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Abstract

Little research has been conducted on how agricultural producers in the northeastern United States conceptualize climate-related risk and how these farmers address risk through on-farm management strategies. Two years following Tropical Storm Irene, our team interviewed 15 farmers in order to investigate their perceptions of climate-related risk and how their decision-making was influenced by these perceptions. Our results show that Vermont farmers are concerned with both ecological and economic risk. Subthemes that emerged included geographic, topographic, and hydrological characteristics of farm sites; stability of land tenure; hydrological erosion; pest and disease pressure; market access; household financial stability; and floods. Farmers in our study believed that these risks are not new but that they are significantly intensified by climate change. Farmer responses were heavily focused on adaptation activities, with discussion of climate change mitigation activities notably absent. Psychological distance construal theory and hyperbolic discounting emerged as well-suited frames to explain why farmers reported adaptation activities but not mitigation strategies. Farmers will probably experience an increasing severity of climate-related impacts in the northeast region; therefore, information about climate-related risks coming from farmers' personal experience should be integrated with forecasting data to help farmers plan effective adaptation strategies.

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Introduction

This paper addresses how agricultural risks are conceptualized in an era of climate change, specifically by farmers in the state of Vermont, in the northeastern United States. In order to do this, we draw from three key concepts that are central to our study: (1) vulnerability, (2) risk, and (3) adaptation. We start by briefly defining these terms within the context of this study.

Adger (2006) wrote that vulnerability is "the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt" (2006, p. 268). It is important to note that theoretical conceptualizations of vulnerability have been applied in many ways to the topic of human relationship to climate change. The degree to which an individual or group is vulnerable to climate change is a function of access to resources and degree of social power, as well as the physical effects of climate change (Mearns and Norton, 2010). A thorough review of this topic is beyond the scope of this study, but a succinct overview of how the term has been used in socioeconomic systems is provided by Fraser et al. (2011). In this study, we use the definition by Adger discussed above, with the added nuance proposed by Mearns and Norton, to examine vulnerability.

Risk is one factor, among many, that influences the success of climate change adaptation activities in agricultural communities (Bartels et al., 2013). For the purpose of this study, we use the definition of risk published by Harwood et al., who writes that risk is "uncertainty that affects an individual's welfare, and is often associated with adversity and loss" (1999, p. iv). While we acknowledge the long-running conversation in the field of economics that addresses the overlap and distinction between risk and uncertainty (LeRoy and Singell, 1987), it is not within the purview of this paper to address this topic in depth. Lastly, adaptation refers to the "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007, p. 869).

With these definitions as starting points, we next review associated conceptual framings that address how risk influences agricultural decision-making as well as informs adoption of practices to reduce vulnerability and support climate change adaptation. Arenas of agricultural risk in which there are many uncertain outcomes include weather and natural disasters, animal diseases and epidemics, price volatility, changing policy environments, inconsistence access to farm inputs, among others. The degree to which these risks factor into farmer decision-making varies, as do the tools farmers use to ameliorate those risks (Pálinkás and Székely, 2008).

How farmers conceptualize and take action to address risks is an important area of investigation. Greiner et al. (2009) argued that understanding how farmers perceive risk is critical in order to design and implement policies and programs that support both improved agricultural management and natural resource conservation. Relevant research on farmer risk perception reveals several important findings, including that there is often a mismatch between perceived and actual risk (Botterill and Mazur, 2004); and, regardless of the accuracy of an individual's risk assessment, risk perception and intention to change behavior does not always lead to actual behavior change (Niles et al., 2016). Menapace et al. (2015) show that belief in climate change and personal experience with crop loss helps to explain why some farmers perceive more risk than others, while Marra et al. (2003) show that risk can serve the dualistic role of both a barrier to the adoption of best management practices *and* a critical component of learning that leads to adoption of new practices. A growing body of scholarship addresses farmer belief or lack of belief in climate change in different geographic regions, such as Scotland (Barnes and Toma, 2012), New Zealand and Australia (Niles, 2014), California (Niles et al., 2013), and the midwestern United States (Loy et al., 2013; Arbuckle et al., 2013). These studies show that, while belief in climate change varies among farmers, most believe that climate change is not a threat to local agriculture (Prokopy et al., 2015).

Despite the advances made by these scholars, this type of research is largely absent in the northeastern United States (Chatrchyan et al., 2015), with the exception of a new study that investigates the perceptions of climate change held by northeastern maple syrup producers (Wharkey et al., 2016). The northeast will likely see climate impacts that differ from those expected for other parts of the United States, i.e., greater increases in average annual precipitation (Tobin et al., 2015). Agriculture in the northeast differs in many ways from other agricultural regions in the United States, i.e., due to its many small-scale farms and a fast-growing population of beginning farmers (National Sustainable Agriculture Coalition, 2014; USDA-ERS, 2016). Our study therefore seeks to address a gap in understanding how farmers in this region conceptualize and address climate change–related risk. Regionally specific studies of these topics are necessary for effective policy and programmatic efforts to increase the use of climate change adaptation activities among farmers.

The research detailed in this paper is part of a larger, transdisciplinary effort to address climate change adaptation on Vermont farms. The Vermont Agricultural Resilience in a Changing Climate Initiative (VAR) was started in 2011 at the University of Vermont (UVM) as a participatory action research effort that encompassed the expertise of a variety of university-based researchers. For a detailed overview of this initiative, see Schattman et al. (2015). Our research approach is narrative, exploratory, and qualitative in nature. We asked 15 farmers in Vermont in a variety of production categories about their risk perceptions specifically related to climate change and its impact on their farms. This was done to better understand how these farmers applied varied types of risk to their specific farming circumstances and business decisions. This type of regional-specific investigation is critical to understanding and supporting the success of farm businesses as the effects of climate change become more pronounced over the course of the current century.

Background

Study site

The state of Vermont is located in the northeast region of the United States. It is a rural state with an increasing percentage of its population living outside of urban areas (USDA-ERS, 2016), and an agricultural tradition dating back to European colonization in the 1700s (Albers, 2002). Contemporary Vermonters are relatively highly educated, more food secure at the household level, and experience less poverty and lower rates of unemployment than average U.S. citizens (see Table 1), although the average per capita income of Vermonters is on par with the national average.

Table 1. Population descriptive statistics for Vermont and the United States (USDA-ERS, 2016)

Population description	Vermont	United States
Population (2014)	626,562	318,857,056
Poverty rate (2010–2014)	12%	15.6%
Average per capital income	$46,428	$46,049
Household level food insecurity (2012–2014 average)	12.6%	14.3%
Education (age 25 and above, 2010–2014)		
No high school	8.4%	13.7%
Completed high school	30.6%	28%
Some college	25.9%	29.1%
Completed college	35.2%	29.3%
Unemployment (2014)	4.1%	6.2%

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Vermont is home to a diversity of agricultural sectors, including dairy, meat, vegetable, and highly diversified operations (USDA-NASS, 2013). The number of farms in the state has slightly increased (from 7,063 farms in 1997 to 7,338 in 2012), with a total acreage in agriculture totaling 1,251,713 acres in 2012. The highest percentage of Vermont farms (31%) are between 10 and 49 acres, with an average farm size of 171 acres (USDA-ERS, 2013). By comparison, the national average farm size is 234 acres (MacDonald et al., 2013). The majority of Vermont farmers work off farm, with 50% of principal farm operators working off-farm at some point during the year, and 39% working off-farm 200 days or more a year. Historically, the majority of Vermont principal operators have reported farming as their primary occupation, though the most recent USDA Census of Agriculture shows that half of Vermont farmers now report a primary occupation other than farming (USDA-NASS, 2012).

The average age of Vermont farmers has steadily increased over the past decade, with the current average being 57 years. However, a significant portion of farmers surveyed in the 2012 agriculture census in Vermont are beginning farmers. Twenty-five percent of farmers in Vermont have been farming between 3–9 years (USDA-NASS, 2012), which is notably higher than the national beginning farmer average of 20% in 2009 (Ahearn, 2011). Between the 2002 and the 2012 USDA censuses alone, Vermont added 1,228 beginning farmers (USDA-NASS, 2012). This is significant in a decade where the number of U.S. farmers who have been in business less than five years is reported to be shrinking (National Sustainable Agriculture Coalition, 2014). Vermont had the largest percentage growth in beginning farmers of any state in the United States between 2007 and 2012 (National Sustainable Agriculture Coalition, 2014).

Climate change in the northeastern United States

Climate change presents nested uncertainties for farmers. In the northeastern United States, the intensity and frequency of heavy downpours is projected to increase in coming decades. This region has already experienced a 71% increase in very heavy precipitation (refering to the heaviest 1% of all daily rain events) since 1958, the largest increase of any region in the United States (Walsh et al., 2014). Flooding, identified as one of the most important climate factors relevant to the northeast (Kunkel et al., 2013), is the result of increasing high water tables in this region, soil saturation, increased base flow in streams (Weider and Boutt, 2010), as well as heavy downpours and extended periods of rainfall. Farms located in flood-prone areas can be negatively impacted by these events in two ways: sediment deposit can render crops unsalable and potentially contaminate the soil, or soil can be removed from farmland by scouring when rivers change course, as occurred in some parts of the region in 2011 during Tropical Storm Irene (Goldstein and Howard, 2013).

While flooding is of great concern in this region, it is not the only climate-related challenge that affects farmers. The impacts of increasing temperatures, humidity, CO_2 levels, and tropospheric ozone are expected to have complex effects on plant, disease and insect interactions in agricultural systems (Fuhrer, 2003). These changes will likely exacerbate familiar challenges: more moisture in the troposphere and soil and an unchanging photoperiod can lead to greater pressure from plant diseases, reducing productivity even as the number of frost-free growing days increase. The interaction of increasing rainfall, increasing temperatures, and greater variability of winter temperatures can also delay plantings in the spring, lead to saturated soils that inhibit plant growth, stress livestock health and productivity, and negatively impact some perennial plantings (Horton et al., 2014; Betts, 2011; Frumhoff et al., 2007; Galford et al., 2014). The number of days per year over 32°C (90°F) is projected to increase by as many as 50 days per year in southern portions of the northeast region by the end of the century (Tobin et al., 2015). While farmers in the northeast are already reporting taking advantage of the increase in growing days (Tobin et al., 2015), it is unclear what impact this will have on agricultural productivity or farmer livelihoods.

Pest-vectored diseases also pose significant risks to farmers. Insect- and arachnid-borne diseases (e.g., Lyme disease, West Nile virus) can lead to potentially serious health consequences (Horton et al., 2014). Farmers are at increased risk for contracting these diseases due to the outdoor nature of their work (Cyre and Johnson, 1998). Over the past century, the northeastern United States has seen an increase of 10 frost-free days annually, and an additional 40–50 days per year are projected for the region by 2099 (Walsh et al., 2014). The impact that these extended warm periods have on plant and animal communities is not completely understood, though some hypothesize that ectotherm species in temperate climates may experience fewer challenges to reproduction and fitness than species in warmer, tropical climates (Deutsch et al., 2008), implying that farmers living in temperate zones, such as the northeastern United States, should expect increasing fitness of some potentially threatening insect and arachnid vector species.

Methods

We conducted semi-structured interviews with 15 Vermont farmers in 2013–2014. While our sampling frame is influenced by participation in the broader VAR initiative, we believe that the findings and analysis from these interviews stand alone as an independent study. In our research, farmers were asked two questions related directly to perceptions of risk: (1) "What does 'risk management' mean to you?" and (2) "What risk management strategies do you use on your farm?" Answers to these questions were probed to further reveal how farmers used risk to make on-farm management decisions (including decisions to use or not to use specific practices). Following these questions, we asked farmers "Have you noticed changes in the climate? If so, how have these changes affected your farm?" The complete interview guide is available in the supplemental material (Text S1, Table S1).

Key contacts in relevant organizations (e.g., land grant, university-based extension services; Natural Resources Conservation Services; the Vermont Vegetable and Berry Growers Association; and the Vermont Grass Farmers Association) were used to identify interview participants. In addition, a survey that targeted farmers in two northern Vermont watersheds, in 2013, asked if respondents were interested in participating in later stages of research for the VAR project, including these interviews. Farmers who indicated in their survey response that they were willing to be contacted were approached to participate in the interviews only if their gross agricultural income was equal to or greater than $10,000 in 2011, and they practiced at least one best management practice (BMP) appropriate for later stages of investigation by researchers on the VAR team: no-till cultivation, cover cropping, storm water runoff management, rotational grazing, and conservation buffers. The producers interviewed included five dairy producers, four vegetable producers, one meat producer, and five highly diversified producers. Highly diversified producers were those that derived significant proportions of gross income from more than two production categories. The demography descriptions of these farms appear in Table 2.

Table 2. Subject demography of farmers interviewed in Vermont in 2013

Interview code	Farm Type	Farm size (leased and owned acres)	Number of years in farming (at current location)	Off farm income in household?	Certified Organic?
1	Diversified: Vegetable, meat	52	10	No	Yes
2	Dairy, meat	330	9	Yes	Yes
3	Vegetable	90	27	No	Yes
4	Diversified: Vegetable, meat, value added, agritourism	100	3.5	Yes	Yes
5	Dairy	38	28	Yes	No
29	Meat	47	30	Yes	No
30	Dairy	900	20	Yes	No
31	Dairy	1100	17	Yes	No
32	Diversified: Vegetable, meat	150	18	No	No
33	Diversified: Vegetable, meat	150	12	No	Yes
34	Vegetable	8	3	No	Yes
35	Diversified: Vegetable, fruit, value added	14	22	Yes	Yes
37	Diversified: Vegetable, meat	178	9	Yes	No
38	Vegetable	44	25	Yes	Yes
39	Dairy, meat	10	1	No	No

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During the interviews, participants reported on which farm management practices they used on their farms and why, and what they perceived to be the risks associated with climate change (both on their farms and more broadly). We specifically asked participants to describe what the term *risk management* meant to them, and what risk management strategies they employed. Interviews lasted between one and one and a half hours and were digitally recorded. The conversations were then transcribed and analyzed using HyperRESEARCH (Researchware Inc., 2013). We did not enter into the interviews with a stated hypothesis, but were informed by grounded theory. Specifically, we followed the inductive approach put forward by Glaser, as described in Reichertz (2007). This approach allows for common themes to emerge during analysis.

Two researchers independently coded the interviews. At several points in the coding process, the researchers compared codebooks, examined examples of coded passages, and identified divergences in interpretations of the text. Early transcripts were returned to and re-coded after the shared codebook had been completed. This double-coder, constant comparison approach to analysis was used to address potential bias of the researchers (Glaser and Strauss, 1967; Glaser, 1992). This approach allowed us to engage in and validate our analysis using axial coding (the disaggregation of core themes, or the process of relating central concepts to each other) to develop a deeper understanding of how farmers perceive risk specifically related to climate change, and how this influences their farm management decisions (Boeije, 2002; Thorne, 2000). A biographical, narrative approach was applied during the analysis of the interviews (Creswell, 2013). This was done by looking for emergent themes related to climate change and on-farm risk and connecting these themes with climate change adaptation approaches, as described by the farmers.

Results

The line of questioning conducted in our interviews led to the emergence of two broad risk themes cited by the majority of participants: ecological and economic. Subthemes that emerged involved how these risks manifested at the farm scale and what practices were used to address them. In addition, several farmers identified farm site selection, insecure land tenure, and flooding as subthemes that spanned both ecological and economic themes. Farmers descriptions of their responses to risks often focused on adaptation strategies, as well as discussion about how decision-making is informed by a balance of vulnerabilities and opportunities associated with different management choices. In the next two sections, we present farmers' themes on both risk and adaptations, including the interweaving of these themes to better show how farmers associate them. In-depth discussions of mitigation approaches were notably absent from the interviews.

Ecological risk

Themes of ecological risks were those typified by pressures not confined by farm boundaries, but which had significant impact on a farm's ability to produce salable agricultural goods. The most notable ecological risk category presented by farmers was the geographical, topographical, and hydrological characteristics of their farms, specifically the proximity to flood-prone areas or the slope and aspect of mountainside locations. These features of farm sites present both challenges and opportunities for farmers. While geographic, topographic, and hydrological site characteristics are one of the most easily discernable aspects of a farm, the interviews showed how farmers were still uncertain about how different features will be impacted by the shocks and stresses of climate change. Additionally, farmers perceived these features as trade-offs to one another. One grower, who at the time of the interview was hoping to relocate her operation out of a floodplain, described the factors she considered as she sought new land:

> Where we are looking we are faced with a choice. We could move onto a mountain and build up topsoil and then worry about erosion, and struggle every year with minimal topsoil, nutrient loss, runoff, cold weather, and investing more in high tunnels. But we would not have to worry about flooding—or we could move to a river valley where we're probably not going to flood as much as we do now. So do we struggle every year and not produce as much, or do we have three or four really good years and run the risk of one devastating year? —Diversified producer

Farmers reported site selection as an adaptation practice farmers used to address geographic, topographic, and hydrological risks. Specifically, farmers discussed strategic land use based on level of vulnerability to perceived climate risks, and reassessment of acreage needs. The availability of suitable production areas was reported as a limiting factor in farmers' ability to perform key production activities in a timely manner, and by extension the ability of the farmer to bring a crop to market. One farmer illustrated how his growing awareness of climate change has influenced where he sites high-value crops, such as salad greens, and how not all areas of his farm are equally suited to production of greens during wet periods. The same grower spoke to the uncertainty he felt regarding early-spring and late-fall production conditions and his reticence to depend upon a growing number of frost-free days:

> With a climate change perspective, what I'm doing now is I'm growing my crops that I need to get in in a timely way on the sandy ground that I have. It's the ground that I can get in onto on a day after two inches of rain. I need just about six or eight hours and I can go in and do my work … I ignore the fact that the springs are getting earlier because you just run into trouble. And the same thing with the fall. I actually feel like the fall is not really helping that things are getting warmer. Because you see what happens, at least for me, is you get this warm dark weather and I just get all this disease and mildew and it's not much better —Diversified producer

Related to strategic site selection, the capacity to purchase land is both a feature of secure land tenure and an additional adaptation approach. One example was reported by a dairy farmer dairy farmer whose business focused on grass production and grazing. This farmer reported how his purchase of extra land allowed him to self-insure against dry periods in which the growth and quality of forage could potentially stall out. Though he reported having more pasture accessible to him now than he would require in a year of normal rainfall, the extra production area has provided critical protection and increased his sense of security. Likewise, a vegetable producer related how acquiring extra land has allowed him to build in longer rotations and increase his use of cover crops. By extension, he now has more soils protected from erosion while he continues to build soil organic matter and biological diversity (through the use of cover crops). His options for the strategic placement of crops have also increased, which helped him avoid some climate change–related problems, such as overly saturated soils and and mounting pest pressure (caused by increasing numbers of generations per season and/or habitat shifts) in recent years.

Insecure land tenure was identified as a factor that had a great deal of influence over farmers' ability to address geographic, topographic, and hydrological vulnerabilities. The greater the investment required to address a site-specific vulnerability, the more the security of land tenure was emphasized by farmers. As one vegetable grower stated: "I have not done anything really to mitigate flooding, and part of the reason for this is that I don't own the property. I'm tied to doing things a certain way financially."

The above responses from farmers with and without secure land tenure show very clearly how economic and ecological risks overlap. Farmers with greater land tenure security (e.g., ownership or long-term lease agreements) had a greater ability to recover the costs of investments from site improvements.

Pest and disease pressures were also noted as an important, broad category of ecological risk. Farmers in this study understood that changing climatic conditions have largely uncertain consequences for ecological communities. Participants often located their farms in the context of greater ecological systems and demonstrated an awareness that shifts in these systems would impact production, though the specifics of how this will unfold was sometimes unclear to them:

> The natural biota, our insects, our trees, and other species. All of these things are dynamic with our farm. Insects in particular. Is [climate change] going to affect the pollinators? Is it going to affect the pests? Are they going to come sooner? Are they going to live year round? Are they going to bring diseases? Will they freeze during the winter? —Diversified producer

Climate-related changes, such as mild winters and longer frost-free periods, influence insect population dynamics (Chen et al., 2011) and by extension agricultural crops (Hatfield et al., 2011). This is especially true for certified organic vegetable producers, for whom chemical control options are limited.

Economic risk

The theme of economic risk pertans to negative impacts on the short- and long-term financial health of the farm business. Four subthemes related to economic risk emerged through the interviews: volatile or unpredictable markets, crop failure, insecure land tenure, and the relationship between climate change adaptation and financial stress. When discussing markets, farmers referenced the ways in which localized markets had served to insulate them from the pressures and relative instability of commodity markets. The state of Vermont includes a definition of local food in state statute: "'local' and 'locally grown,' and any substantially similar term shall mean that the goods being advertised originated within Vermont or 30 miles of the place where they are sold, measured directly, point to point" (State of Vermont, 2007). As one cheese producer stated, focus on local markets is a way for farmers to "decouple from the commodity market." This is an especially important and useful approach for those generating products with high levels of price volatility in commodity markets, such as milk.

A second marketing strategy specifically cited as a way to reduce market-related risk on an annual basis was community-supported agriculture (CSA). In CSA programs, customers (called "members") subscribe to a farm at the beginning of a farm season and agree to receive a selection of products on a predetermined schedule. In this scenario, the members agree to tolerate the risk of crop failure and guarantee financial support of the farm through the subscription period. As one interview participant described:

> You have a consumer base who have agreed to take on some of the risk of farming with you. They understand that they aren't going to get tomatoes every time they want tomatoes. They aren't going to get cucumbers every time they want cucumbers … there is a risk, and they are going to accept it. —Vegetable producer

This is an approach that has been widespread for many years in the northeastern United States. In cases of extreme weather events when a farm's production may be devastated mid-season, it is unclear if CSA members will remain loyal to this model. There is great variation in how CSA farms interact with their membership, and some farms may be able to rely more upon their customers in the event of complete crop loss. The same vegetable producer noted: "Every CSA structures themselves differently, so I think some consumers are more accepting than others depending on the farm and the farmers."

Farmers felt that some types of production and product mixes are more economically vulnerable to climate change than others. One grazer compared his level of risk to that of maple syrup producers, specifically referencing the emerging global demand for maple syrup and the increasingly short window in which Vermont syrup producers are able to collect sap:

> If I were a sugar maker, I'd be stressing a bit. You derive a massive proportion of your income in a very short period of time, and lately they have been tremendous investments made up here in northwestern Vermont. It's just insane what people are putting into the woods … investing hundreds of thousands of dollars into systems. They have one of the most stable markets now that China has discovered maple sugar. The supply is so much less than the demand. The market is incredibly stable, but the production system is incredibly variable, and it's only going to get worse. They have a very short window. I'm glad not to be a sugarer! —Dairy and meat producer

Other producers noted how they have adapted their product mix in response to extreme weather events. One farmer told the story of how, because of flooding associated with Tropical Storm Irene, she and her husband were forced to bring animals to slaughter earlier than they had originally planned. This was largely because they did not have another contingency plan for purchasing extra feed and were not able to graze their animals during a critical period. The unfortunate scenario caused a loss in income in the year of Irene, but also introduced the farmer to a new production and marketing direction:

> We were able to sell the young calves as veal at the price we sold the beef, so it made us realize that humanely raised, pasture-based veal might be an untapped market. —Diversified producer

In a similar vein, farmers reported that certain crops did not perform as well under the conditions of increasing wet periods and with the potential risk of flooding. They reported vulnerable crops to be those that required relatively longer growing periods (such as cabbage or winter squash), or that required significant investments prior to harvest. Farmers' adaptations to this perceived threat varied: one farm reported changing the crop mix to a greater focus on crops that had short growth periods between seeding and harvest, and required relatively low investments prior to the wash-and-pack phase of production. A second farmer reported that she did not have plans to change her product mix but she did express anxiety about the production of high investment crops like tomatoes. Though she believed tomatoes were an important part of her product mix and she was not willing to stop producing them at the point we interviewed her, she also felt frustrated that she did not have the financial resources to start as many successions of tomatoes as she felt may be needed to guarantee a successful planting.

Insecure land tenure also came up as a type of economic risk, especially for properties that require the farmer to make significant financial investments in order to produce salable products. Depending on the situation, some vulnerabilities can be ameliorated with protective leasing agreements. One farmer described how she and her husband have limited the risks they face related to investments made on leased land. She stated:

> One of (leased fields), we had to drill a well and it was really expensive. It turned out to be horrible, but we had written leases. When we knew we had to drill a well, we asked for a longer lease so we would have time to recover our costs. We also added a clause that if they wanted us out of the lease sooner, they would pay us the depreciated value of that investment. —Diversified producer

This producer specifically indicated climate change effects as one reason why a long-term lease may be broken prematurely, and that these types of agreements are important ways for farmers to decrease their degree of vulnerability.

Lastly, there is a relationship between farmers' ability to adapt to climate change and financial stress. Instability in the farm business can lead to financial stress, and both of these things can be exacerbated by climate-related extreme weather events. It is well established that off-farm income (or *pluriactivity*) helps to moderate the financial losses associated with decreased farm earnings (Kinsella et al., 2000), whether those losses are caused by extreme weather events or otherwise. In our study, one farmer without off-farm income associated her household economic vulnerability with annual farm sales, which were in-turn vulnerable to extreme weather events. She stated:

> Farming is so deeply satisfying, but after (Tropical Storm) Irene there were definitely a couple weeks where it was like "well, this is how it stops, this is how it ends." We spruced up our resumes and realized we are totally unemployable except for farming… If Irene-like events become more common, we need to have a plan that does not involve all of our income being dependent on farming." – Diversified producer

While six of our interview participants relied on farming for their entire household income, nine out of the 15 interviewed farmers reported off-farm income earned by either themselves or a spouse or partner. This ameliorated some of the risk of farming, and increased their ability to both recover from extreme weather events and make strategic investments in climate adapations. For example, one farmer transitioned from homestead to commercial production after retiring from another career. His prior career afforded him the financial flexibility to complete site work around his barn, including improvements in manure storage areas and an expansion of a covered sheep pen. By managing water and manure around the barn, the farmer was able to protect his flock from negative health impacts associated with standing in wet, muddy barn yards.

Flooding: Extreme weather of greatest concern in the northeast

As noted previously, the northeastern United States has experienced an increase in precipitation and flooding that outpaces that seen in other regions of the country. Farmers in our study attested to the severity with which these floods have impacted them. Concerns about flooding spanned the themes of ecological and economic risk; and producers of vegetable and fruit crops were especially sensitive to flooding consequences at the nexus of food safety regulations, crop loss, soil degradation, and increasing numbers of regulations around food production.

In the case of Tropical Storm Irene, several farmers reported significant crop loss caused by both the flood itself and an unfortunate lack of clarity in the weeks following the flood regarding regulations about selling produce that had been touched by floodwater. While rules were eventually released that prohibited the sale of crops contaminated by floodwater, the delayed release of those rules left many growers in a position of great uncertainty as to how much of their production was an economic loss. This was especially true for winter storage crops (e.g., carrots), including those that appeared to be undamaged after the recession of floodwater from the fields. As one producer stated:

> All of our crops survived Irene, but we couldn't sell any of them because of the USDA declaration … some people thought it was better safe than sorry; some people thought it was really stupid and we should be able to sell whatever we want, torpedoes be damned. I think there is a sound policy in between the two. —Diversified producer

While the farmers in our study were clear that they did not want to take risks that could lead to illness, they were unconvinced that the rules prohibiting flood-contaminated produce were based on sound research. Another farmer reported:

> The regulatory element is challenging because everybody really wants to provide a wholesome, safe, food supply … but I was digging into the data after Irene, and other people were also trying to figure out what the risks were. What are the rules? It became clear that there was not a lot of data for a lot of crops, and there was almost nothing from this bioregion, and very little about flooding specifically … there are a lot of unanswered scientific questions. The prohibitions on things right now are [created] with a risk management perspective, which is really different than saying we have this many lab studies and this many field surveys of flooded produce. —Vegetable producer

Like food safety, hydrologic erosion was identified as a subtheme directly related to flooding. Farmers reported feeling anxiety regarding how flooding can potentially deposit undesired materials (silt or upstream waste) or scour farmland and remove topsoil. There was no clear consensus among interview participants when it came to which management approaches would be most effective at reducing these risks, though interview participants were forthcoming with the individual strategies they have tried. One pair of livestock farmers related that they have chosen to continue to graze animals who can walk off of a floodplain in the most vulnerable areas. These farmers use river flood stage projections that forecast seven-day periods (provided online by the National Oceanic and Atmospheric Association) to judge when to remove mobile animals off of these floodplain pastures. Livestock that are more difficult to move (e.g. young animals, poultry) are kept on high ground during times when flooding is probable.

There was general agreement that annual vegetable and crop production is the riskiest type of production system to locate on floodplains because of potential hydrological erosion or fluvial deposits. Opinions diverged when farmers addressed how perennial crops should be used in these areas. While some farmers have decided not to invest in such perennials as rhubarb, asparagus, and blueberries in areas likely to be flooded, other interview participants discussed how some perennial species can tolerate wet root zones, and may be a strategic crop choice for vulnerable sites.

Farmers' tolerance of flood frequency depends on the financial stability of their farms because of the economic ramifications of floods. As one vegetable producer stated: "I think everybody is expecting that we will face an increased risk of flooding relative to what there has been in the twentieth century … I think everybody's expecting that's going to be the case. The question becomes how much we can withstand and what we can do to keep the farm functioning."

Discussion

Perceptions of risks associated with climate change are a critical factor in understanding the likelihood that individuals intend to adopt adaptation activities (Helling et al., 2015; O'Conner et al., 1999) and in strategically supporting farmers and their businesses. Emplacement, which refers to individuals engaging climate change–related information in the context of places that individuals identify with, has been shown to be an important factor in building usable climate-planning knowledge for various publics (Leith and Vanclay, 2015). Our research explored how Vermont farmers conceptualize climate-related risk and what strategies they have used to address these risks. This information can be used as a starting point to develop a more comprehensive understanding of perceptions of and responses to climate change risks by northeastern farmers that would capture a broader range of experiences—research that is largely absent in the northeast region.

The two broad themes of ecological and economic risk identified in this study are similar, though not identical, to those identified in studies from around the world, including Europe (weather and natural disasters, price volatility) (Pálinkás and Székely, 2008), Brazil (climate change, fluctuation of product prices, increase of production costs) (Borges and Machado, 2012), and other regions in the United States (price and yield) (Harwood et al., 1999). Within the broad themes of ecological and economic risk, several important risk subthemes emerged from the interviews: geographic, topographic, and hydrological farm features, insecure land tenure, hydrological erosion, pest and disease pressure, volatile markets, farm financial stability, and floods. Hydrological erosion, pest pressure and disease pressure have been well established in the literature as risks specific to the northeastern United States (Tobin et al., 2015) but land tenure and household financial stability have not been widely discussed.

Farmer experiences of the risks cited above are not exclusive to climate change, though interview participants believed climate change exacerbated preexisting risks. This belief is supported by findings from the Fourth Assessment Report (Schneider et al., 2007) of the Intergovernmental Panel on Climate Change (IPCC). Our interviews elicited how farmers' personal experience with and knowledge of various risks influenced on-farm management decisions. Practices that farmers cited as being useful for controlling climate-related risk included careful site selection, securing access to more land than previously needed, crop selection and timing, protective lease agreements, and incorporation of off-farm income. Notably, these practices are all adaptation practices, with mitigation practices being largely absent from the discussion.

Sociopsychological influences on risk perception

The tendency to discount future risks in favor of attending to more immediate risks is referred to as *hyperbolic discounting*, a concept that has been used to explain why climate change does not cause worry and anxiety to the degree that perhaps it should for individual land managers, and why adaptation activities are easier for farmers to adopt than mitigation activities (Weber, 2006). The phenomenon can be described, in part, through psychological distance construal theory, the premise of which states that future events that impact society at large are perceived as more abstract while near future and highly personal events are more concrete (Trope and Liberman, 2010; Liberman et al., 2007; Trope and Liberman, 2003). In the absence of intervention, individuals are likely to make choices based on the concrete and immediate factors. From this and our interview results, we can infer that farmers are more likely to adopt practices that support adaptation at the farm scale than practices that mitigate climate change in the public sphere.

This is supported by research that compares the relative effectiveness of different types of climate information on motivating adaptation activities: abstract information about general climate change impacts is less effective while locally specific information is more effective (Scannell and Gifford, 2013). The comfort with which different groups conceptualize various time horizons may be a contributing factor to this. It has been argued that the time lines used by climate scientists to describe future changes (e.g., 50- and 100-year forecasts) are too far removed from the experience of nonscientists and not conceptually accessible to most people (Pahl et al., 2014). Because more recent events are given greater weight in our decision-making than more distant ones (Hansen et al., 2004), the conceptual abstractions of the future effects of climate change may lead more farmers toward adaptation-focused activities before mitigation-focused activities.

According to Weber (2006), there are two distinct ways in which risk is expressed in the human experience: risk can either be motivated by emotions stemming from personal experiences (e.g., personal loss due to an extreme storm), or risk can be the product of logical calculation (e.g., learning about the statistical probability of an extreme storm). The former has been shown to be more motivating than the latter, with recent personal experience with climate change–related disasters being highly motivating (Hansen et al., 2004).

Psychological distance construal theory and hyperbolic discounting can help to explain the absence of mitigation strategies reported by our interviewed farmers, and also help us to frame future research questions about the adaptation strategies that were identified. Haden et al. (2012) have established that, in California, voluntary climate change mitigation activities undertaken by farmers are motivated by global (distant) concerns, while adaptation activities are more likely to be motivated by local (proximal) concerns. When viewed through this lens, we can hypothesize that the scale at which we asked interview participants to consider climate change (specifically its impact on their farms) biased their responses toward adaptation practices. Had we questioned them more about the broader implications of climate change on society, perhaps more narrative around mitigation may have surfaced.

Our interview guide was not originally framed with an examination of personal and temporal proximity to a perceived risk as important variables. However, it is clear from the interviews that these farmers dedicate greater resources to climate-related risks with which they have the most personal experience, and that personal experience with weather disasters increases their sense of vulnerability and uncertainty. This is further supported by the differentiation made by Dessai et al. (2004) between external dangers associated with climate change (e.g., usually determined by topical experts, presented as data or modeled information) and internal danger, which is experienced by the individual based on perceptions and/or experiences. Future investigations that look at the degree to which personal experiences and outside sources of information (such as climate forecasting) influence different types of adaptation practices would help identify which practices farmers are more likely to adopt as the effects of climate change increasingly impact the northeastern region.

It is clear that many of the farmers in this study have firsthand experience with extreme weather events. Fourteen of the farmers we interviewed stated that they believe these events to be, at least in part, caused by climate change. Their perceptions of climate risk are informed and shaped by a combination of their personal experiences and external sources. All farmers in our study referenced Tropical Storm Irene, which had significant impact on the state of Vermont in 2011, two years before our interviews were conducted. Though the storm had been downgraded from hurricane status prior to arriving in Vermont, the effects were devastating in many regions of the state (Mears and McKearnan, 2012). Farms interviewed for this research were impacted to varying degrees, though many experienced significant economic losses in 2011. Though our research does not present conclusive evidence of the relationship between the temporal proximity of extreme weather events and farmer adoption of adaptive practices, this is an important topic that should be further explored.

Despite the importance of personal experience as a critical motivator for adoption of climate change adaptation practices, there is a clear problem with overreliance on personal experiences. This is true for two reasons: first, personal experiences may bias farmers toward adaptation practices instead of mitigation. Greater farmer adoption of mitigation practices is needed in order to meet such important greenhouse gas reduction goals as those outlined by USDA Secretary Vilsack in his Building Blocks for Climate Smart Agriculture and Forestry initiative (Vilsack, 2015). Second, the effects of climate change will likely be felt with increasing frequency, variability, and intensity in coming decades (Walsh et al., 2014), making an individual's historical experiences insufficient as guides. Farmers of today have not yet experienced the extremes of climate change expected later in this century (Naess, 2013). However, this should not be a reason to exclude farmer perceptions and experiences in addressing climate change; specifically, climate forecasting endeavors that exclude end users run the risk of quickly become irrelevant (Cash and Borck, 2006). Participatory climate forecasting approaches enable added benefits, such as community-specific dissemination approaches, increased community empowerment and decreased vulnerability through a collaborative process (Roncoli, 2006), and monitoring systems that take into account both climatic and contextual factors (Leclerc et al., 2013). Open lines of communication between farmers, associations and communities of practice, and institutions are needed to collaboratively manage for climate change adaptation and mitigation (Raymond and Robinson, 2013).

The farmer bias toward adaptation activities, in their responses during our interviews, does not imply that climate change mitigation practices are not being utilized or that farmers are opposed to their use. Climate change mitigation is a temporally and socially distant concept, which implies that it often plays second fiddle to adaptation at the farm level. Despite this, we should not be overly discouraged by the tendency in human behavior to discount future climate risks. The temporal decision hypothesis, as presented by Kaplan (2014), states that the order in which we think about different categories of risk influences our ability to make decisions that support positive future outcomes over immediate ones. Focusing on abstract and distant events has been shown to increase the ability of people to make decisions with a greater degree of self-control (Spence et al., 2012). Weber (2006) suggests that the order in which we receive information is important: if we encourage individuals to think about the far-distant future before the immediate future, perhaps more value will be placed on the future. This perspective encourages us to continue pursuit of programs and policies that encourage agricultural activities to mitigate climate change.

Limitations of our study

The qualitative research reported here explored the views of 15 Vermont farmers. We cannot infer whether their perspectives represent a larger population of farmers. Rather, this exploratory research was designed to help generate hypotheses that can be tested with a broader, more representative population of farmers through surveys or other approaches. This is a necessary first step in successful and meaningful mixed-methods research, which is currently needed in this subject area and in this geographic region.

Conclusion

Two years after an extreme weather event (Tropical Storm Irene), this study captured how Vermont agricultural producers conceptualize climate-related risks in both ecological and economic terms, with subthemes of geographic, topographic, and hydrological farm features; insecure land tenure; erosion; pest and disease pressure; volatile markets; household financial stability; and floods. There is great variability in how risks are experienced on farms, but farmers clearly believed that climate change intensifies already existing risks. Personal experiences with recent climate-related events likely has an impact on farmer perception of risk and willingness to adopt adaptive practices. This topic should be investigated with a broader population of farmers in order to better understand the degree to which it is a driving factor for farmer decisions. The increasing severity of climate-related impacts means that we must integrate farmer perceptions, especially those born out of their personal experiences, with projections and broader regional risk assessments. It would be a mistake, however, to rely solely on farmer knowledge of climate change impacts when designing climate change programs and policy, as the worst has not yet been experienced by most farms in the northeast region. Efforts to promote adoption of climate change mitigation activities should take into account psychological conditions that may change the degree to which individuals discount future events. In addition, the temporal relationship between personal experience with extreme weather events and farmer perceptions of risk should be investigated. Lastly, this research provides a point-in-time, report of risk perceptions and associated strategies undertaken by a small number of Vermont farmers. The results would best be put to use to guide future, mixed-methods research that captures the attitudes, intentions, and actions of a broader range of agricultural producers. Futher work that addresses these areas of inquiry are necessary to enhance our understanding of the connections between farmer perceptions of climate risk, land stewardship, and sustainability in agro-ecological systems.

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Contributions

- Contributed to acquisition of data: EM, RS
- Contributed to conception and design: EM, RS, DC
- Contributed to analysis and interpretation of data: RS, DC
- Drafted and/or revised the article: EM, RS, DC
- Approved the final version for submission: EM, DC, RS

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Competing interests

The authors have no competing interests to declare.

Data accessiblity statement

Our complete interview instrument is available as supplementary material to this manuscript.

Supplemental material

- **Text S1. Guide used to interview 15 farmers in Vermont, 2013.**
  doi: 10.12952/journal.elementa.000131.s001
- **Table S1. Climate adaptation practice evaluation table.**
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