ecological understanding necessary to operate their farms and in turn manage them in a changing climate. For the purpose of this study, however, there was a need to examine further inputs regarding what influences farmers to adapt specifically to climate change. To do this a second framework was utilized, taken from a study done by John F. Morton (2007) that looked into the impacts of climate change on smallholder agriculture in

African countries. This framework was useful in developing additional questions related to climate-change stressors, beyond those noted in the EUM. Below is table highlighting the mechanisms, the example from Morton (2007), and then the application to small-scale Maine farmers.

Table 3: Morton Framework Adapted to Small-Scale Maine Farmers

Mechanism	Example from Text	Example for Small-Scale Maine Farmers
Complexity and Location Specificity	Relative importance of a crop Use of wild resources Positive/negative trends in specific crops	Most important crop vs. diversity Wild resources or indicators Increasing or decreasing difficulty growing certain crops
Non Climate Stressors and Vulnerability	Market access/availability	CSA vs. Farmers' Market
Environmental and Physical Processes	Effect of increased extreme weather events Rainfall Soil fertility/water holding capability	Experience with extreme weather events Lack of or too much rainfall for certain crops Necessity of maintaining soil health

Both of the models described contributed to the final interview questions for the small-scale Maine farmers. The EUM was the primary framework used and Morton's model supplemented small gaps in the EUM. By using these frameworks, researchers were able to obtain a more comprehensive view of the ecological conditions farmers in Maine have

previously experienced and are currently experiencing due to climate change.

Understanding the scope of how and what farmers are experiencing in the context of climate change allows for a better understanding of why certain adaptations are being utilized, and provides researchers the opportunity to support farmers in future adaptation.

METHODS

The theoretical models from Turner and Berkes (2006) and Morton (2007) were used as frameworks to create all of the interview questions. Based on the mechanisms presented by each framework, examples relevant to small-scale Maine farmers were generated. From those mechanisms and subsequent examples, interview questions on a range of factors were then developed and edited. Questions included ecological and environmental changes, knowledge acquisition methods, and general farmer concerns. The table below details an example of this process with only two of the mechanisms from Turner and Berkes' (2006) EUM, with the full table found in Appendix A. The sample interview questions found in the table below are not the final interview questions. The final interview questions can be found in Appendix B.

Table 4: EUM to Interview Question Development

Mechanism	Explanation	Examples for Small Maine Farmers	Interview Questions
Lessons from the past	Stories of positive and negative experiences, embedded in individual or institutional memory, and transmitted through oral and written history	Memories of abundance from early farming years The intensity of NE winters in the past	What are some negative or positive experiences that you have had in your time as a farmer in regards to the weather and what effect did they have on your ability to farm successfully? What would you say is the most significant thing you have learned as a farmer?

<p>Trial and Error Experimentation and Incremental Modification</p>	<p>Observing the results—both positive and negative, intentional or incidental, short and long-term—of people’s activities</p>	<p>Having just been farming for a few years, changing methods based on what they want to grow</p> <p>Adaptations they have been using for many years as a way to be resilient</p> <p>Rotation of crops, what works best</p> <p>Where to grow certain things</p>	<p>Since you began farming what adaptations have you had to make, if any, to your farming practices due to the climate?</p> <p>Have you had to make any significant modification to your practices in order to continue farming and produce a yield?</p> <p>Have you had any difficulties determining the best management practice for certain crops?</p> <p>Has it become more difficult in the past 5-10 years?</p>
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The following mechanisms taken from both models were used to create interview questions specifically addressing ecological and environmental changes that farmers were perceiving and experiencing: *Learning from animals/insects/disease; monitoring/building on experiences and expectations; observing ecosystem cycles and disturbance events; complexity and location specificity; environmental and physical processes*. The questions resulting from these mechanisms served to identify any biological or ecological processes in which farmers perceive changes. The adaptations resulting from those perceived changes were specifically addressed in other interview questions, although many farmers described adaptations throughout the interview, as a follow up to questions such as these.

Mechanisms used to formulate questions not specific to environmental changes, but instead geared towards farmer concerns and economic stressors were as follows:

Lessons from the past; lessons from other places; non climate stressors and vulnerability; and non-agricultural climate change impacts. These questions targeted issues that farmers were experiencing that may have been connected to climate change, but were not necessarily ecological. For example, access to viable markets and market saturation were both relevant to what the farmers were experiencing, but before the coding process did not necessarily directly link with issues connected to climate change.

Finally, the mechanisms used to identify any other specific adaptations to climate that the farmers may have been utilizing were as follows: *Trial and error experimentation and incremental modification; learning by association, extension, or extrapolation; and elaborating and building sophistication.* The interview questions resulting from these mechanisms allowed researchers to highlight both where farmers were getting their information from as well as add and expand upon any adaptations that had previously been mentioned by farmers during other questions in the interview. While the focus of the research was to identify perceived changes in the environment and the resulting adaptations, it was important to ask a range of questions to understand the many factors and inputs on small-scale farming in Maine, and therefore be able to connect them to climate change.

NOAA defines weather and climate as, “The state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc. *Weather* refers to these conditions at a given point in time (e.g., today's high temperature), whereas *climate* refers to the "average" weather conditions for an area over a long period of time (e.g., the average high temperature for today's date)” (NOAA, 2004). Although the definitions differ on paper, we felt it would not affect farmers’ perceptions of environmental changes

if the word weather was used in place of climate or climate change. It was very important to consider how the interview questions were framed in the context of climate change in order to effectively gather data that was true to the individual farmer perceptions and avoid producing bias. A “frame” is defined as “interpretive storylines that set a specific train of thought in motion, communicating why an issue might be a problem, who or what might be responsible for it, and what should be done about it” (Nisbet, 2009).

While farmers have a strong knowledge base surrounding the environment, they may not be distinguishing between the two definitions of weather and climate, and it was hypothesized that they may use them interchangeably. It was not an issue of the farmers understanding the science, but instead an issue of considering one’s audience and how to best frame climate change for that audience. How a question is framed is what leads the audience to interpret and discuss an issue, and was therefore taken into consideration as interview questions were written (Nisbet, 2009).

By using the word weather the aim was to avoid politically charged answers due to the current divides surrounding the phrase “climate change,” as well as avoid making the interview participants feel as though the researchers had an agenda. This also allowed researchers to note when the phrase “climate change” or simply “climate” was brought up during the interviews. Non-persuasive communication towards the public in which researchers dispassionately present the evidence or research questions allows them to maintain a trusted social position as well as allows the evidence to speak for itself without an agenda (Pidgeon & Fischhoff, 2011). In an article published in the *New York Times* authors discussed with “bread basket” farmers, professors, and editors of popular agricultural magazines the implications of the phrase climate change in their daily lives

and publications. One farmer was quoted saying, “When you start quoting ‘climate scientists’ and the United Nations you are as nutty as Al Gore...Measures to control emissions are just seductive names for socialist programs intended to micromanage people and businesses” (Tabuchi, 2017, Publication Takes a Stand, para. 11). Editors of *Successful Farming* magazine Gil Gullickson and David Kurn were hesitant to publish materials using the phrase climate change, and had been warned to avoid its use, “I was told: ‘Readers hate that phrase. Just talk about the weather’” (Tabuchi, 2017, Publication Takes a Stand, para. 8). While they did publish a cover story directly addressing climate change, and much of their farmer audience has been found to acknowledge extreme changes in weather patterns, they received a great deal of backlash from many of their subscribing farmers protesting their “endorsement” of climate change (Tabuchi, 2017). It is perspectives such as these that led the our study to opt to use the word weather instead of climate, to promote unbiased responses and avoid coming off as having a preconceived agenda. A full list of interview questions in the order asked during the interviews can be found in Appendix B.

The study sites for this research were primarily in western Maine, and partially in central Maine. The majority of farmers were from Franklin County, one from Somerset, and one from Kennebec County. Below is a map of the Maine Counties, followed by an elevation map of Maine meant to highlight the mountainous and foothill landscape that creates the microclimates the study participants experience

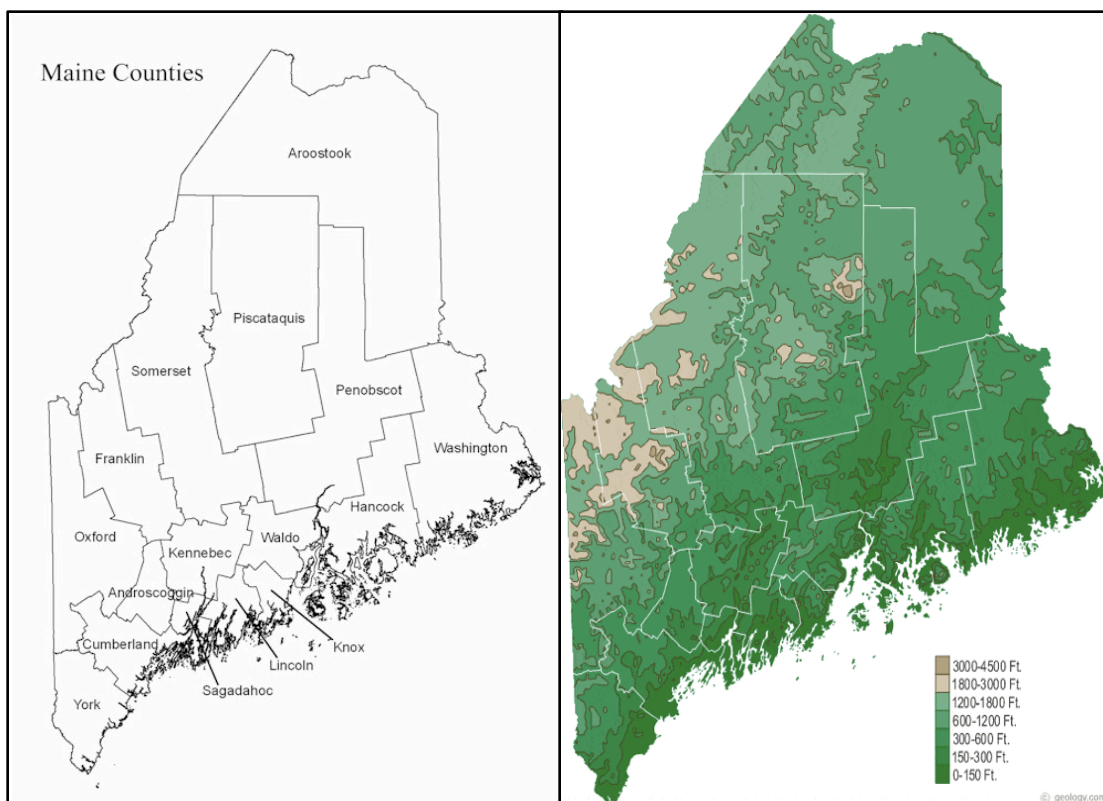


Figure 1: Maine Counties Map

Figure 2: Maine Elevation Map

There are a total of 5 farmers' markets in Franklin County, 10 in Kennebec County, and 3 in Somerset County (Farmers' Market Directory, n.d.). The average age of a principal operator of a farm in Maine is 57 years old. Of the 8,200 operating farms in Maine approximately 5,000 of them have a GCFI of less than \$10,000 but more than \$2,000 annually, and therefore are considered small-scale (USDA, 2016). All of the participating farms were diversified vegetable producers and were either organically certified or were using organic methods as their primary agricultural practice.

Using a past IRB package supplied by a committee member, I created the IRB package for this research. Once I completed the package and it was edited by my thesis advisor, my advisor then sent it to be reviewed by the IRB. Due to the fact that all the

participants were adults, the package was eligible for an expedited review. The package was sent back one time for minor edits to the language and structure of certain aspects of the research. It was sent a second time and at that point the research questions and call/email script were then approved by the IRB. The full approved IRB package may be found in Appendix C.

The farmers interviewed were contacted via email and phone calls. Many of the participants I had existing relationships with several of the farmers that I contacted, via past employment and my mother's participation in the farmers' markets in western Maine. The farmers I previously knew were able to connect me with several of the other participating farmers. There were a total of 10 face to face interviews conducted with a total of 12 interviewees, as two of the interviews were conducted with couples. Each interview took approximately one hour and was recorded.

After completing the interviews the recordings were transcribed verbatim. All recordings and transcriptions were kept private and secure by the researchers, and only limited sections of transcriptions are found in the results with all names and identifying factors removed. Once transcribed, all the interviews were coded based on the research questions using exploratory, and causation coding methods (Saladaña, 2013). No software was used for coding beyond Excel. Exploratory coding methods were used for the phase of coding in order to identify broad categories based on the research questions. Exploratory coding methods are used in the early stages of the coding process as a way to explore raw data and assign preliminary codes before more specific coding methods are applied (Saladaña, 2013). The next phase of coding consisted of causation coding. Causation coding is meant to uncover "what people believe about events and their

causes...An attribution is an expression of the way a person thinks about the relationship between a cause and an outcome” whether that is an event, characteristic, or action (Munton et al., 1999, pp.5-6). Ultimately the goal is to discover or infer beliefs, and in the case of our research, uncover perceptions and the resulting adaptations. These were the primary methods of coding used because they allowed us to both identify broad themes such as warming temperatures and erratic precipitation, as well as drill down to specific adaptations within those themes. For example:

I think we're not starting as soon in the spring some years. It's got longer in the fall but we also don't feel that as much because our business is based on season extension high tunnels. One of our points of resiliency is not to rely on a length of growing season outdoors, we have to create some kind of stability with length of growing season because it's erratic.

Here via exploratory coding I was able to identify the perception of shifting and uncertainty in the growing season, in the context of the perception of warming temperatures. Causation coding allowed researchers to then identify the farmers' adaptation to that shifting and uncertainty. The farmers discussed the need for stability, and therefore referenced growing in controlled spaces in order to adapt to the erratic nature of the weather, and not rely on the natural constraints of the growing season. An example of coding sheet can be found in Appendix D.

There were several limitations to this study. Limited time resulted in a relatively small sample size, therefore making drawing conclusions and identifying common trends somewhat difficult. Additional interviews would strengthen the data by solidifying common perceptions and adaptations. Other limitations are in my beginner level of experience with coding and coding methods. Additional time would have allowed for expansion on this learning process and experimentation with coding methods beyond those used, which may have led to further results and or strengthen the existing results.

Below are the demographics of the farmers and their farms. While there were 12 total people involved in the 10 interviews, 11 farmers are reported in the Farmer Demographic Table as “Farmer 2” completed the demographic survey as a couple. In the Farm Characteristic Table there are there 10 total farms reported, as “Farmer 9 & 10” came from the same farm.

Table 5: Farmer Demographics

FARMER	AGE	GENDER	COUNTY OF RESIDENCE	PEOPLE IN HOUSEHOLD	EDUCATION LEVEL	EMPLOYMENT STATUS ON FARM
1	31	F	FRANKLIN	2	BACHELORS	SELF
2	71/70	F/M	FRANKLIN	2	MASTERS	PART TIME/FULL TIME
3	39	F	SOMERSET	4	BACHELORS	SELF
4	26	M	KENNEBEC	2	BACHELORS	SELF
5	58	F	FRANKLIN	2	MASTERS	SELF
6	41	F	FRANKLIN	4	MASTERS	FULL TIME
7	34	F	FRANKLIN	2	BACHELORS	SELF
8	70	F	FRANKLIN	2	BACHELORS	SELF
9	65	F	FRANKLIN	2	MASTERS	PART TIME
10	66	M	FRANKLIN	2	BACHELORS	SELF
11	51	F	FRANKLIN	2	MASTERS	SELF

Table 6: Farm Characteristics

<i>Farm</i>	<i>FARM ACREAGE</i>	<i>YEARS FARMING</i>	<i>ANNUAL INCOME</i>	<i>FARMING IS PRIMARY INCOME</i>	<i>MEMBER OF FARMERS' MARKET</i>
1	N/A	10	DID NOT REPORT	NO	NO
2	2	9	>20,000	NO	NO (CSA)
3	10	15	35,000-49,999	YES	YES
4	15	8	DID NOT REPORT	YES	NO (CSA)
5	3	17	>20,000	YES	YES
6	99	15	50,000-74,999	NO	NO (CSA)
7	2	9	20,000-34,999	NO	YES (+CSA)
8	2	40	50,000-74,999	NO	YES
9	5	30	DID NOT REPORT	NO	YES
10	2	9	>20,000	YES	YES

RESULTS

The results section is divided into four sections. The first and second section reveal two common perceptual themes between the small-scale Maine farmers that we interviewed. The third section focuses on farmer concerns, the adaptations that correspond to those concerns, and the linkages between concerns, adaptive behavior, and the changing climate. The two perceptual themes or trends that emerged during the early coding process were *Warming Temperatures* and *Erratic Precipitation*. It is within both of these broad perceptions where experiences and beliefs about temperature and precipitation ultimately caused farmers to implement various adaptations to cope with each of these themes. Certain adaptations were relevant to multiple perceptual themes and concerns. The concerns farmers discussed are both economic and environmental in the context of climate change. Farmers also frequently discussed the need for increased knowledge in relation to ongoing changes. Therefore, the final section of results focuses on where farmers source their knowledge. Figure 3 is a concept map of the following results. The overarching sub-themes are in blue, perceived results in gray, and adaptations in white.

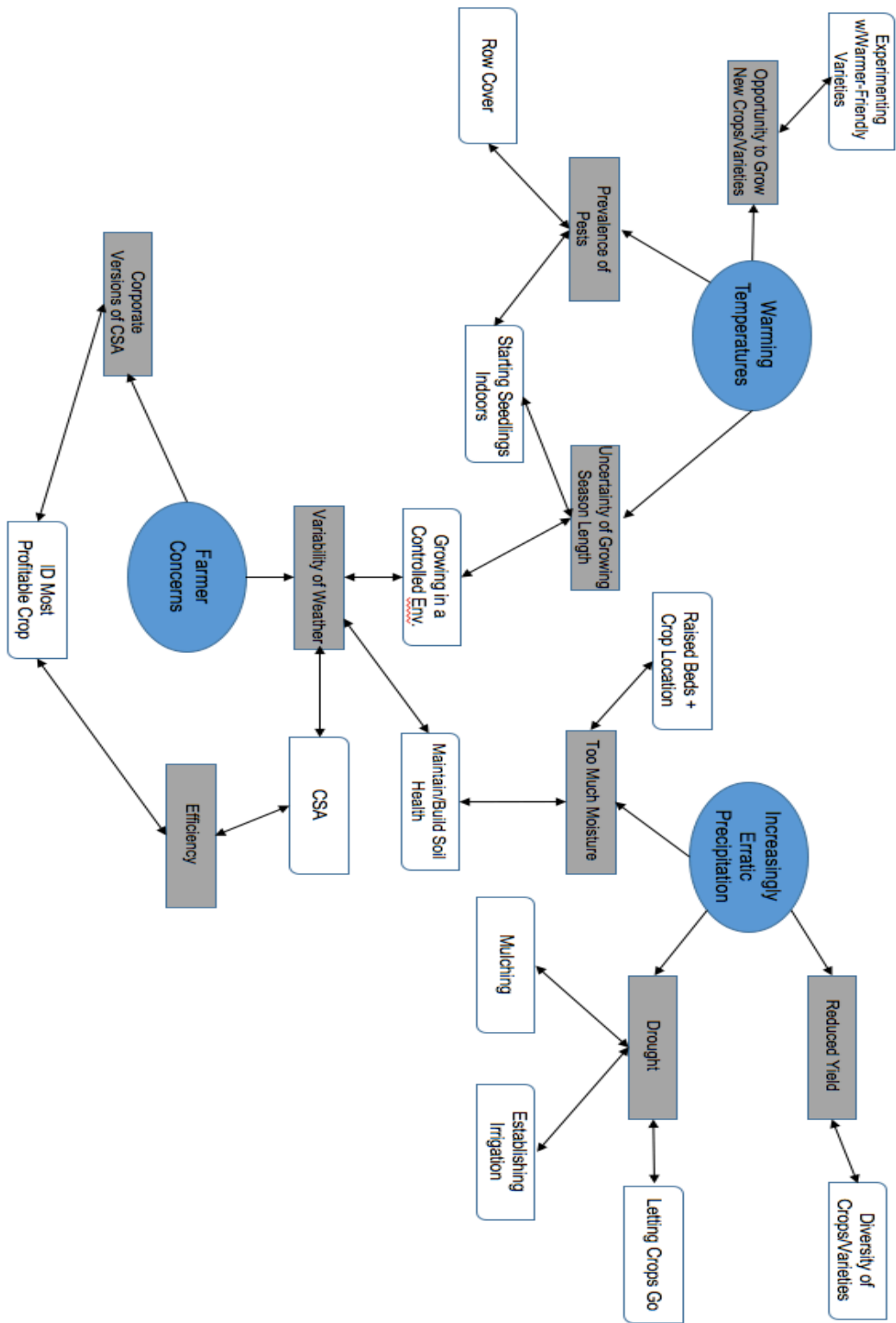


Figure 3: Concept Map of Farmer Perceptions and Adaptations

1. Perception One: Warming Temperatures

The trend of warming temperatures was mentioned across multiple interviews. Overall age and farmer experience level did not play a significant role in perceptions or resulting adaptations, but the perception of longer term warming specifically, was described differently depending on farmer experience. Farmers that had been farming for longer periods of time tended to be more confident in their perception that it was getting warmer, while younger farmers tended to describe warming temperatures in the context of extension of the growing season in the fall. One farmer who has been farming for 40 years said:

It's warmer. I used to describe us as USDA zone 4 on a good day. I think it's probably now 4.5 on a good day because overall things are warmer. Now that doesn't mean that we don't have cold snaps, we just had one this week. But I think overall it's warmer and that's why things have changed."

Here the farmer connects both the change and the result of the change. Warmer temperatures have caused zone shifts and therefore caused changes in his farming practice. A younger less experienced farmer still notes the change and the trend towards warming, but does so via warmer late-summer temps and season extension in the fall:

It's not uncommon to see the thermometer downtown reading 100 degrees in August or July. The fall is lasting longer, there's definitely a shift. I don't put things out any earlier but I don't think I took my garden until November. I put my garlic in a little bit late, it stayed warm. It kept on staying warm, we got some frosts. I feel like the frost came at night on time in September but I didn't take tomatoes out until November. And the garlic I didn't put in until November, and usually I'm planting that in the middle of October.

Regardless of age, all farmers but one stated or alluded to the perception that the temperature was warming. Based on the broad concept of warming several sub-themes

and associated adaptations emerged. The sub-themes that emerged from the perception of warming were: Uncertainty of Growing Season Length, Prevalence of Pests, and the Opportunity for New Crop Variety/Increased Yield in Existing Crops.

Uncertainty of Growing Season Length

While many farmers did note that it seemed as though their seasons were extending into the fall, many also associated that perception with general sense of uncertainty. Many noted the positive opportunities involved with a longer season, such as increased yields, but the uncertainty made it difficult to plan best practice or crop selection from year to year:

It starts earlier and it goes later. For some years in there, [it] seemed like an advantage. We knew that we had more time. I've brought basil to [the] Common Ground [Fair] for the last several years and I never would have been able to do that before. We had Silver Queen Corn a couple of years too. It's a late white corn and normally would get killed by frost. There are some advantages to some of the changes but it being so erratic makes it hard to know what to plan for.

Sentiments of uncertainty were inherent while discussing growing season length. As a result of existing unpredictability in Maine and increasing trends towards erratic weather there were common adaptations among the participating farmers. The most popular adaptations were the use of high tunnels, and the method of starting seedlings indoors to extend the spring and fall growing seasons.

Adaptation: High Tunnels (Controlled Space)

The use and necessity of high tunnels was emphasized by all but one of the participating farmers. High tunnels, or any controllable space such as a greenhouse, are considered a

vital method to protect against the unpredictability of the weather and the season length. A high tunnel is essentially a greenhouse, therefore farmers can control the temperature conditions within. The high tunnels provide stability and consistency when the climate does not:

I think we're not starting as soon in the spring some years. It's got longer in the fall but we also don't feel that as much because our business is based on season extension high tunnels. One of our points of resiliency is not to rely on a length of growing season outdoors, we have to create some kind of stability with length of growing season because it's erratic.

One farmer described the weather as, “*The one thing you can't control.*” Therefore controlled spaces like high tunnels allow farmers to better plan their crops and management practices, knowing they have more control over the environment in which their plants are growing. All of the farmers who had high tunnels already in place spoke to their utility and the younger farmers stressed the desire for more controlled spaces:

We want as many high tunnels as we can put up. After this first season with one, we've just seen the benefit in terms of consistency and quality of product. Especially in Maine it's giving some crops some added heat so you can get earlier bulkier tomatoes. Like I was saying about our peppers, our best ever pepper crop from a covered space as opposed to just field grown peppers. So that's the one adaptation, any high tunnel we can afford to put up we're going to put up in the future.

Adaptation: Starting Seedlings Indoors

Similar to growing in high tunnels, starting certain varieties as seedlings indoors allows farmers more control in the early stages of the growing season. Spring is considered fairly erratic:

There's also been a major change in trends. I haven't really kept careful records, but I remember in the past April was cool and wet usually. May might not be too bad, June was often very wet. And now April for the past 2-3 years is warm and

dry, like too dry at times. May is up for grabs and June is totally unpredictable now.

Starting seedlings inside is protection against this perceived unpredictability. In addition, it was noted several times that starting seedlings inside allows for heartier plants when they are finally planted. Ultimately their motivation for doing so was to make the seedlings more resilient to fluctuation, as their structure and roots are more established.

Prevalence of Pests

Pests pose a particular challenge to organic farmers, as they cannot use traditional pesticides. Much of the adaptation surrounding pests consists of preventative measures to stop the establishment of pests and therefore halt regeneration to some degree. It is important to understand existing methods for pest prevention as new pests, may arrive and existing pests may become more prevalent throughout the season.

Adaptation: Starting Seedlings Indoors

In addition to starting seedlings indoors as a way to increase seedling and plant resilience to climatic changes, farmers do this as way to enhance the plant's natural ability to fight off the effects of pests:

That's why I do a lot of seedlings, I feel that it's like if the plants are strong and healthy when you plant them and they're getting water and nutrients then hopefully they can outcompete the bugs. So I feed them and I compost around them and I give them some fish emulsion to keep it going.

Also:

You get them in and you get them real established they have a better chance of fighting off the bugs naturally.

While most of the participating farmers directly noted the practice of starting seedlings indoors as a way to protect against negative inputs, those that didn't still discussed the perception of having healthy established plants as a way to be more resilient to climatic changes.

Adaptation: Row Cover

Row cover, both plastic and cloth, was discussed by six of the farmers as a key way they protect their crops against pest populations. The row cover allows farmers to bypass generations of specific pests to some degree for specific crops.

I plant everything under row cover in the beginning. All the brassicas, cucumber, squashes go out under row cover. To minimize things like the flea beetle, and other early bugs. You can pretty much get through their major time by using row cover and then uncover and be okay

Many of the farmers noted that organic sprays are available, but due to cost and perceived effectiveness, row cover was the more prominent adaptation.

Yeah so we try and put row cover over things, that is the number one defense. There is an organic approved spray that we've used in the past, I don't think it works that great, so I've stopped buying it, I think that it works as good as the row cover.

Opportunity for New Crops Variety/Increased Yield in Existing Crops

Small-scale Maine farmers face many challenges, but there are also opportunities. While most farmers discussed the negative perceived results of the climatic changes, a few of the farmers saw the possibility for new opportunities in the varieties they were currently growing as well as those they may be able to grow in the foreseeable future.

Adaptation: Experimenting with Cultivation of Warmer-Friendly Varieties

Several of the farmers interviewed already experiment with and have had success growing warm temperature loving crops such as melon. The melons they do grow are specifically suited for the growing season in Maine, but as the season extends and temperature continue to warm, farmers see opportunities in increasing yields for these types of crops, and the possibility of increasing profit. Utilizing the possibilities of these warmer-zone varieties also helps mitigate losses in crops that may struggle with the heat:

Well the warmer it is the better melon we get, and people like melon. Same with corn, tomatoes, peppers, most things like it warm, most things that people like. This year it was hot and dry so some things really sucked but our melon and corn were fantastic, and those are two things people love, so, great! Broccoli wasn't that great, and a lot of people like broccoli but then there's a large population that thinks broccoli is pretty lame. It kind of all evens out, it can't be perfect.

Farmers also noted the possibility of growing crops that have never been inherent to Maine agriculture such as citrus:

I've got citrus plants and right now they live 365 days indoors, but I can conceive of a time where with some protection but without added heat it might be possible to keep them outside.

2. Perception Two: Increasingly Erratic Precipitation

The theme of variability was frequently mentioned when farmers discussed precipitation. Despite Maine typically receiving 40 inches of relatively predictable precipitation throughout the year, every farmer considered Maine precipitation to be increasingly erratic:

It's pretty much erratic. It's kinda like what they say "When it rains it pours," I feel like you can use that expression for a lot of things. If the weather is going to do something it's going to do it all the way until it's the worst possible way. So like you're in 2009 when it starts raining it doesn't stop raining, but then the years between then were pretty good. I feel like once the weather starts going a certain way, it will either go one extreme or it will even out. It's not like June will be all wet and July will be all wet, August all dry. It's like off and on all wet, all dry. Pretty all over the place.

Drought & Lack of Moisture (Summer 2016)

Erratic precipitation as noted by the above farmer, can lean towards extremes of both moisture and drought. This poses a challenge for Maine farmers year to year as they plan crop location and variety. Interviews were conducted following the growing season of 2016 during which much of Maine was experiencing drought throughout the summer and therefore every single farmer interviewed discussed drought to some degree.

The problem is you don't have a rat's ass chance of knowing what's going to happen. This year was a good example. No rain for six weeks and 95 degree temperatures for 3 of those six weeks. So that's the hard part. We've had hot spells before, and I won't say never, but extremely rarely have we had the combination for as long a period. The entire state is back in a drought status.

For certain farmers it posed more of a challenge than others. Adaptations to erratic precipitation ranged from preventative measures such as mulching, to responsive measures such as simply letting crops grow. Much of the adaptation depended upon farm location and cost of irrigation.

Adaptation: Mulching

One adaptation that was common to almost every farmer was mulching. Many of the farmers noted mulching was something they practiced whether or not there was a drought as a way to maintain soil moisture and suppress the growth of weeds. In the context of the

previous summer however, mulching was frequently discussed in response to the drought conditions. Mulching helps maintain soil moisture by trapping the moisture. Farmers used a range of materials to mulch, from fallen leaves to manufactured black plastic:

I have used plastic mulch at farms - that was really helpful. The things that I found the most useful were this white on top and black on bottom plastic film mulch. That was primarily used for growing brassicas, and the black on the bottom keeps the weeds from germinating and the white on top keeps the soil cool. I am a permaculturist and I am not a big advocate of plastic mulch, but at that particular farm the farmer wanted to use plastic mulches, and they were very successful with the drip irrigation under the plastic mulch. There you have a system that basically is beds that are vegetable growing machines, that had automatic water and weed killer.

Adaptation: Establishing Irrigation

Those with established irrigation were less concerned with the past summer's drought or droughts to come, while those without established irrigation had trouble producing desired yield. This quote comes from a farmer who had established irrigation the previous growing season, yet still experienced some difficulty with desired yield:

Control of water has also been important. Without the irrigation we would have been very bad off, it would have been hard to get things to germinate and have second crops. Once a crop got established it seemed to do fairly well. As it got drier and drier the sequential plantings got harder and harder, and slower.

Due to the small scale of these operations, many of the farmers are sourcing their irrigation from the same well as their household water. This resulted in many of the farmers having to be selective in what they watered and what they didn't, as the rains were less predictable. Without rain and sufficient irrigation farmers such as the one quoted below had difficulty getting their crops to take on the desired weight. Weeds outcompeting crops was another result of the low rainfall and therefore also affected desired yield:

So it was a cold spring so things like didn't really accelerate the way they should of, and then it was low rainfall so then when they kinda started to pick up and start growing, a lot of our typical mid-summer vegetables didn't really put on as nearly much weight or bulk that we were looking for, and when you have no rainfall, you still get weeds that outpace your vegetables.

Adaptation: Letting Crops Go

Many of the participating farmers run their irrigation systems off of their household drilled well. As a result, many were faced with the challenge of watering certain crops sufficiently, or having ample amounts of water for their household needs. In the interest of efficiency, and due to the decision they made regarding what would get water and what wouldn't, many of the farmers simply had to submit to letting crops go. Letting crops go allows farmers to direct the small supply of water they did have towards the crops they deemed more vital or profitable to their individual farm.

So carrots do not compete well with weeds and for the first time ever we tilled in an entire bed of carrots because the water never came We were irrigating it but we had to kinda play triage with our irrigation. It did get water but probably not as much as it should have been, and then the weeds came up, and it was in an area where the primary root is grass, so we tilled it in and that's always heartbreaking. We just sent the tractor through, we said we're not going to keep weeding this, this is never going to come to fruition so let's till it in and kill all the weeds and start thinking about what we're going to plant there next.

Too Much Moisture & Need for Established Drainage System or Mechanism

In contrast to the drought experienced during 2016, many of the farmers discussed the greater challenge posed by growing seasons with too much moisture. Specifically many farmers noted the summers of 2008, 2009 and 2010 as excessively wet. Farmers seem to be more concerned when there is too much moisture due to factors such as diseases that are worsened in damp conditions:

Not just in terms of weather itself but how it affects your practices. I think the wet prompted more of that than the dry. The solution for dry is more obvious, you water and you mulch, mulch, mulch repeatedly. It felt like there were more disease issues that came with wet weather, that prompted a lot more of the research and collaborating about how do you deal with what comes out of that. Like how do you deal with late blight for example, '09 was really the first year it was prevalent everywhere, and people were just figuring out how to deal with it. In that year a lot of people found that the learning curve was behind the weather curve.

Adaptation: Raised Beds & Crop Location

Farmers noted how important it was to consider where they are placing their crops based on the knowledge of their land and how it drains. Certain farmers chose to shift the location of their crops proceeding damp growing seasons based on the difficulty with drainage they had experienced with the given location:

We used to have our garden down in the lower field and then just groundwater management was the problem. When we started we didn't have that field up there, so it wasn't an option. Then water management in very clay heavy soils was very difficult so our solution has been to find better and different growing space. We moved it up there three years ago. I think the first year the we were up there and my mom said, "This is like sewing with velvet after sewing with burlap." It was just the perfect summary of that soil compared to down there.

In addition to crop location, many farmers cultivate their crops in raised beds as a way to control and promote drainage. Some of the farmers interviewed had both raised beds and field space, whereas a few were completely in raised beds due to either poor soils or the fact that they were on or below a slope:

The last thing in our mind this year was to put in irrigation because we're always fighting to get the moisture out earlier in the spring. We want to put in drainage tiles and we've formed raised beds that pulled the moisture away.

We started going towards that raised bed idea to provide a little more drainage in future seasons.

Putting in the raised beds was pretty crucial, it's going to take work to get the soil here to be anything reliable. I needed some reliable soil so I bought some and that's working.

Adaptation: Managing Soil Composition for Drainage

Every farmer discussed the importance of managing soil composition in relation to resiliency to weather changes. In the context of too much moisture it was frequently emphasized that having soils that drain well is vital to maintain healthy soils and therefore crops:

One of the other things is soil depending on if it's sand or clay makes a huge difference. Growers on sand care more about irrigation because it drains so much quicker. We have clay soils here and they don't drain very well at all. Our soils probably dry out four weeks after a sandy soil would.

Also:

The soil drains really well. Fryeburg loam or something like that. It's incredible because my rows are 200 feet and one end of the row is much sandier from the runoff from the river. Things like the carrots are dramatically different from one end of the row to the other. I went out this summer in July after a wicked rain/hail storm and I sunk five inches but the next day I didn't have a problem.

Reduced Yield

As noted in previous sections, reduction of yield was something that many farmers experienced due to the drought as well as the years with too much precipitation. Every single farmer described their operation as diversified: *“If you're going to try to make kind of living or some kind of a living on a small amount of acreage in Maine you have to be diversified.”* Many discussed the diversification as a way to hedge against unknown variables resulting from the erratic climate.

Adaptation: Diversity of Crops

The farmers, particularly those who ran cooperative sustainable agriculture (CSA) programs, felt that diversity gives them more leeway with the season-to-season variability if one crop is more successful than another. Diversity gives them the opportunity to let certain crops go if need be as well as gain knowledge regarding which crops and varieties do well in which conditions:

Well it's a mix of annual and perennial. It's an intentional plan to hedge against weather changes. I like to grow a lot of things, and not relying on one thing. I like to be as diverse as possible to handle the wide range of growing situations. Hedging my bets.

3. Farmer Concerns and Adaptations

At the end of each interview farmers were asked a simple, open-ended question: “*What concerns you as a farmer?*” This question allowed the farmers to discuss freely the concerns they had for both the present and future of their farms and farming in Maine, without being specific to climate change or adaptation. In a separate round of coding, several key farmer concerns were identified, both ecological and economic, that were either relevant to both temperature and precipitation, or stood alone as broader concerns associated with climate. There is some repetition among adaptations, but the following adaptations were discussed in the context of the given concern, and were not specific to the perception of erratic precipitation or warming temperatures.

Erratic/Variability of Maine Weather

As noted in the sections above, the variability and erratic changes in both annual temperatures and precipitation in Maine pose a significant challenge for farmers. The

uncertainty that results from this variability makes it difficult for farmers to plan for things such as which varieties they should cultivate, frosts, planting and harvesting dates, etc. Every farmer interviewed noted the trend towards more erratic weather and the challenges therein:

The hardest part is the unpredictability. For example comparing this past growing season with the year before, this year we had to contend with weeks of blistering heat, and had there been rain at the same time it would have been more manageable, but we did not. So we haven't [had] a summer like this in 15 years or more. The flipside is when you have a long slow spring and it's cool right through June and it rains all the time which is what happened in 2014. It's the extremes and coping that's the challenge.

Adaptation: CSA

Half of the interviewed farmers participated in CSA, and one participated in both farmers' market and CSA. Those farmers all seemed to believe that CSA was an effective way to safeguard against unknown variables due, in part, to the diversity involved in being a CSA, as well as the direct interaction they have with customers. The farmers had CSAs that were both pickup and drop-off based. Some farmers sent out a weekly newsletter with the shares to give their customers a description of why certain things were in their shares and why certain things were not, due to the given weather, *"I can say sorry the lettuce is gone, but the chard is okay."*

Also:

I think CSA is particularly helpful in that situation because you have direct contact with your customers and you have a chance to have a little bit of an explanation every week, 'Hey this is why you have more of this and less of this, the spinach is great because it's been raining.' You can provide some education to the people buying your products, and how what's there is tied to the weather. You don't have a contract to provide a specific crop to a restaurant or something, you either do it or you don't. But CSA lets you share that weather risk with customers.

Adaptation: Maintaining/Building Soil Health

There was significant emphasis on the importance of farmers knowing and amending their soil composition to maintain its health as a way to protect against erosion, help grow stronger crops, and ultimately remain resilient in the face of climate change. The farmers amended their soils via organic matter such as manure, utilized cover cropping, etc. All of the farmers interviewed clearly had a strong understanding of their own soils and the importance of adding to them each year:

When you grow up in the organic farming world that's something you're bent on regardless of climate change. I think because people are in habit of doing that our soil will be more resilient during climate change.

I manage that, I control that. We're on very shallow clay based soil on a slope, and because we're on a slope I'm in raised beds to prevent erosion. So that means I'm managing the soil texture. We add a lot of organic matter and leave roots to rot.

Our soil by itself is really horrible, very low pH. I've been working on it most years, I do big plantings of buckwheat to try and enrich the soil and it also breaks up the hard pack. We have very heavy clay and lots of rocks. Rocks are by far our best crop.

I think that resiliency to climate change is all in the soil. With variety thrown in there certainly. It's all going to be in the soil management. Those protozoa, bacteria, fungi, and the tilth and the ability for resiliency is all in the soil, I'm speechless as to how much it depends on the quality of the soil.

Adaptation: Growing in Controlled Environment

Growing in controlled environments has been previously discussed in terms of warming temperature, but almost every farmer discussed the role of structures such as high tunnels as vitally important in the face of variable climate, beyond just temperature. There is an element of control the high tunnels (or similar structures) provide, that the farmers feel they otherwise would not have while growing in Maine climate conditions:

A lot of farmers are going almost 100% under cover. One of my young men friends, he's got three NRCS (Natural Resources Conservation Service) houses now, and he's totally CSA and he's gonna be totally under cover for that reason, to protect.

Many of the farmers discussed high tunnels in the context of certain crops that would otherwise not come to the desired fruition without the added heat and season extension provided by a high tunnel:

The erratic weather is hard. I don't grow any unsupported tomatoes, I don't grow any peppers out of the greenhouse. Supporting against wind and violent weather, we're getting better at it because we have to be. That's a fact.

Yeah I've given up on outside tomatoes. Other than the tomatoes all the other crops some I do outside and some are in the greenhouse. It's pretty hard to know what the variables are and sometimes the stuff is better outside and sometimes it's better inside. That's a hedge for me.

In addition to the crops that grow more easily in the protection and heat of a high tunnel, season extension is also a factor in why these farmers utilize high tunnels:

I think it's essential to have some covered growing space in a climate like this. It gives you some control. Even aside from moisture, there's not a long enough season to grow red and yellow peppers easily. We didn't find a way to do it until we had a high tunnel. Same with melons. Some of those warm loving things you have to have a high tunnel.

Efficiency & Market Viability/Saturation in Western Maine

Farmers were asked, “Do you find that this area provides a viable market for you to sell your product in?” In response to this the majority of farmers expressed concern regarding the demographics in western Maine, and concern for the market becoming too saturated as new farms are continuing to pop up in the region. Much of farmers’ concern for the market viability in the area was in the context of efficiency. Farmers expressed

concern for spending large amounts of time on producing, transporting, and attempting to sell their products, in the markets of rural western Maine:

I would love it if I could sell everything in one market. Because every time you go to a market it's time away from the actual work. Two markets is fine because you're going to have cucumbers that ripen for Tuesday's market and then they'll be ready again on Friday... I don't know what has happened if it was the economy, but I think I used to do pretty well when I first started to do the markets... Maybe people don't have the money or they've got discouraged because they think vendors at the market charge too much. Some of my products are cheaper than they are at the grocery store. They're freshly picked and organically grown.

Adaptation: CSA

The farmers whose farms are CSA based, as opposed to farmers' markets, expressed more positive attitudes towards the market viability based on the fact that they were CSA.

CSA allows them to have a guaranteed profit at the beginning of the season with shares.

Many also felt that CSA was a better fit for the given population in western Maine:

Oh yeah for sure. I think it's just kind of the way the world is working. We live in Maine not New York, not a lot of people around here. If you look at the percentages of people that frequent a farmer's market it's extremely low compared to people who are more susceptible to do a CSA. That's kind of what we stuck with.

Other farmers felt that CSA was a more efficient model because they didn't have to spend time standing at a market for several hours instead of working on the farm, as CSA often has on-farm pick-up.

Adaptation: Identifying Most Profitable Crop for Individual Farm

Farmers discussed identifying the most profitable crop for the individual farm in the given region or market as one of the best ways to maintain profits and livelihood.

Understanding what customers are wanting to see and buy whether it is at a farmers' market, food hub, or CSA they felt was key in order to go on farming:

It's always interesting to me when I hear farmers in southern Maine, they tell me their profit on tomatoes. And they tell me that they can't keep a tomato on their market table, and that is not the case for us. Because in rural Maine, everybody has a tomato plant. If you're going to plant three crops you're going to plant a cucumber, a tomato, and a pepper. So we have a hard time pushing these tomatoes through. But, if you want to talk about beet greens, we could sell trash bags of beet greens at the farmer's market because we have a population where beet greens resonate with them. So the biggest learning is figuring out what our customers want, at the market and at our roadside stand, and really adapting to what is being purchased.

One farmer, despite acknowledging the poorer market in western Maine, had hope for the farming community based on the success of small-scale farming communities:

I know that there's a connotation, the struggling farmer story. We're undervalued, it's way hard work, all that kind of stuff. But I'm kind of sick of that narrative. It's like figure it out. There are farms out there that are thriving. Let's look at those farms and stop feeling sorry for ourselves. Just figure it out. I would kind of say, don't join in that narrative.

Corporate Versions of CSA (Blue Apron or Amazon)

One interesting concern brought up only by two of the younger farmers that were interviewed, was the threat posed by more corporate version of CSA such as Blue Apron, as the organic, farm-to-table movement continues to grow. One of the farmers even discussed the idea of the online market company Amazon, as a worry for the future of CSA's:

To be honest, this might sound funny, but Amazon worries me as a farmer. What we do is what Amazon and like Blue Apron, home delivery. That's what we do. A lot of people don't see a difference between what we do, and what Blue Apron wants to do for you. There is a cost difference, I'm pretty sure we're cheaper because every time I go on and check but those kinds of things make us worry. I don't see how it can be fresh shipped to your door. Amazon for me also stands for

like corporate large money, that's pretty much what's ruined America and the world.

Adaptation: Identifying the Most Profitable Crop for Individual Farms

Again farmers expressed that identifying what makes the most sense for an individual farm to focus on growing, as far as consumer demand and profits are concerned is a key method in maintaining their operations, and in this context when faced with the challenge of corporate dominance:

I think staying viable on a farm always [requires] analyzing what's next. With high speed communication and all that stuff. How many home delivery dinner companies have popped up in the last two months? So our Food Hub is thinking like should we become a local Blue Apron? Our mission is to buy farmers' products, we want to money in the hands of the farmers. We want farmers to get their product out there. What form that takes is what always changes. Is it prepackaged salads? Is it totally old school rustic farmers market? Is it high end retail everything has got your label farmers market? Is it wholesale get it into the hospitals and get people demanding local food at their local institutions where it didn't previously exist? How is it going to get from the farm to somebody's plate in any form or fashion? It's only a viable market if you are constantly assessing how to keep it viable.

4. Knowledge Sourcing

We felt it was important to identify where farmers were sourcing their information regarding both the climate and agricultural practices, in order to make suggestions for how to best provide support to farmers in the future climate. Understanding where their knowledge was sourced from also allowed researchers to better understand perceptions. Farmers frequently discussed the need for new knowledge as well as the need to farm on a learning curve.

Use of Local Weather News Outlets and NOAA

We asked farmers, “*What would you say your primary source of information regarding weather changes is?*” Eight of the farmers relied on NOAA, seven relied on various local weather sources, and there was overlap between the two groups. Often farmers expressed that they felt the need to look at multiple sources in order to gain a good idea of what’s actually going to happen in their area:

Well I just pay attention to a combination of things. Since we live in the foothills we get this weird combination of mountain weather or central Maine weather and it’s never really sure which is going to strike. So I use a combination of the Channel 8 online stuff and the local newspaper, for immediate weather. I pay attention to NOAA as well. I pay attention to the seasons changing.

Use of Cooperative Extension and Maine Organic Farmers and Gardeners Association

(MOFGA)

We asked farmers, “*What would you say your primary source of information regarding farming is?*” The majority of farmers noted MOFGA as a primary source for pest and disease information, crop and variety selection, as well as a promoter of educational venues for farmers. “*MOFGA is an amazing source of support and information and I try to avail myself at all times of those.*” Many farmers also discussed how appreciative they were of the support from their local Cooperative Extension specialists:

Another source is my extension guy [name], and if he doesn’t know he knows how to find out or to send me to the right kind of person to find out. Extension has just been an incredible source because they’re connected to the university system, which is also connected to other university systems.

Farming on a Learning Curve & Learning From Fellow Farmers

Farmers expressed the need for new knowledge as a critical aspect of being a farmer.

“Mostly still I’m always on a learning curve. I’m adapting based on what I learn.” Many of them discussed the need for new knowledge in the context of climatic changes:

I’m not so much concerned about the overall warmer as I am on a day to day basis. What’s being dished out this week, and then overall I’ve had to learn about a whole bunch of stuff I never knew I need to learn about, just from what’s happening outside.

Being able to learn and adapt based on new knowledge was considered key in maintaining their farms. One of the major sources for new knowledge was the knowledge of fellow farmers:

Oh absolutely because one of the most important parts of having a network of farmers to talk to is that maybe they’ve experienced that and have a damn good solution, whatever that happens to be. People come to each other’s aid with information and physical help as well.

Other farmers provide a trusted source of knowledge that is easily accessible. As noted in the previous quotes farmers felt that while MOFGA and Extension were great resources, it was likely that other farmers in the area had a solution or adaptation that would make the sense for the given region.

DISCUSSION

The primary goal of our study was to understand what ecological or climatic changes small-scale Maine farmers perceive, compare those perceptions to climate data, and explore what and how they are making adaptations based on those perceptions. In order to do this we used Turner and Berkes (2006) Ecological Understanding Models and Morton's (2007) framework for small-scale agricultural adaptation. We chose these theoretical frameworks in order to best identify and evaluate small-scale Maine farmer knowledge, perceptions and adaptations in the context of climate change. We hoped to provide suggestions that will assist both the farmers and other stakeholders in supporting the small-scale Maine farming community as it adapts to current and projected climate change.

The first objective of our study was to understand the ecological and climatic changes that farmers were observing. We were then able to compare those perceptions to the actual climate data provided in *Maine's Climate Future* (Griffin et al., 2009) (Fernandez et al., 2009). Our analysis revealed the most significant perceived changes were trends of warming temperatures and increasingly erratic precipitation. Both perceptions were consistent with the actual climate data, current and projected.

Farmers discussed warmer temperatures in terms of shifts in the length of growing season and USDA hardiness zones, the prevalence of pests, and opportunities for cultivating new varieties and crops in the warmer climate. Maine temperatures have been increasing since 1895 and are projected to increase another 1.1-1.7°C by 2050. Such changes will result in shifts of the “relative length and character of each season”(Fernandez et al., 2015, p. 3). These shifts are consistent with what the

interviewed farmers had noticed. New pests are expected to begin arriving from the South that had not previously been able to survive in the Maine climate, and existing species are expected to generate more times throughout the season as average temperatures rise and the season extends (Griffin et al., 2009). Many of the farmers stressed their concern for the arrival of unknown pests and additional generations of pests like the Colorado potato beetle (*Leptinotarsa decemlineata*), and the labor and cost associated with managing each. While increasing temps and seasonal shifts will pose challenges to farmers, many of our farmers expressed hope for opportunities to cultivate new varieties as well as enhance yields in existing varieties as hardiness zones continue to shift. Crops such as melon were discussed as a crop that is highly popular with customers that will be far easier to grow in a warmer Maine climate. Overall when compared with the existing climate data for Maine, specifically temperature, the perceptions of the farmers interviewed were accurate accounts of the ongoing changes.

Farmers discussed increasingly erratic temperatures in terms of extremes. Drought, or lack of water, was one extreme, while too much moisture in a growing season was the other extreme. Both concerned farmers and resulted in adaptations. Maine, overall, is projected to experience a 5-10% increase in total precipitation. Typically precipitation is distributed evenly throughout the year in Maine, but models project that distribution will become more erratic (Jacobson et al., 2009). Current increases in precipitation are most visible on the coast of Maine but, in the future, the interior of the state, where our participants reside, is likely to experience more extreme precipitation events (Jacobson et al., 2009). While the farmers did not imply that they perceived more precipitation, they did note that it is becoming more erratic. Some

farmers described the occasional extreme weather event in their time farming but it was not something they stressed or seemed to be taking note of, despite the climate data projections for increases in such events. Their main concern was the increased uncertainty associated with the erratic precipitation as it affects their ability to produce desired yield. Many crops will not take on the desired weight without consistent early season rains. This was frequently discussed by several of the farmers interviewed and is noted in the literature in regards to Maine's blueberry crops that rely on the same early summer rains (Fernandez et al., 2015).

Farmers' livelihoods depend upon the given environmental and climatic conditions. Based on our analysis it is clear that these small-scale farmers are highly perceptive to changes in the climate and environment, and their perceptions are consistent with the climate data. Researchers should therefore continue similar research across the state to determine whether farmers at multiple size and spatial scales and within various climate regions perceive similar changes. Documenting the extent of farmer knowledge allows researchers to take the next step in determining how farmers are adapting to the given climatic changes. It is important to note if farmers across the state are perceptive to these changes because regional changes vary, and therefore adaptations will vary. Understanding climate division and county-specific adaptation benefits farmers, researchers, and other stakeholders in effectively providing support as the climate continues to pressure farming practices in the state to adapt.

The second objective of our study was to understand farmers' adaptations, if any, based on their perceived changes in climate. To evaluate farmer perceptions and adaptations, we utilized the Ecological Understanding Model (Turner & Berkes, 2006)

and Morton (2007) frameworks. The aim of the EUM is to identify mechanisms through which farmers build their ecological understanding, surrounding sustainable and conservation practices, and provide a pathway for further development of that knowledge via those specific mechanisms. Through this theoretical lens, we aimed to understand which mechanisms the farmers utilized to gain the ecological understanding necessary to operate their farms and in turn how they used that understanding to manage and adapt practices in the changing climate.

As discussed previously, farmers were highly perceptive to the ongoing changes in the Maine climate, and their given perceptions were accurate to the existing climate data. The primary mechanisms within the EUM that allowed researchers to determine farmer perceptions of climatic changes were *Experiences and Expectations* and *Learning from Animals/Insects/Disease*. These mechanisms allowed researchers to create questions that specifically targeted farmer perceptions of temperature, precipitation, growing season length, and pests. Both mechanisms were effective tools to determine farmer perceptions of the climate, as our results show. Therefore, future researchers should consider the EUM as an efficient way to identify the extent of farmer knowledge, when conducting research in the context of environmental and climatic changes.

Adaptations such as the use of raised beds for improved drainage, and the importance of mulching for moisture retention, were both identified via interview questions rooted in mechanisms of the EUM. Specifically *Trial and Error Experimentation and Incremental Modification* and *Elaborating and Building Sophistication* were the primary mechanisms within the EUM that aided researchers in identifying adaptations due to climate change.

While these mechanisms were effective in determining some of the adaptations farmers were using, we determined several other adaptations through the supplementary Morton (2007) framework. Certain mechanisms such as *Lessons from the past* and *Lessons from other places* were less prominent in the results in terms of perceptions and adaptations to climate change. The intention of the interview questions rooted in these mechanisms aimed to identify where farmers get their information from (both for climate and agricultural practices). The responses to these questions did reveal some of those knowledge sources farmers utilized, such as NOAA and local weather stations, but those mechanisms weren't necessarily vital in identifying knowledge sources.

Based on our results and analysis the EUM is an effective framework for researchers to use in order to understand both farmer perceptions and some of the resulting adaptations to climate change. It does not necessarily provide a way to connect specific adaptations to perceptions, as such connections only became clear during the coding process and in this research we did not utilize the frameworks as part of the coding process. In our study the model was also only used on farmers with diversified vegetable farms and we found it effective in that context. It could conceivably be used for any scale of crop-based farming, as farmers at any scale are likely going to be perceptive of the environment in which they grow their crops. Whether farmers are growing vegetables for CSAs or producing a single crop for wholesale, their environment, including climate, directly impacts their livelihoods, and therefore the EUM should be an effective framework at any scale of crop-based farming and ultimately has a lot to offer to research surrounding climate change and agriculture in the United States.

The second framework taken from Morton's (2007) case study of small-scale agricultural adaptation to climate change in Sub-Saharan Africa, was necessary to identify and extrapolate further climate change-specific adaptations beyond those identified via the EUM. The EUM also did not provide an effective pathway for determining non-ecological stressors or general farmer concerns that were still related to climate but not necessarily based on ecological changes. The secondary model was able to fill that data gap via its mechanisms. Adaptations such as the necessity of building and maintaining soil health for climate change resilience was something that every farmer considered critical, and we were able to understand it through a mechanism from this model, called *Environmental and Physical Processes*. Another important aspect to this research and to the farmers was market access and viability in the context of climate change, but the EUM did not present a mechanism that targeted this aspect of farmer life. In Morton's framework, the mechanism *Non-Climate Stressors and Vulnerability* allowed researchers to ask questions that allowed farmers the opportunity to discuss how they adapt to their given market, and how climate change may affect that market. Adapting by becoming a CSA-based versus a primarily farmers' market-based farm was a common way the interviewed farmers kept their farms viable in the markets of western Maine. CSA was also considered by many of the farmers as a way to keep their farms viable due to climate uncertainty and growing season volatility. Future researchers should consider the role of this model in ag-focused studies, and its ability to fill gaps in other frameworks. While the EUM was effective in determining most of the key perceptions and adaptations, it did have gaps. Researchers do not necessarily need to use this specific framework to fill gaps in the EUM or any other given framework, but it is important

when conducting such research that multiple stressors, factors, and changes are explored by the chosen framework. Being able to identify and fill gaps in a framework is a key part of obtaining data that accurately depicts all the aspects of farming and farmer life in the context of climate change.

It may be possible and likely would be beneficial in future research to combine these two frameworks into a new singular framework. This framework could again be used to create interview questions rooted in specific mechanism and could also be used as part of the coding process. Have a single framework may benefit future research as it would bring together the key elements of both the EUM and Morton's model and possibly eliminate the less useful mechanisms, ultimately creating a more effective framework that targets farmers' perceptions, adaptations, as well as the exterior inputs on the farmer experience in the context of climate change.

As stated previously we did not use the frameworks as part of our coding process, they were used specifically to generate the interview questions, and it has been previously discussed which mechanisms from the frameworks resulted in the most effective interview questions targeting precipitation and temperature changes. In future research however, had I more time and a larger sample size the frameworks certainly could have been used as part of the coding, and they may have generated an entire new section of results. In addition to the limitations discussed in the methods, such as the beginner-level experience with coding, having access to a qualitative coding program would make further coding more viable particularly if the frameworks were being used as a part of the coding process. For example, had I done coding using the frameworks I may have been able to integrate them into something like the concept map in order to highlight how the

frameworks were able to identify farmer knowledge in addition to any adaptations that may have been drawn out due to specific mechanisms in either of the two frameworks. This would have also further highlighted the advantages of the EUM versus Morton's model in the results, and therefore make the process of combining the two frameworks more successful. Ultimately having done another round of coding using the frameworks as the overarching code would have identified the role the frameworks played in the given results and likely would have further supported their effectiveness in this type of research

The third objective was to use the gathered data on farmer's perceptions and adaptations to assist other stakeholders in supporting the small-scale Maine farming community of Maine, and provide adaptation strategies for other farmers, as they will face growing adaptation pressures with future climate changes. As noted in the literature, the majority of existing farmer studies are quantitatively based, and tend to focus on larger scale operations, yet local smaller-scale farmer knowledge plays a vital role in climate change resilience (FAO, 2004). By conducting face to face interviews and qualitative analysis our study revealed the extensive knowledge farmers in western Maine have of their given environment and local climate. Due to this knowledge, the farmers interviewed possessed various site-specific adaptations as well as several adaptations that would likely translate into any microclimate or regional climate division in Maine, such as the frequent use of controlled growing spaces like high tunnels.

Similar to the study conducted in the Danghou Watershed of China, our study revealed non-climate specific stressors, like market viability, played a critical role in farmers' adaptation choices (Hageback, et al., 2005). As noted previously, many of the

farmers found that being CSA-based instead of regularly attending a farmers market, was a more viable business model for their farm in the given region. It was also apparent during the interview and our analysis, that in addition to being an adaptation to markets, CSA was a common adaptation to an increasingly erratic and uncertain Maine climate.

While such adaptation may have become apparent in a quantitative study, the qualitative structure allowed researchers to obtain a more holistic view of the life of farmers in western Maine in the context of climate change, and make connections that may not otherwise have been apparent without qualitative analysis. Future researchers should consider the benefit of a qualitative study when working to understand the issues surrounding climate change and farmers. The interviews provided a setting for farmers to extrapolate on both their knowledge, perceptions, and adaptations in a way that they may not have been able to had they simply taken a survey.

Stakeholders such as MOFGA and Cooperative Extension benefit from this type of research because it directly connects them to farmer knowledge, and highlights farmers' climate concerns. Understanding farmers' perceptions of environmental and climatic changes, their adaptations to those changes, and their overarching climate change concerns, may equip MOFGA staff and Cooperative Extension specialists to provide better support strategies for our participating farmers and others across the state.

Other stakeholders such as policymakers benefit from this type of research because it provides a primary account of what a community and vital part of the Maine economy is experiencing. With this knowledge, they may create both policy and incentives that support and encourage farmer adaptations to climate, such as providing grant money to build high tunnels. Lastly, other small-scale farmers in the state may

greatly benefit from reading first-hand accounts of what their fellow farmers are experiencing due to climate change, and what specific adaptations they are implementing as a result of those changes. As discussed by many of the farmers, farmer-to-farmer knowledge is both valued and useful to the farmer community as a whole, and research that promotes the exchange of farmer-to-farmer knowledge supports the resiliency of the individual farms as well as the state as a whole.

CONCLUSION

Climate change poses a threat to agriculture not just in Maine and across the globe. Our study highlights the effects of climate change on the small-scale farming community in Maine due to the state's tradition of farming and agricultural identity, as well as its unique climate variability. In order to maintain both the livelihoods of farmers and the stability of agriculture in the state, farmers will be pressured to adapt their practices to the new and changing climate. Understanding the extent of farmer knowledge, and the climatic and resulting environmental changes farmers perceive will be key in supporting such adaptation. Our study highlighted the relationship between specific perceptions and adaptations, which assists farmer learning adaptation strategies, and provides key information for stakeholders to support farmers and local agriculture in Maine. Understanding current perceptions and adaptations to climate change benefits future research and supporting stakeholders by providing a comprehensive view of the experience and knowledge base of the small-scale farming community. With this knowledge the suggested support strategies may be better tailored to the individual region and farmer. This research promotes the exchange of highly valued farmer-to-farmer knowledge and therefore will play a key role in developing adaptation strategies to keep both the farms and the state resilient to climate change. Similar research is needed across the state due to the highly variable climate. While certain adaptation strategies may be applicable regardless of climate division or microclimate, there are likely many region- or site-specific adaptation methods used by farmers that other nearby farmers would benefit from learning. For this reason, extensive qualitative research, such as our study approach, will be vital as the agricultural community of Maine adapts to the effects of climate change.

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APPENDICES

Appendix A: Framework to Interview Question Development

Turner and Berkes (2006) Ecological Understanding Model

Mechanism	Explanation	Examples for Small Maine Farmers	Interview Questions
Lessons from the past	Stories of positive and negative experiences, embedded in individual or institutional memory, and transmitted through oral and written history	Memories of abundance from early farming years The intensity of NE winters in the past	What are some negative or positive experiences that you have had in your time as a farmer in regards to the weather? What effect did they have on your ability to farm successfully? What would you say is the most significant thing you have learned as a farmer?
Lessons from other places	Technologies, products, names, and ideas relating to conservation and environmental stewardship passed through communication networks	Information via facebook Books written by small farmers for small farmer Exposure to climate change ideas early on Learning from other farmers	What would you say your primary source of information about farming is? Are you utilizing social media and if so how? What are the “go-to” books that you use? What is your primary source for information

			<p>regarding climate change?</p> <p>Do you see or hear about it via social media?</p> <p>Is weather something that you frequently discuss with other farmers?</p>
<p>Learning from animals/insects/disease</p>	<p>Observations of animal foraging strategies, populations, browsing and predation, behaviors that might engender understandings of kinship and reciprocity</p>	<p>Noticing any types of pest, prevalence of one particular species</p> <p>The emergence of new pest/disease that threatens crops</p> <p>Predictions for increased/pest disease</p>	<p>In the time that you have been farming have you noticed the prevalence of any new pests and or trends of existing pests becoming more prevalent? This can be an insect, bird, or a different animal.</p> <p>Which pests in particular?</p> <p>How have these pests affected your ability to farm successfully?</p> <p>In the time that you have been farming are there any diseases, such as tomato blight, that you have seen an increase of, and or any new diseases that have been affecting your ability to farm</p>

			successfully.
Monitoring – Building on Experiences and Expectations	Routine observations of seasonal changes and plant and animal life cycles, bringing recognition of expected patterns and ability to detect variation from the norm	Changes in growing season Precipitation changes Temperature changes Extreme weather events	Have you noticed any changes in the length of your growing season? Have you noticed changes in precipitation and temperature? What, if any, extreme weather events have you experienced and how have they affected your ability to successfully farm? How do you monitor or record any of the above changes in weather?
Observing Ecosystem Cycles and Disturbance Events	Relative abundance, diversity, and productivity of plants and animals in particular circumstances, both spatial and temporal, guiding peoples’ land and resource management strategies	The ability to produce the same yield as easily as previous years Knowing the best times to plant/harvest how that may have changed	Have you found it easy to produce the desired yield a from a crop on a yearly basis using similar practices year to year? What helps you make your decision regarding the right time to plant and the right time to harvest? Are there any “wild” indicators in the flora/fauna surrounding your

			farm?
Trial and Error Experimentation and Incremental Modification	Observing the results—both positive and negative, intentional or incidental, short and long-term—of people’s activities	<p>Changing methods based on what they want to grow</p> <p>Adaptations they have been using for many years as a way to be resilient</p> <p>Rotation of crops, what works best</p> <p>Where to grow certain things</p>	<p>Since you began farming what adaptations have you had to make, if any, to your farming practices due to the climate?</p> <p>In the last five years have you had to make any significant modification to your practices in order to continue farming and produce a yield?</p> <p>Have you had any difficulties determining the best management practice for certain crops?</p> <p>Has it become more difficult in the past 5-10 years?</p>
Learning by Association, Extension, and Extrapolation	Applying observations and knowledge— positive or negative— from one place, time, or context, to another (e.g., a different field, crop, season, or community)	<p>Knowing what works well for one crop and applying it to others</p> <p>What association they belong to</p> <p>Using other local farmers’</p>	<p>If a certain practice is working well for a particular crop are you likely to try to apply it to another crop?</p> <p>Do you belong to any associations or coalitions of farmers?</p>

		knowledge	<p>What does being a member of that group do for you? Provide information, support, etc?</p> <p>Do you rely on other local farmers for knowledge and support?</p>
Elaborating and Building Sophistication	Combining the lessons and understandings gained from all of these pathways, and building up knowledge, practices, and beliefs into complex systems of land and resource management	<p>Are their “adaptations” just normal practice, as they have begun their farming during this climate change era/period</p> <p>What have they been doing to adapt to the climate long term</p> <p>What will they have to do in the future to further adapt</p>	<p>What future do you see for your farm considering the current and predicted climate change?</p> <p>Do you see yourself having to (or continuing to) make significant changes in practice in order to compensate for change in climate?</p> <p>Would you describe your farm as resilient to climate change?</p> <p>Would you describe your farm as diversified?</p>

John F Morton (2007) Framework for Small-Scale Agricultural Adaptation to Climate Change

Mechanism	Example from Text	Interview Questions
Complexity and Location Specificity	Relative importance of a crop	What is your most important crop?

	<p>Use of wild resources</p> <p>Positive/negative trends in specific crops</p>	<p>In which crops, if any, have you been seeing positive or negative growing trends in?</p> <p>Are there any “wild” resources you rely on?</p> <p>Are they abundant or have you seen any diminishing trends?</p>
Non Climate Stressors and Vulnerability	Market access/availability	CSA vs Farmers Market
Biological Processes at Organism and Field Level	<p>Temperature change</p> <p>Changes in irrigation methods/amounts</p> <p>Risk of crop pests and disease</p>	*Same questions in the previous framework*
Environmental and Physical processes	<p>Effect of increased extreme weather events</p> <p>Rainfall</p> <p>Soil Fertility/Water Holding capability</p>	<p>What extreme weather events have you experienced on your farm?</p> <p>What effect did they have?</p> <p>Have you noticed a change in soil fertility or water holding capacity?</p> <p>What changes in rainfall have you noticed and how have they affected your farm?</p>
Nonagricultural Climate Change Impacts	<p>Malaria risk</p> <p>Ability to provide labor</p> <p>How they’re affected by climate change in life, not necessarily related to agriculture</p>	Beyond farming what role does climate change play in your life?

Appendix B: Final Interview Questions in Order

1. What are some negative or positive experiences that you have had in your time as a farmer in regards to the weather?
 - a. What effect did they have on your ability to farm successfully?
2. What extreme weather events have you experienced on your farm?
 - a. What effect did they have?
3. What would you say your primary source of information about farming is?
 - a. Are you utilizing social media and if so how?
 - b. What are the “go-to” books that you use?
4. What is your primary source for information regarding weather changes?
 - a. Do you see or hear about it via social media?
 - b. Is your knowledge of changing weather primarily sourced from your own experience?
 - c. Is it something that you discuss with other farmers?
5. Do you belong to any associations or coalitions of farmers?
 - a. What does being a member of that group do for you? Provide information, support, etc?
6. Do you find there many viable markets for you to sell your product in?
 - a. Do you find difficulty getting into Farmers’ markets?
7. Do you rely on other local farmers for knowledge and support?
 - a. If so, in what way?
8. Have you noticed changes in precipitation and temperature?
9. What changes in rainfall have you noticed and how have they affected your farm?
10. Have you noticed any changes in the length of your growing season?
11. How do you monitor or record any of the above changes in climate?
12. What helps you make your decision regarding the right time to plant and the right time to harvest?
 - a. Are there any “wild” indicators in the flora/fauna surrounding your farm?
13. In the time that you have been farming have you noticed the prevalence of any new pests and or trends of existing pests becoming more prevalent? This can be an insect, bird, or a different animal.

- i. Which pests in particular?
 - ii. How have these pests affected your ability to farm successfully?
14. In the time that you have been farming are there any diseases, such as tomato blight, that you have seen an increase of, and or any new diseases that have been affecting your ability to farm successfully.
15. Have you noticed a change in soil fertility or water holding capacity?
16. Are there any “wild” resources you rely on?
 - a. Are they abundant or have you seen any diminishing trends?
17. What is your most important crop?
18. In which crops, if any, have you been seeing positive or negative growing trends in?
19. Have you found it easy to produce the desired yield a from a crop on a yearly basis using similar practices year to year?
20. Have you had any difficulties determining the best management practice for certain crops?
 - a. Has it become more difficult in the past 5-10 years?
21. If a certain practice is working well for a particular crop are you likely to try to apply it to another crop?
22. Since you began farming what adaptations have you had to make, if any, to your farming practices due to the weather?
 - a. In the last five years have you had to make any significant modification to your practices in order to continue farming and produce a yield?
23. Would you describe your farm as resilient to changes in weather patterns?
24. Would you describe your farm as diversified and if so why?
25. What future do you see for your farm considering the current and predicted weather patterns?
 - a. Do you see yourself having to (or continuing to) make significant changes in practice in order to compensate for change in weather patterns?
26. What would you say is the most significant thing you have learned as a farmer?
27. What worries you as a farmer?

Appendix C: Full IRB Approved Application Package

(KEEP THIS PAGE AS ONE PAGE – DO NOT CHANGE MARGINS/FONTS!!!!!!!!!!)

APPLICATION FOR APPROVAL OF RESEARCH WITH HUMAN SUBJECTS
Protection of Human Subjects Review Board, 418 Corbett Hall, 581-1498

(Type inside gray areas)

PRINCIPAL INVESTIGATOR: Shireen Luick

EMAIL: shireen.luick@maine.edu

TELEPHONE: (207)-778-0347

CO-INVESTIGATOR(S): Julia McGuire, Melissa Ladenheim, Kourtney Collum

FACULTY SPONSOR (Required if PI is a student): Jessica Leahy

TITLE OF PROJECT: Small Maine Farmers’ Perceptions and Adaptations to Climate Change

START DATE: 11/21/2016

PI DEPARTMENT: School of Forest

Resources

MAILING ADDRESS: 241 Nutting Hall, Orono ME 04469

FUNDING AGENCY (if any):

STATUS OF PI: Undergraduate

FACULTY/STAFF/GRADUATE/UNDERGRADUATE: Undergraduate

1. If PI is a student, is this research to be performed:

- | | | | |
|-------------------------------------|---|--------------------------|-------------------------------|
| <input checked="" type="checkbox"/> | for an honors thesis/senior thesis/capstone? | <input type="checkbox"/> | for a master's thesis? |
| <input type="checkbox"/> | for a doctoral dissertation? | <input type="checkbox"/> | for a course project? |
| <input type="checkbox"/> | other (specify) | | |

2. Does this application modify a previously approved project? (Y/N) No . If yes, please give assigned number (if known) of previously approved project:

3. Is an expedited review requested? (Y/N). Yes

Submitting the application indicates the principal investigator’s agreement to abide by the responsibilities outlined in [Section I.E. of the Policies and Procedures for the Protection of Human Subjects](#).

Faculty Sponsors are responsible for oversight of research conducted by their students. The Faculty Sponsor ensures that he/she has read the application and that the conduct of such research will be in accordance with the University of Maine’s Policies and Procedures for the Protection of Human Subjects of Research. **REMINDER:** if the principal investigator is an undergraduate student, the Faculty Sponsor **MUST** submit the application to the IRB.

Email complete application to Gayle Jones (gayle.jones@umit.maine.edu)

FOR IRB USE ONLY Application # Date received Review (F/E):

Expedited Category:

ACTION TAKEN:

- Judged Exempt; category Modifications required? Accepted (date)**
- Approved as submitted. Date of next review: by Degree of Risk:**
- Approved pending modifications. Date of next review: by Degree of Risk:
Modifications accepted (date):**
- Not approved (see attached statement)**
- Judged not research with human subjects**

FINAL APPROVAL TO BEGIN

Date

1. Summary of Proposal

This thesis will focus on small Maine farmers' perceptions, adaptations, and resilience to climate change, comparing those who are considered new farmers by the USDA versus those who have been farming for long periods of their life beyond the USDA new farmer rankings. The research will be qualitative, as all of the data that is collected will be interview based, in order to acquire a better perception of each individual farmer's views on the different ways they may be perceiving and experiencing climate change in Maine. The intention is to interview approximately 10-14 farmers in Maine. The purpose of this research is to provide a look into how climate change is affecting USDA delineated small farmers in Maine, as there is no similar research currently available. The research may be used by small farmers in Maine as well as New England as a way to understand what fellow farmers are experiencing as well as what practices they are utilizing adaptation practices to further enhance their own farming practices.

Climate change is arguably the biggest issue facing the global community and its effects will be and are being felt throughout multiple sectors of human life. The environment we know is changing so therefore understanding how it is going to affect us as individual is important. Farmers were chosen to study because their livelihood revolves around the environment and the health of that environment. Using Turner and Berkes (2006) Ecological Understanding Model, small Maine farmers will be interviewed to gain an understanding of the changes in climate they have already experienced, as well as those being experienced currently. To supplement the Ecological Understanding Model framework I will also use Morton's (2007) framework in order to highlight things such as non-climate stressors and trends. In order to compare the information provided in the interview with climate data and changes in Maine, I will rely on the *Maine's Climate Future: 2015 Update* (Fernandez, et al. 2015).

Hypotheses

I hypothesize that both the USDA delineated new farmers as well as the experienced farmers will have strong perceptions of the changing climate as it directly affects their ability to maintain their livelihood. There may be differences in where the farmers source their information, whether that be from other farmers, books, or online. The more experienced farmers are hypothesized to have actual memory and experience in regards to how the climate has changed in Maine in their time farming, while those younger farmers may not realize that what is being experienced now is indeed very different from the climate over the past few decades. While conducting the interviews I will be using the word “weather” as opposed to saying climate change in order to see which farmers bring it up on their own, without me prompting them to do so by including it in the body of the question.

Methods

Interviews and informal conversations will allow for a qualitative analysis of the various factors surrounding small farmers in Maine in relation to climate change. The interview will allow for farmers to answer in their own words, about issues specific to themselves and their farm, while having answers fall into designated scales of understanding and categories.

Potential participants will be contacted via mail, email and phone calls that they are invited to participate in the study (See Appendix I for Invitation Text and 3. Participant Recruitment for method). Multiple notification methods are necessary due to the diversity of participants based on the assumption that they do not all have reliable access to the same technology. If they agree to participate in the study they will be to contacted Shireen Luick to set up the best time for an interview.

All interviews will be conducted in person. The interviews will be recorded and transcribed, with consent. All electronic copies of the data will be kept on password-protected computers to which only the investigators will have access. Data will be retained for ten years for the purpose of future research. The Researcher will explain and

provide a consent form to all interview participants on the day of the interview as well as provide the forms as an attachment to the invitation email (Appendix II for Informed Consent). There will also be a demographic survey given to participants once the interview is completed (See Appendix III for Demographic Survey).

Transcription will be done by the researcher. Confidentiality of participants will be maintained throughout the process. Participants' names will be replaced with a number at the point of transcription to protect identities, the key for which will be password protected and stored in 101 Winslow Hall. All records from the study, including the informed consent forms, will be stored in a secure location in 101 Winslow Hall in the office of the faculty advisor.

2. Personnel

Principal Investigator

Shireen Luick, Undergraduate student in the Ecology and Environmental Sciences Program and the Honors College.

Faculty Sponsor

Jessica Leahy, PhD, Interim Assoc. Dean for Research & Assoc. Director, College of Natural Sciences, Forestry, and Agriculture, Maine Agricultural and Forest Experiment Station, phone (207) 581-3228, mail: 5782 Winslow Hall, Room 101, University of Maine, Orono, ME 04469, or e-mail: jessica.leahy@maine.edu

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Kourtney Collum, Ph.D., Partridge Chair in Food and Sustainable Agriculture Systems, phone (207)-801-5732, mail: 105 Eden St, College of the Atlantic, Bar Harbor, ME 04609, or e-mail: kcollum@coa.edu

3. Participant Recruitment

Potential participants will all be at least 18 years of age and be involved in the network of small farmers in Maine selling at local farmers markets. Potential participants will be recruited from local farmers markets in Western Maine. There is a list of organic farmers in Maine, I have contacts in UMaine Cooperative Extension who will be helping in the farmer recruitment, as well as personal contacts from previous interaction with Maine Farmers' markets. The invitation text can work for a variety of contacts such as in-person, email, and phone.

Because of the process used in this research proposal, it is unknown at this point how many interviews, and surveys will be conducted. We anticipate 10-14 smaller farmers, 5-7 newer small farmers and 5-7 from more experienced small farmers. (See Appendix I for professional invitation letter).

Part I: Interviews

Participants will receive an interview request via in-person, phone, mail or email. I will explain the purpose of the study and ask individuals if they wish to participate in the interview (See Appendix IV for interview questions). Participation in the interview is voluntary. Interviews will be recorded.

Part II: Survey

Following each interview, participants will be given a short demographic survey (See Appendix III for survey questions). The purpose of this survey is to acquire statistics to supplement the findings from the interviews.

4. Informed Consent

All invited participants will have the choice whether or not to participate in the interviews and demographic survey. The informed consent form will be emailed to the participants, and it will be available to participants as a hard copy the day of the interview. An informed consent form for the interview and survey is attached as Appendix II.

5. Confidentiality

Any and all information will be completely confidential. No identifying information will be published. For the transcripts, a hardcopy key linking the participant name and code will be kept in Jessica Leahy's locked office. Transcripts will be entered into the computer, encrypted, and hard copies will be destroyed. For interviews, electronic audio files and interview transcripts will be kept on an external hard drive in a locked drawer in the faculty sponsor's office. Electronic files and transcripts of the interviews will kept up to ten years until November 2026 by Luick and Leahy, as it will contribute to her long term research studying small producers in this region, after which time they will be destroyed.

6. Risks to Participants

Risks are no greater than everyday living. Except for time and inconvenience, there are no foreseeable risks to participants in participating in this study.

Informants will be informed that participation is voluntary and they can refuse to answer any or all questions.

7. Benefits.

There are no direct benefits but this research will help us progress future research in understanding farmer adaptation to climate change. There may be possible policy implications as well. This research will help to ensure that concerns and limitations within small Maine farmer community are better understood. Furthermore, the project

will highlight the importance of small farmer knowledge in a social and ecological system that will contribute to future research in the study of climate change and agriculture.

8. Compensation

There will be no compensation available.

References

Turner, N. J., & Berkes, F. (2006). Coming to Understanding: Developing Conservation through Incremental Learning in the Pacific Northwest. *Human Ecology*, 34(4), 495-513. doi:10.1007/s10745-006-9042-0

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Fernandez, I.J., C.V. Schmitt, S.D. Birkel, E. Stancioff, A.J. Pershing, J.T. Kelley, J.A. Runge, G.L. Jacobson, and P.A. Mayewski. 2015. Maine's Climate Future: 2015 Update. Orono, ME: University of Maine. 24pp.

Appendix I

Invitation Letter

Dear (Name of Farmer)

My name is Shireen Luick and I am an undergraduate student at the University of Maine. My research focus is the perceptions and adaptations to weather by small farmers in Maine. I am writing to request your assistance in a confidential research study where I hope to visit a sample of small Maine farms and interview farmers. I acquired your name and contact information via the UMaine Cooperative Extension and from public listings of organic farmers in Maine. These upcoming visits to farms will help me to understand first-hand the opportunities and challenges being experienced due to weather on small Maine farms.

The interview will take approximately one hour, and it would be preferable to speak to those involved in the day-to-day operation. If you agree to be interviewed, it can take place wherever convenient. If possible, it would be a benefit to this research if it could be conducted on-farm. The interview will be recorded.

If you would like to participate or if you have any questions, please

- 1) contact me at shireen.luick@maine.edu or at (207) 491-3920,
- 2) or my faculty advisor Jessica Leahy at jessica.leahy@maine.edu or at (207)581-3228

Participation in this study is voluntary and you must be at least 18 years old to participate. This study has been approved by the University of Maine Protection of Human Subjects Review Board.

Sincerely,

Shireen Luick
Undergraduate Honors Student
University of Maine, Orono
Ecology and Environmental Science

Appendix II

INFORMED CONSENT

You are invited to participate in a research project being carried out by Shireen Luick, an undergraduate honors student at the University of Maine, Orono in the Ecology and Environmental Science Program. The faculty sponsor for this research is Jessica Leahy. You must be at least 18 years of age to participate. The purpose of the study is to understand farmers' perceptions and adaptations to changing weather in Maine.

What Will You Be Asked To Do:

If you agree to be interviewed, the interviewer will ask you questions about your experiences with weather in Maine. Here are a few sample questions:

What new pests or trends in pests have you seen emerge?

Have you noticed a change in growing seasons?

What adaptations have you made due to changing weather patterns?

Following the interview, there will be a short demographic survey to complete. The interview will be recorded and will take approximately one hour.

Risks

Risks in participation are no greater than everyday living. Except for your time and inconvenience, there are no foreseeable risks to you in participating in this study.

Benefits

No direct benefit to you but this research will help us progress future research in systems knowledge and possible policy implications. This research will help to ensure that concerns and limitations with changing weather patterns are better understood. Furthermore, the project will likely benefit small farmers and professionals working to address their needs.

Confidentiality

We will keep the interview completely confidential. Only our research team will have access to the interview. No identifying information will be published. The researchers will not tell anyone that we have talked to you and your name will never be connected to your responses. The electronic audio files and typed interview transcripts will be kept in a locked drawer in the faculty advisor's office. Electronic files and transcripts of the interviews will be kept until November 2026

by our research team, as it will contribute to her long term research studying small farmers in this region, and after the ten year period they will be destroyed.

Voluntary

Your participation is completely voluntary and you are free to withdraw at any point. You are always free skip any question or to end the interview altogether. If you would prefer not to be recorded, but would like to participate, that is also an option. Should you decide to withdraw after taping has begun, the tape will be erased of any recorded material pertaining to you.

Contact Information

If you have any questions, comments, or concerns about the study, please contact Shireen via: phone: (207) 491-3920; or e-mail: shireen.luick@maine.edu. You may also reach the faculty advisor, Jessica Leahy, via: phone (207)581-3228, mail: 5782 Winslow Hall, Room 101, University of Maine, Orono, ME 04469, or e-mail: jessica.leahy@maine.edu. If you have any questions about your rights as a research participant, please call or write: Gayle Jones, Assistant to the University of Maine's Protection of Human Subjects Review Board, at: (207) 581-1498 or gayle.jones@umit.maine.edu.

Appendix III
Demographic Survey

1. What is your date and place of birth?
2. What is your gender?
3. What county do you live in?
4. How many people live in your household?
5. What is your education level?
6. What is your employment status?
7. How many years have you been farming?
8. What is your total annual income before taxes?
9. Is farming your primary source of income?
10. Are you a member of a farmers' market?

Appendix IV

Interview Questions

1. What are some negative or positive experiences that you have had in your time as a farmer in regards to the weather
 - a. What effect did they have on your ability to farm successfully?
2. What would you say is the most significant thing you have learned as a farmer?
3. What worries you as a farmer?
4. What would you say your primary source of information about farming is?
 - a. Are you utilizing social media and if so how?
 - b. What are the “go-to” books that you use?
5. What is your primary source for information regarding weather changes?
 - a. Do you see or hear about it via social media?
 - b. Is your knowledge of changing weather primarily sourced from your own experience?
 - c. Is it something that you discuss with other farmers?
6. In the time that you have been farming have you noticed the prevalence of any new pests and or trends of existing pests becoming more prevalent? This can be an insect, bird, or a different animal.
 - a. Which pests in particular?
 - b. How have these pests affected your ability to farm successfully?
7. In the time that you have been farming are there any diseases, such as tomato blight, that you have seen an increase of, and or any new diseases that have been affecting your ability to farm successfully.
8. Have you noticed any changes in the length of your growing season?
9. Have you noticed changes in precipitation and temperature?
10. What, if any, extreme weather events have you experienced and how have they affected your ability to successfully farm?
11. How do you monitor or record any of the above changes in climate?
12. Have you found it easy to produce the desired yield a from a crop on a yearly basis using similar practices year to year?
13. What helps you make your decision regarding the right time to plant and the right time to harvest?
 - a. Are there any “wild” indicators in the flora/fauna surrounding your farm?
14. Since you began farming what adaptations have you had to make, if any, to your farming practices due to the weather?
 - a. In the last five years have you had to make any significant modification to your practices in order to continue farming and produce a yield?
15. Have you had any difficulties determining the best management practice for certain crops?
 - a. Has it become more difficult in the past 5-10 years?
16. If a certain practice is working well for a particular crop are you likely to try to apply it to another crop?
17. Do you belong to any associations or coalitions of farmers?

- a. What does being a member of that group do for you? Provide information, support, etc?
- 18. Do you rely on other local farmers for knowledge and support?
 - a. If so, in what way?
- 19. What future do you see for your farm considering the current and predicted weather patterns?
 - a. Do you see yourself having to (or continuing to) make significant changes in practice in order to compensate for change in weather patterns?
- 20. Would you describe your farm as resilient to changes in weather patterns?
- 21. Would you describe your farm as diversified and if so why?
- 22. What is your most important crop?
- 23. In which crops, if any, have you been seeing positive or negative growing trends in?
- 24. Are there any “wild” resources you rely on?
 - a. Are they abundant or have you seen any diminishing trends?
- 25. What extreme weather events have you experienced on your farm?
 - a. What effect did they have?
- 26. Have you noticed a change in soil fertility or water holding capacity?
- 27. What changes in rainfall have you noticed and how have they affected your farm?
- 28. Beyond farming what role does weather play in your life?
- 29. Are there many viable markets for you to sell your product in?
 - a. Do you find difficulty getting into Farmers’ markets?

Appendix D: Example Coding Sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Perceived Result	Perceived Result	Perceived Result	Perceived Result	Perceived Result	Perceived Result	Perceived Result	Perceived Result	Perceived Result	Adaptation	Adaptation	Adaptation	Adaptation	Adaptation
1	80	0								A				
2	81													
3	82	0												
4	83		0								A A		(A)	
5	84		1											
6	85			1										
7	86				0									
8	87				2									
9	88													
10	89													
11														
12		0=negative 1=positive 2=neither positive/negative, respondent did not infer either								Adaptation color coded with result that is causing that adaptation			(A) = adaptation that doesn't connect directly with a result, just something they're doing as an adaptation to either erratic precipitation or warming temp in general	
13														
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“Read Me” Sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
		Drought/ Lack of Moisture	Need for irrigation system	Need for drainage	Variability (per season)	Too much moisture	Reduced Yield	Enhanced Weed Growth	Disease due to moisture		Raised Beds	Crop/Bed Location	Sharing knowledge with other farmers	Dry Farming	Mulching	Establishing Irrigation	Soil Mulching/differe nt from normal mulching	Managing Soil comp. for drainage	Managing Soil comp. for retention	Letting Crops go	Variety of Crops	Farming on a learning curve
1	80	0	0	0	0	0	0	0	1			A	A	AA	AAA			(A) A	AA	AA	AA	A
2	81	0	0	0	0	0	0	0	0			(A) A		A				A	A	A	A	A
3	82	0.2			0.02	0.02	2.0	2.00	0.0			A		A				AA	A	A	AA	A
4	83	0.0	0.0			2.00	2.0		0.0			(A)		A				A	A	AA	AA	AA
5	84	1			0	2	0	0	0			(A)		A				A	A	AA	AA	AA
6	85	1.1	2	2	0.00	0.0	0	0.00	0			(A) A		A				A	A	(A)	A	A
7	86	2			0	0.00			0			(A) A		A				A	A	(A) A	(A) A	(A) A
8	87	0	2	2	0.1				0			AA		A				A	A	A	A	(A)
9	88	1	2	2	2.20				0			AA		AA				(A)	(A)	A	A	(A)
10	89	2	0	2		0	0	0	0			AA		A				(A)	(A)	A	A	(A)
11																						
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Example Coding Sheet: Precipitation

AUTHOR BIOGRAPHY

Shireen Luick was born November 8th, 1995 in Honolulu, Hawaii. Since moving to Maine in 2003 her love for the environment and appreciation for local food has grown immensely. After four years at the University of Maine studying Ecology and Environmental Science she feels ready to head out into the world to help educate people about the importance of protecting our environment, and the role local-based food can have as we adapt to the changing climate. This summer she will be living with her sister near Bar Harbor, while working an internship in the Wild Gardens of Acadia. She is excited to live by the ocean for the first time since she was born, and looking forward to the unknown opportunities to come in following months.