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by

Alexander Helling

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ABSTRACT

Changing weather patterns, the declining social fabric of rural communities, and economic uncertainty increasingly pose challenges to Vermont communities. The socially and environmentally embedded production practices within sustainable agriculture present a potential solution to these problems. In order to make the most of the potential benefits of these practices society must maximize their adoption. This requires an understanding of both farmer adoption of these practices and consumer perceptions of the resulting food products. This thesis contributes two original articles on sustainable agriculture through the analysis of factors driving both farmer adoption and consumer perceptions of products and practices often thought of as sustainable.

The first article seeks to understand farmer adoption of climate change best management practices (CCBMPs). Farmer perceptions of risk and profitability of best management practices (BMPs) are key determinants of adoption, which traditional incentive programs like the Environmental Quality Incentives Program (EQIP) attempt to address by providing financial and technical support. To ensure appropriate price points are offered through these programs, regional price structures must be based upon locally established costs. Thus, this article focuses on the economic cost of implementing and maintaining CCBMPs for twelve diverse farms in Vermont. Specifically, three CCBMPs for Vermont are examined: cover cropping, management intensive rotational grazing (MIRG), and riparian buffer strips. Results of a yearlong farmer based data collection process indicate that the average cost for cover cropping is $129.24/acre, for MIRG is $79.82/acre, and for a tree based riparian buffer strip is $807.33/acre. We conclude that existing incentive payments for cover cropping and MIRG are below costs, likely resulting in under-adoption.

The second article reports on a study which seeks to understand the factors influencing Vermont consumer perceptions of raw milk safety. While this article makes no assertion regarding the sustainability of raw milk, an association is established between the motivations for raw milk consumption and sustainable agriculture support. Vermonter’s appear to be continuing the trend of consuming raw milk at an increasing rate despite continued declarations from local and national public health officials that raw milk is too microbiologically dangerous to justify its consumption. Thus this study was designed to increase understanding of the factors driving consumer perceptions of raw milk safety. A conceptual model was developed to establish potential factors and related questions were incorporated into the 2014 Vermonter Poll. Resulting data were analyzed using a Probit regression analysis. We conclude that observable factors have the greatest influence on perceptions of raw milk safety. Specifically, perceived health benefits, presence of children in the household, and taste, all influence perceptions of raw milk safety.
CITATIONS

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CHAPTER 1: COMPREHENSIVE LITERATURE REVIEW

1.1. Changing Rurality

Changing climatic patterns, unraveling social fabrics, and economic uncertainty increasingly pose challenges to global agricultural systems and local rural communities. Communities’ ability to sustain themselves moving further into the 21st century depends upon their ability to acknowledge and adapt to these changes. The concept of sustainable agriculture is increasingly touted as a potential solution to these problems (Food and Agriculture Organization of the United Nations, 2015), and this study seeks to understand the factors that impact perceptions and adoption of practices and products within this agricultural system.

1.1.1. Impacts from Climate Change

In its fifth report of the state of global climate change the Intergovernmental Panel on Climate Change (IPCC, 2007; IPCC, 2014) said that the impacts of climate change are now being felt by natural and human systems across the planet. On the global scale, climate change will increasingly have an impact on biodiversity, hydrology, terrestrial ecosystems, human livelihoods, and food production (IPCC, 2007; IPCC, 2014). Climate change projection models of agriculture in the United States predict both negative and positive impacts in the next 50 years, with direct impacts to agricultural operations resulting from changes to land, water, temperature, atmospheric CO2, and weather patterns (Kurukulasuriya & Rosenthal, 2013). These changes will be accompanied by broader and more complex economic variability and uncertainty in both local and global markets (Malcolm et al., 2012; Rötter & Van de Geijn, 1999; Wheeler & Reynolds, 2013) Furthermore, plant and animal production systems will experience

Vermont will experience global and national variations in CO2 fertilization rates, elevated tropospheric ozone, increased extreme weather events, and generally increased global temperatures (Cure & Acock, 1986). Local areas will also experience regionally specific impacts (Malcolm et al., 2012) such as an increasing length of the growing season and modified pest distributions. Hayhoe et al. (2007) found that the growing season in the northeastern United States will extend by nearly one month by the year 2100 due to an extended frost-free period. A changing climate also enables invasive species to expand their ranges and move into new regions; specifically, kudzu (Pueraria lobata) and privet (Ligustrum sinense; L vulgare) will be able to reach into the New England states by 2100 (Bradley, Wilcove, & Oppenheimer, 2010).

The 2014 report Considering Vermont’s Future in a Changing Climate: The First Vermont Climate Assessment concluded that it is “essential that Vermont agricultural enterprises develop forward-looking adaptation plans,” in response to additional impending climatic changes (Galford et al., 2014).

1.1.2. Impacts from Industrialized Agriculture

Alongside the often subtle changes in weather that communities are experiencing as a result of climate change, rural communities and their surrounding environment have been changing in a more dramatic and noticeable fashion over the past half century. Declining populations, decreased economic activity, little to no job creation, and smaller local tax bases have become increasing common in rural areas over this time period, and the trend threatens to continue (Kirschenmann, Stevenson, Buttel, Lyson, & Duffy,
Furthermore, agriculture and food systems are directly connected, often negatively in modern times, to public health, the environment, and civic life (Tegtmeier & Duffy, 2004). Modern industrialized agriculture contributes greatly to environmental degradation through nutrient runoff that leads to locally contaminated water bodies and ocean dead zones, dominant usage of carbon emitting fossil fuels that contributes to climate change, topsoil loss through soil erosion that destabilizes soil structure and increases local water turbidity, and diminished biodiversity through devotion to monoculture cropping (Horrigan, Lawrence, & Walker, 2002). John Ikerd (1996) notes that civic life in rural areas has decreased with the shift towards an industrial agriculture system, with fewer farm families to support local schools, churches, and other public institutions. Ikerd (1996) said “it takes productive people, not just production, to sustain local communities. The social costs of industrialization continue to grow as rural communities wither and die.” This quote speaks clearly that for rural communities to be sustained and even thrive, there must be consideration of the social fabric and underlying environmental supports upon which rural communities are created from and depend upon.

These social and environmental changes are due in part to the shift in the agricultural base from large numbers of small, family-labor farms to a much smaller number of industrial-model based operations. This shift has been in combination with and as a result of a vastly more globalized society driven by a neoclassical economic system based upon the free market (Lyson, 2004).

One factor within this shift that has caused a decline in rural livelihoods is a decrease in small scale, local economic activity. Larger farms tend to bypass the local
community in purchasing farm inputs and machinery, and are unlikely to sell their products to neighborhood businesses such as the local grain elevator or livestock auction company (Flora & Flora, 2013). These business transactions through distant supply chains have siphoned the necessary economic lifeblood from local businesses, dramatically reducing the ability of smaller, local operations to benefit from economic activity in their area (Kirschenmann, Stevenson, Buttel, Lyson, & Duffy; 2008).

1.2. Alternative and Sustainable Agriculture

Alternative agriculture is essentially, an alternative to the conventional industrialized paradigm of producing agricultural goods through large scale, capital intensive, mechanized techniques that heavily utilize synthetic fertilizers and pesticides. This method has been defined as a broad spectrum of alternative approaches to conventional agriculture such as organic, sustainable, regenerative, ecoagriculture, permaculture, bio-dynamic, agroecology, natural, and low-input techniques (Beus & Dunlap, 1990; Buttel, Gillespie, Janke, Caldwell, & Sarrantonio, 1986). Organic production methods are at the core of any definition of alternative agriculture, but alternative agriculturists’ desire much more than the reduction of synthetic pesticides and fertilizers. Smaller farms, reduced energy use, increased farm and regional self-sufficiency, conservation of natural finite resources, and direct-to-consumer sales are some of the key motivators for a substitute to conventional agriculture (Beus & Dunlap, 1990). Beus and Dunlap (1990) also identify a shift towards more ecologically sustainable agriculture, with restraint, diversity, and harmony with nature, as the core reasons for alternative agriculture. Social structures, such as community and independence, also play an important role.
Similar to alternative agriculture, sustainable agriculture has been defined in a number of ways. One definition is that of an agricultural system of social and environmental values, in which food is produced without depleting nonrenewable resources or polluting the natural environment, and where rural communities are vibrant, lives of all those included in the agricultural system are rich, and the food produced is wholesome (Earles & Williams, 2005). Earles and Williams note that this sustainable agricultural system could include various approaches including family-scale, direct to consumer local markets, organic, low-input, regenerative, and biodynamic methods. These components match closely to those identified within the alternative agricultural paradigm identified by Beus and Dunlap (1990), but with a more narrow perspective. Therefore, for the purposes of this document, sustainable agriculture is a more rigidly defined subset of a broader alternative agricultural system, in which products have environmental and social traits embedded within, through the implementation and use of certain methods such as organic and local production.

Sustainable agriculture has also been defined as "one, that over the long term, enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fibre needs, is economically viable and enhances the quality of life for farmers and society as a whole" (Wilson & Tyrchniewicz, 1995)." This definition of sustainable agriculture shifts and evolves over time, but inherent within the concept is a sustained environmental, social, and economic resource base and thriving population (Earles & Williams, 2005; Wilson & Tyrchniewicz, 1995; Wall & Smit 2005). Distilling the multiple definitions of sustainable agriculture yields a description of healthy food produced with socially, economically, and environmentally sound practices.
1.3. Sustainable Agriculture Adoption

Given the negative impacts of conventional industrialized agriculture on rural communities and the environment, many organizations such as the Food and Agricultural Organization of the United Nations have begun to promote sustainable agriculture (Knowler & Bradshaw, 2007; FAO, 2015). Principle 4 of the FAO’s 2015 guiding principles for sustainable agriculture is “Sustainable agriculture must enhance the resilience of people, communities and ecosystems, especially to climate change and market volatility,” while the third principle notes “Agriculture that fails to protect and improve rural livelihoods and social well-being is unsustainable (FAO, 2015).” Practices that yield environmental and social benefit to farmers, such as increased resilience or social embeddedness are often referred to as best management practices (BMPs). Increasing the adoption of these BMPs is vital to increase the embedded cumulative benefits these practices provide. Therefore, it is important to understand both the various factors that influence perceptions of and decisions to adopt such practices. Additionally, the products that these practices produce must also be considered.

1.4. Practices and Products of Sustainable Agriculture

The task of assessing the adoption of sustainable agriculture practices and products could take many forms given the substantial array of practices employed in agriculture and products. The research reported in this thesis was conducted in Vermont, so relevant practices and products were selected from within the Vermont area. The USDA Census of Agriculture reported that Vermont had 7,338 farms as of 2012, with a combined market value of agricultural products sold of over $776 million on 1,251,713 acres, with the dairy industry accounting for approximately 73% of sales (US Department
of Agriculture, 2012; Vermont Dairy Promotion Council, n.d.). Beyond these sales numbers, the dairy industry brings in $2.2 billion of broader economic activity (Vermont Dairy Promotion Council, n.d.). Furthermore, over 10,500 people are employed through agricultural processes in Vermont (Dunnington, 2010), and over 97% of Vermonters say dairy farms are important to the state (Vermont Dairy Promotion Council, n.d.). Based upon these data, this study focuses upon two topics important to Vermont’s agriculture future: climate change and dairy with a specific focus on raw milk. Factors impacting farmer adoption of climate change best management practices are assessed in the first study, and consumer perceptions of raw milk are assessed in the second.

1.5. Climate Change Best Management Practices

Given the recent storm damage caused by Hurricane Irene in 2011 (Vermont Agency of Natural Resources, 2012), the notable changes to Vermont’s climate (Galford et al., 2014), and the importance of agriculture to Vermont’s economy (US Department of Agriculture, 2012; Dunnington, 2010, Vermont Dairy Promotion Council, n.d.), understanding the practices that may be implemented to mitigate and adapt to climate change are vital.

1.5.1. Responding to Climate Change

Climate change impacts highlight a daunting list of present and future agriculture threats and potential vulnerabilities. Fortunately, research concerning mitigation strategies to address these challenges has increased dramatically over the past several decades with adaptation strategies moving to the forefront. Mitigation strategies for responding to climate change are divided into three categories: reducing emissions of CO2, CH4, and N2O, enhancing removal of atmospheric CO2, and avoiding or
displacing emissions (Smith et al., 2008). A study of converting conventional agricultural to alternative practices found that no-till management reduces CO2 emissions from 168 to 137 kg C ha\(^{-1}\) per year and also increases the levels of soil carbon sequestration (West & Marland, 2002). Additional research shows that sustainable management of soils and water resources, through sustainable practices such as cover cropping and nutrient cycling through use of compost and manure, has the potential to offset annual CO2 emissions by one-fourth to one-third (Lal, 2004). Given that adequate technology exists and that agriculture has such a potential impact on climate change, CCBMPs for climate change mitigation can and should be implemented immediately (Smith et al., 2008, Council for Agricultural Science and Technology, 1992). The potential impact of these actions is huge given that agricultural land accounts for 37% of the Earth’s surface, and agriculture produces 52% of methane and 84% of nitrous oxide emissions globally (Smith et al., 2008).

While mitigation strategies aim to minimize the extent of climate change itself, adaptation strategies are responses or adjustments to the actual effects and impacts of climate change. Smit and Skinner (2002) categorized potential climate change adaptation practices as farm production through modified intensity and product types, land use through crop siting and tillage practices, land topography for manipulating moisture levels, irrigation strategies, and operational timing. The Intergovernmental Panel on Climate Change’s 2014 report on climate change gives similar recommendations with an emphasis on cropland management, grazing land management, and restoration of organic matter in soils (IPCC, 2014). Dunnington (2010) also identifies crop diversity, river management, and research as the ways forward for Vermont’s climate adaptation. These
identified strategies are quite broad in scope and there are abundant BMPs within each category that agricultural can employ in the service of climate mitigation and adaptation.

1.5.2. Best Management Practices

Traditional farm BMPs, those positively tested and proven approaches for farm production and management, are broad in scope and have been shown to result in a wide range of farm improvements such as enhanced soil quality, increased vegetative cover, reduced erosion, cleaner water, increased economic viability, and generally reduced farm risk. These practices also have the potential to address the impacts of climate change (Lal, 2004; Schattman et al., 2015). More specifically, climate change best management practices (CCBMPs) are a set of best management practices seeking to mitigate and adapt to the negative impacts of climate change. Wilson and Tyrchniewicz (1995) state, “sustainable agriculture is thought of in terms of its adaptability and flexibility over time to respond to the demands for food and fiber (both high and low), its demands on natural resources for production, and its ability to protect the soil and the resources.” Milestad and Darnhofer (2003) further describe that the ability to adapt to changes, both expected and unexpected, is integral to resiliency, and that resiliency is prerequisite for sustainability. The ability to adapt to climate change is therefore clearly inherent within sustainable agriculture. Furthermore, Wall and Smit (2005) detail specific sustainable agriculture strategies aimed at managing climatic and weather related risks: diversifying crops, diversifying enterprises within one farming operation, land resource management, water resource management, and livestock management.

The specific best practices for climate change that also serve more traditional farm needs vary from region to region, and must be determined based upon local
characteristics and adaptation measures must be tailored based upon local conditions (Malcom et al., 2012; Smith et al., 2008). Locally relevant CCBMPs in Vermont include cover crops, riparian buffer strips, and MIRG (Schattman et al., 2015). These three CCBMPs constitute the sustainable agricultural practices that will be assessed in the climate change element of this study.

Cover cropping is one of the more common practices in Vermont and provides both traditional BMP benefits as well as additional climate affects. The Vermont Natural Resources Conservation Service (2014) defined cover crops as “crops including close growing grasses, legumes, and forbs for seasonal cover and other conservation purposes.” Cover crops serve to reduce erosion, increase soil organic matter, capture and recycle nutrients in the soil, promote biological nutrient fixation and reduce energy use, increase biodiversity, suppress weeds, manage soil moisture, and minimize and reduce soil compaction (Vermont Natural Resources Conservation Service, 2014; Cornell Cooperative Extension, 2009). Utilizing legume cover crops also reduces reliance on GHG intensive nitrogen fertilizers by fixing nitrogen through the plant’s life cycle (Smith et al., 2008). A study on the economics of cover crop biomass found that including cover crops in cropping systems has both direct and indirect economic costs and benefits that will vary based upon farm operations and characteristics (Morton, Bergtold, & Price, 2006). As with all farming practices, these benefits come with financial, labor, and time costs.

Costs to establish and maintain cover crops include inputs of seeds, and labor of ground preparation, planting, mowing or discing, and incorporation (Solano and Yolo County Resource Conservation Districts, 2006). A Purdue University estimate of cover
crop cost per acre for Indiana in 1982 was $33-$39 per acre, or $79.92 - $94.45 in 2015 dollars (Mannering, Griffith, & Johnson, 2007). A California study estimated the cost at $90 - $170 per acre (Solano and Yolo County Resource Conservation Districts, 2006). Cover cropping costs for larger scale corn and soybean operations tend to fall in the $30-$50 range (North Central SARE, 2014). A study on Vermont farmers’ Willingness-to-Accept (WTA) payments for cover crops found farmers accepted a mean price of $125.16 per acre (Miller, 2014). The Sustainable Agriculture Research & Education (SARE) study (2014) also found that incentive payments can be an important catalyst to cover crop adoption for some farmers, but additional motivation comes from the readily apparent benefits.

Management-intensive rotational grazing (MIRG), planned rotational grazing, or simply rotational grazing, is “any grazing method that utilizes repeating periods of grazing and rest among two or more paddocks or pastures (Hancock & Andrae, 2009).” MIRG has advantages of wasting less forage by the animals leading to increased stocking density, decreased hay requirements, better animal temperament, and heightened farmer awareness of and ability to detect diseases or other problems, improved nutrient distribution, and greater environmental stewardship (Hancock & Andrae, 2009). Intensively managed pastures, based on the intensity, animal numbers, and frequency of their grazing, can also sequester carbon (Bruce et al., 1999). A summary of the research on the social implications of MIRG in Wisconsin found that grazing operations are typically profitable and often provide higher profits per cow than confinement operations (Mariola, Stiles, & Lloyd, 2005). Additionally, a study at the University of Vermont (2007) assessing Northeastern US dairy farmers who utilize rotational grazing reported
higher levels of farming satisfaction, reduced stress, financial progress and improved herd health. The same study also reported that income, land, and labor required were the most common barriers to adoption for farmers.

Economic costs to raise animals through incorporation of MIRG are traditionally calculated as cost per animal to produce milk or meat. This study is specifically interested in the cost per acre of the MIRG practice itself, as the climate benefits from MIRG are conferred on a per acre basis as opposed to per animal. In addition, our study seeks to understand the specific costs associated with implementing and maintaining MIRG as a practice, as opposed to the comprehensive cost for a product. As a result, our MIRG CCBMP findings are divergent from typical enterprise budgets for MIRG production systems. Little research exists which documents either the cost of implementing the practice or farmers’ WTA levels.

A third BMP utilized in Vermont is the buffer strip. A riparian buffer strip, also called vegetative filter strip (Nakao, Brown, & Leeds, n.d.), or riparian forest buffer, is an “area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands (Natural Resources Conservation Service, 1997).” The NRCS contends that these buffer strips help keep sediment, nutrients, agricultural inputs, and other pollutants from entering water bodies and reduce nutrients in shallow subsurface water flows. In addition, they provide food and habitat for wildlife, lower local water temperatures, slow flood flows, reduce erosion, and produce economic timber or wood fiber products. Increasing vegetation in previously degraded areas can also increase carbon storage.

Costs to establish and maintain a conservation, or forest buffer strip vary greatly depending upon size, density, and type of buffer. A 2000 study in Maryland found the
costs range from $218 - $729 per acre (Lynch & Tjaden, 2000), with grass buffers tending to cost less than tree variations. Additionally, a Pennsylvania Department of Environmental Protection riparian forest buffer guide found an even broader range of $385 - $4,723 per acre, including labor, with density of tree plantings being the greater driver of variability (Oerke, 2006). Given these large ranges, local numbers are needed to accurately assess potential costs. A study on farmers WTA levels for buffer strips found a price of $168.33 per acre (Miller, 2014). However, this estimate appears to be centered upon grass based buffer strips, as opposed to tree based.

1.5.3. Farmer Adoption

Resistance to changing farm production practices solely in response to climate impacts may be a roadblock to adoption. One study found only 20% of farmers who experienced climatic variations consciously modified their farm operations (Smit, McNabb, & Smithers, 1996). Wall and Smit (2005) stated that farmers will likely not adopt practices purely due to climate implications, but for other risk management, environmental, and economic reasons. Widespread adoption of CCBMPs will therefore require that they provide traditional risk management, environmental, and economic benefits, in addition to their climate change mitigation and adaptation affects.

Perceptions of these and other CCBMPs and the adoption of best management practices in general are influenced by demographics, environmental awareness and concern, income and wealth, farm characteristics, agricultural extension support, and available information (Baumgart-Getz, Prokopy, & Floress, 2012; Knowler & Bradshaw, 2007). A meta-analysis of farmer best management practices adoption literature found that information, financial, and networking variables were most capable of predicting
best management practice adoption ((Baumgart-Getz, Prokopy, & Floress, 2012; Knowler & Bradshaw, 2007). In Vermont, incentive levels were found to significantly impact farmer decision-making regarding BMPs (Miller, 2014).

Perceptions of risk and profitability are also important to BMP adoption as perceived risk is related to the perceived profitability of a BMP (Cary & Wilkinson, 1997; Marra, Pannell, & Adadi, 2003; Saltiel, Bauder, & Palakovish, 1994). If there is a perceived risk that implementing a best management practice will threaten the viability of a farm, this will typically outweigh the perceived benefits of implementing that practice regardless of environmental awareness and other factors (Marra, Pannell, & Adadi, 2003). Understanding the costs of CCBMPs is necessary given the importance financial considerations play in their adoption, as well as the reality that many farmers have net negative incomes (United States Department of Agriculture Census of Agriculture, 2012). While limited enterprise budgets may exist for farm best management practices and general crop production, they may often be “rule-of-thumbed” by academic experts utilizing average costs and profits, potentially resulting in dangerously misleading estimations of total budgets and unnecessarily increased economic risk (Conner, 2006). As a result, more locally specific studies are needed to determine accurate costs for establishing these practices to ensure revenues cover costs and economic risks can be adequately addressed (Schattman et al., 2015). Dunnington also identifies additional research in Vermont aimed at reducing the cost and risks for farmers in experimenting with new production practices as important for Vermont’s agricultural future (Dunnington, 2010).
Federal programs exist, such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP), that attempt to address these economic barriers to adoption of BMPs, by incentivizing BMPs through financial and technical assistance. While these programs were not designed to include climate change adaptation and mitigation, the practices they promote often yield additional climate benefits. Hypothetically, these programs pay farmers for BMP adoption at the point where a farmer’s willingness to accept (WTA) equals the government or public’s willingness to pay (WTP) (Swinton, Lupi, Robertson, & Hamilton, 2007). WTA and WTP levels vary from farmer to farmer and must be regionally assessed to ensure cost effectiveness for both farmers and the government. WTA levels for CCBMPs in the Northeast have been established at a limited scale, with a recent study finding farmer WTA level of $125.16 for cover cropping and $168.33 for buffer strips (Miller, 2014).

The regional and local variability in CCBMP costs along with the necessity of incentive programs offering accurate and efficient practice payments based upon WTP and WTA levels, resulted in the decision to investigate the economic costs of implementing, maintaining, and removing or incorporating CCBMPs for one season in Vermont. While these results will be narrowly focused upon the economic costs of CCBMPs, they speak to the broader issue of the factors impacting sustainable agriculture practice adoption; primarily that economics play a central role.

The practices within sustainable agriculture provide numerous benefits, as discussed in the preceding paragraphs. Maximizing adoption through effective incentive programs will increase the cumulative public benefits sustainable agriculture provides. However, an equally important consideration within the ability of sustainable agriculture
to positively impact social, environmental, and economic systems, is the consumption of the products created with sustainable agriculture practices. In other words, the benefits created through sustainable agriculture can be increased through the general rise in adoption of those practices, or through the growth in demand for products thought to use sustainable agricultural practices. This study’s second article focuses upon consumer perceptions of a product that many people consume because of perceived sustainable characteristics of its production.

1.6. Raw Milk

Raw milk refers to goat, cow, or sheep’s milk that has not been pasteurized. Raw milk is typically not homogenized and retains the milk fat present upon milking. The production of raw milk has been part of Vermont’s agricultural system for hundreds of years (Rural Vermont, 2014), and a recent survey report states over 53,000 gallons of raw milk from 76 farms was sold from November 1, 2012 through October 31, 2013 amounting to 373,018$ (Rural Vermont, 2014). Rural Vermont’s survey also found that the average price for a gallon of raw cow or goat milk in Vermont was $7 and $10 per gallon, respectively, a significant price premium compared to the average price of pasteurized cow’s milk in January 2014 of just above $3.50 per gallon (US BLS, 2015). The Vermont legislature also recently increased the ability of consumers to obtain raw milk by passing Act No. 149 (S.70) Agriculture; milk and milk products; raw milk; delivery at farmers’ markets. This act allows for the delivery of raw milk to customers at farmers’ markets (Vermont General Assembly, 2014).

The growing interest in raw milk consumption has been linked to the current trend towards more local and natural food consumption (Oliver, Boor, Murphy, & Murinda,
2009; Jay-Russell & Michele, 2010). A desire to support small-scale, local and sustainable farms, perceived increased health benefits, better flavor, and cultivating a relationship with family farmers are all reasons consumers consume raw milk (Leamy, Heiss, and Roche, 2014; Katafiasz & Bartlett, 2012; Bell, 2010; Paxson 2008; Berg, 2008). Berg’s (2008) qualitative research on raw milk consumers also found that perceptions of raw milk incorporated a general critique of conventional mass food production. This broad list of raw milk consumption motivations and perceptions are similar to the environmental and social motivations of sustainable agriculture, clearly placing it within the same realm. Note that no assertion is made here that raw milk is inherently or necessarily a sustainable product or more sustainable than pasteurized milk, it is simply stated that the perception of such exists. It is outside the scope of this report to assess the true sustainability of raw milk. However, the true sustainability of the product is irrelevant for the purposes of this study, as it aims to understand the perceptions of the product as opposed to its inherent characteristics. Understanding perceptions of raw milk, a perceived sustainable product, will inform perceptions of

1.6.1. Perceptions of Raw Milk

This consumption of raw milk in Vermont is a contentious issue given the potential for raw milk to carry foodborne pathogens. Experts from the U.S. Food and Drug Administration (FDA, 2014), American Academy of Pediatrics (Brady et al., 2014), Centers for Disease Control and Prevention (CDC, 2014), and Vermont Department of Health (VT Dept. of Health, 2014) all hold the position that raw milk may be harmful to your health, derived almost exclusively from considerations of microbiological food safety. Specifically, the potential for the presence of disease-causing pathogens such as
E-coli, Salmonella, Campylobacter, and Listeria is of great concern (Claeys et al., 2013). The academic side of the discussion on the safety of consuming raw milk also focuses almost exclusively on these microbiological risks (Oliver, Boor, Murphy, & Murinda, 2009; Claeys et al., 2013).

In contrast to the perceptions of raw milk held by a majority of public health experts and those researching food safety in academia, raw milk advocacy groups say raw milk, produced under sanitary conditions, is both safe to drink and possesses many more health benefits than pasteurized milk (A Campaign for Real milk, 2014). Proponents also argue that raw milk is safe because it “contains many components that kill pathogens and strengthen the immune system” (A Campaign for Real Milk, 2014). While the perceptions and positions of these groups are well documented in academic literature, research concerning those who actually consume raw milk is limited.

Motivations for consuming raw milk vary widely and diverge from the central focus on microbiological safety. Broadly speaking, consumers of unpasteurized food products, such as raw milk, could be called “post-Pasteurians,” those who resist the “hyper hygienic” dream of Pasteurians, and may be concerned with broader issues such as antibiotic resistance, and believe that microbes are not only a part of life but may also enhance life (Paxson, 2008). Such consumers likely support a complex idea of small-scale, labor-intensive, artisanal farming, and may hold a broad critique of mass food production (Berg, 2008). More specifically, the taste of raw milk, perceived increased health benefits over pasteurized milk, cultivated relationships with family farmers, and support for local and sustainable farms appear in the literature as important motivations for consumers of raw milk (Leamy, Heiss, and Roche, 2014; Katafiasz & Bartlett, 2012;
Bell, 2010). Understanding why consumers and experts perceive a product differently is vital to understanding the debate surrounding raw milk. In addition, this understanding informs how the perceptions of raw milk consumers interact with those of public health or academic experts.

1.6.2. Perceptions of Risk

Differing perceptions of a potentially dangerous food product is not uncommon, and risk tends to be a central concept in driving these differences. Literature regarding the quantification of perceived risk has shown that experts and the general public perceive risks differently (Slovic, 1987; Slovic, 1999; Ueland et al., 2012). Risk experts tend to define risk through measures of harm or mortality, while the public tends to define risk through broader measures such as uncertainty, dread, catastrophic potential, controllability, and equity (Slovic, 1999; Ueland et al., 2012). Slovic (1987) further asserts that for the public, connections exist between these various risk characteristics, such as something voluntary being perceived as controllable, or something highly uncontrollable being perceived as a high risk to future generations, and that these connections can manifest themselves in public perceptions of risk. Furthermore, food risk research has shown that food products perceived to be highly beneficial are also perceived to have low risk (Ueland et al., 2012). Differing perceptions of risk are further complicated in that evidence is often not enough to remedy disagreements due to strongly held initial beliefs about a product (Slovic, 1987).

Both sides of the raw milk discussion clearly fit within Slovic’s (1987) conceptual analysis of the differences between experts and the public regarding risk. For this study’s purposes, the food safety of raw milk is the dominant risk being analyzed. Risk, or food
safety, in the eyes of the public is not some simple concept influenced only by directly perceived danger such as the potential for foodborne illness. The degree of perceived risk is influenced by a broad set of factors. This study seeks to understand which of these factors related to raw milk, including production methods, perceived benefits, and demographic variables, interact with perceptions of raw milk safety. For example, consumers may judge raw milk’s risk as reduced because the degree of risk is perceived as controllable, through the proxy of knowing the farmer who produced the raw milk. In order to understand how raw milk aligns with these theories, it was necessary to develop a conceptual model of potential factors that may influence perceptions of raw milk safety.

1.6.3. Factors that May Influence Perceptions of Raw Milk

Because little research exists regarding the broad factors influencing perceptions of raw milk safety, literature concerning raw milk and similar food products, along with logical reasoning were used to determine which factors would be assessed in the raw milk component of this thesis. Existing literature on raw milk consumption motivations often have similarities with studies on motivations for the support of sustainable agriculture. Here, sustainable agriculture is outlined as an agricultural system of social and environmental values, in which food is produced without depleting nonrenewable resources or polluting the natural environment, and where rural communities are vibrant, lives of all those included in the agricultural system are rich, and food produced is wholesome (Earles & Williams, 2005). In other words, sustainable agriculture produces healthy food through environmental and socially embedded production methods. Raw milk is typically perceived as a healthy food by those who consume it, and the
motivations for raw milk consumption of increased social relationships, small-scale production, support for local farms, and broad turn away from conventional production techniques can all be classified as socially or environmentally embedded elements of a sustainable agriculture system. (Leamy, Heiss, & Roche, 2014; Katafiasz & Bartlett, 2012; Bell, 2010; Paxson 2008; Berg, 2008).

No research exists that examines the link between perceptions of sustainable agriculture and raw milk. This topic will be analyzed in this thesis to inform the broader issue of factors influencing raw milk safety perceptions. Given the potential relationship between perceptions of raw milk and sustainable agriculture, research regarding factors influencing perceptions of sustainable agriculture products will be used in determining which factors to investigate in this study.

1.6.4. Conceptual Model

The conceptual model used to inform this paper’s final analysis draws from existing research on perceptions and motivations of raw milk consumption, sustainable agriculture products, raw milk cheese, beef, and risk perception. Local and organic production methods (Tobin, Thomson, & LaBorde, 2012; Berlin, Lockeretz, & Bell, 2009; Nganje, Hughner, & Patterson 2014), humane animal treatment (Harper & Makatouni, 2002), and food supply control (Leamy, Heiss, & Roche, 2014; Katafiasz & Bartlett, 2012; Bell, 2010) are four elements of sustainable agriculture that have been identified in academic literature as impacting perceptions of food safety. These four production traits make up the first four factors in the conceptual model. The fifth and sixth factors, taste and perceived nutritional value, appear frequently in the existing raw milk literature as the strongest motivations for consumption (Bell 2010; Katafiasz 2012;
Trust in information supplied by health officials (Slovic 1999; Katafiasz, 2012) and personal experiences with a food product (Tonsor, Schroeder, & Pennings, 2009) appear in the academic literature concerning raw milk cheese and perceptions of beef safety as influencing consumer perceptions of food safety, and are factors seven and eight. Demographic variables were also selected as potential factors for the conceptual model, including income, education, gender, rurality, age, and the presence of children in the household. Combined, this results in a conceptual model consisting of 14 potential factors influencing perceptions of raw milk safety.

A study on factors impacting food safety risk perceptions of beef was used as the framework within which to categorize the factors within the conceptual model. This past research split factors into five dimensions: reliance on observable attributes, reliance on credence attributes, trust in industry, grocery and government, trust in researchers and consumer groups, and trust in doctors (Tonsor, Schroeder, & Pennings, 2009). Here, potential factors are categorized into credence, observable, and trust-based indicators.

This thesis ultimately seeks to understand some of the numerous factors impacting perceptions and adoption of sustainable agriculture practices and products. Through use of CCBMPs to assess farmer adoption of sustainable agriculture practices, and raw milk to assess consumer perception of a perceived sustainable agriculture product, a narrow window into this topic will be opened.
CHAPTER 2: ECONOMIC ANALYSIS OF CLIMATE CHANGE BEST MANAGEMENT PRACTICES IN VERMONT

2.1. Introduction

In its fifth report of the state of global climate change the Intergovernmental Panel on Climate Change [1,2,3] said that the impacts of climate change are now being felt by natural and human systems across the planet. On the global scale, climate change is having and will increasingly have an impact on biodiversity, hydrology, terrestrial ecosystems, human livelihoods, and food production [1,2,3]. Climate change projection models of agriculture in the United States predict both negative and positive impacts in the next 50 years, with direct impacts to agricultural operations resulting from changes to land, water, temperature, atmospheric CO$_2$, and weather patterns [4]. These changes will be accompanied by broader and more complex economic variability and uncertainty in both local and global markets [5,6,7]. Furthermore, plant and animal production systems will experience variable effects from climate change [8,9,10].

This paper explores climatic impacts within the Northeastern United States, farmer adoption of practices to externally mitigate and internally adapt to these impacts, and costs associated with these practices compared with financial incentive payments through programs like the Environmental Quality Incentives Program (EQIP). This research will inform incentive payment programs from locally derived Best Management Practices (BMPs) costs to increase adoption by the farming community. Research utilizing direct from farmer, daily data collection for Climate Change Best Management Practice (CCBMP) costs in the Northeastern United States has not been conducted previously.
2.1.1. Agricultural Impacts from Climate Change

Climate change will result in a range of impacts for agriculture in the United States. Plants will exhibit variations in growth and yield due to higher temperatures, variable precipitation amounts, intensity, and frequency, and higher concentrations of atmospheric CO$_2$ [9]. Higher temperatures, increases in consecutive dry days, and increases in hot nights have been found to reduce the yield and quality of crops [10]. Changes in precipitation patterns will result in varied consequences based on prior climate variables such as base rainfall amounts and soil characteristics, but more frequent and intense flooding and droughts are both likely [9]. Changes in soil erosion rates will also vary in response to changes in precipitation with areas experiencing significant rainfall increases likely to experience increases in soil erosion, and areas experiencing decreasing rainfall amounts likely to experience either increases or decreases in erosion due to changes in biomass production [11].

Agriculture will also experience changes as a direct consequence of changing CO$_2$ levels. Increases in atmospheric CO$_2$ have been show to typically result in an increase in plant photosynthesis and reduced water transpiration and usage in controlled experiments [12,13]. However, these changes also tend to decrease the longer the plant is exposed to increased levels of CO$_2$ [6,12]. Increased CO$_2$ fertilization effect may provide benefits for growth rates, but interactions with other direct factors such as water availability and nutrient variations may counter some of these increases [13]. In addition, the Third National Climate Assessment in the United States [10] stated that these increases in photosynthesis may be further offset by a reduction in solar radiation from greenhouse gas increases. Increased tropospheric ozone also leads to photosynthesis suppression and
lower yields, further impacting potential yield increases from increased levels of atmospheric CO$_2$ [14]. Some researchers also call into question the CO$_2$ fertilization impact under real world conditions, and further found that the potential benefits from elevated CO$_2$ may not fully offset losses due to climate change [15,16]. However, the CO$_2$ fertilization effect should not be discounted in discussions regarding climate change impacts on agriculture. If agricultural systems were to see increases in crop yields due to rising CO$_2$ levels, there would be local, national, and global implications. This issue should be closely monitored in future CCBMP research for further developments.

Parallel to these plant related climate impacts, animals will experience additional effects. Rötter and Van de Geijn identified four categories in which climate change will impact animal agriculture: 1) livestock feedgrain availability and price; 2) livestock pastures and forage crop production and quality; 3) weather and extreme events on animal health, growth and reproduction and 4) livestock diseases and pests [6]. Specifically, animal heat stress increases with increasing numbers of hotter days and nights, resulting in reduced reproduction and production of not only milk and meat, but eggs as well [6,10,17]. Additionally, while pasture productivity may increase due to a longer growing season and enhanced atmospheric CO$_2$ fertilization effects [18], these increases are likely to be counteracted by decreased pasture productivity from increased weed pressure [19], losses due to heat stress [20], and increased operational costs from global market impacts [7]. Variable warming along with changing rainfall distribution may also modify the distribution of animal diseases that are sensitive to moisture and temperature levels, leading to increases in diseases such as mastitis [21].
These direct plant and animal impacts will also be accompanied by increased economic variability. The results of research regarding the economic impacts on United States and global agriculture from climate change are mixed depending on climate change projection models, inclusion and/or amount of yield changes from CO$_2$ fertilization effects, water usage, and general modelling methods [8]. Adams further concluded that the economic impact on agriculture in the United States would be limited due to the globalized nature of the market based agricultural system. If United States crop production decreases, other countries would likely increase production to fulfill the existing demand hole the loss of United States crops left [8]. In other words, supply would rise in other countries to fill the gap left in the United States production. However, once again some studies [15,16] question the real world benefits of CO$_2$ fertilization, and call into question the results of earlier economic impact studies. Calzadilla [22] found that global food production and GDP will fall as a result of climate change. In the United States, the economic impacts of climate change on agriculture have been projected to likely be negative [23]. Additionally, Malcom [5] found that while impacts could range from estimated increase in net returns of 3.6$ billion to a decrease in 1.5$ billion per year based on different climate change scenarios, the inclusion of the spread and redistribution of pests further reduced net returns by 1.5$ billion to 3.0$ billion. Projected increases in agricultural land use as a response to climate change have also been shown to result in increased negative impacts on environmental resources, including increased nitrogen runoff, soil erosion, and land use conversion [5].

Vermont will experience these global and national variations in CO$_2$ fertilization rates, elevated tropospheric ozone, increased extreme weather events, and generally
increased global temperatures [12]. However, local areas will also experience regionally specific impacts [5] such as an increasing length of the growing season and modified pest distributions. Hayhoe [18] predicted that the growing season in the northeastern United States will extend by nearly one month by the year 2100 due to an extended frost-free period. A changing climate also enables invasive species to expand their ranges and move into new regions; specifically, kudzu (Pueraria lobata) and privet (Ligustrum sinense; L vulgare) will be able to reach into the New England states by 2100 [25].

The local impacts Vermont will experience will be at least partially determined by its specific climatic, geological, and topographic characteristics. Climatically, Vermont has the classification of Continental Moist, and it experiences mild summers with temperatures between 70°F -80°F, rarely exceeding 90°F, but with high humidity. Winters are cold, and precipitation is moderate for all seasons, with growing seasons often experiencing large amount of rain [63]. Vermont’s soil tends to be loamy, formed in glacial till. In addition, most of the landscape is that of sloping hills, with several larger rivers. Crop agriculture has historically been based on the flatter areas nearby these rivers. The sloping hills have historically been grazed with sheep and other livestock [64].

The USDA Census of Agriculture reported that Vermont had 7,338 farms as of 2012, with a combined market value of agricultural products sold of over $776 million on 1,251,713 acres, with the dairy industry accounting for approximately 73% of sales [26]. Furthermore, over 10,500 people are employed in agricultural processes in Vermont [27]. The recent devastation Vermont experienced as a result of Hurricane Irene [28], changing seasonal weather patterns [18], variable future economic conditions [5], changing disease
and pest distributions [6,25], and more frequent and intense flooding [9] demonstrate that
the long term health and viability of this important industry is threatened by a changing
climate. While it is still somewhat unclear if hurricanes are increasing in intensity and
frequency as a result of climate change [61], incidents like Hurricane Irene will likely be
exacerbated by these additional impacts. The 2014 report Considering Vermont’s Future
in a Changing Climate: The First Vermont Climate Assessment concluded that it is
“essential that Vermont agricultural enterprises develop forward-looking adaptation
plans,” in response to additional impending climatic changes [24].

2.1.2. Responding to Climate Change

Climate change impacts such as changing seasonal weather patterns [18], variable
future economic conditions [5], changing disease and pest distributions [6,25], and more
frequent and intense flooding [9] highlight a daunting list of present and future
agriculture threats and potential vulnerabilities. In response to these challenges, various
agricultural practices can be employed that offer both internal and external benefits.
External benefits, or public benefits that occur off-site from the farm, are those that
society broadly experiences as a result of on-farm practice changes. These external
benefits would broadly be associated with climate change mitigation, and would consist
primarily of greenhouse gas emission reductions, but could also include benefits such as
improved water quality. Internal benefits, also thought of as private or on-site benefits,
generally consist of improvements at the farm deploying the practice. In the context of
climate change, internal benefits would most closely be associated with climate
adaptation and could include enhancements in soil quality, reduced nutrient runoff, or
increased environmental or economic resilience.
Fortunately, research concerning mitigation strategies to address climate change has increased dramatically over the past several decades. Mitigation strategies for responding to climate change have been divided into three categories: reducing emissions of CO\(_2\), CH\(_4\), and N\(_2\)O, enhancing removal of atmospheric CO\(_2\), and avoiding or displacing emissions [29]. The potential impact of these actions is huge given that agricultural land accounts for 37% of the Earth’s surface, and agriculture produces 52% of methane and 84% of nitrous oxide emissions globally [29]. In a study based on U.S. crop averages that looked at converting conventional agricultural to alternative practices, it was found that no-till management reduces CO\(_2\) emissions from 168 to 137 kg C ha\(^{-1}\) per year and also increases the levels of soil carbon sequestration [30]. Additional research shows that sustainable management of soils and water resources, through sustainable practices such as cover cropping and nutrient cycling through use of compost and manure, has the potential to offset annual CO\(_2\) emissions by one-fourth to one-third [31]. Given that adequate technology and best management practices already exist, and that specific agricultural practices have such a potential to reduce or sequester greenhouse gas emissions, CCBMPs for climate change mitigation can and should be implemented immediately [29,32].

While mitigation strategies aim to provide external benefits that minimize the extent of climate change itself, adaptation strategies are responses or adjustments to the increased internal risks posed to the farm itself by climate change. Vermont farmers are unlikely to experience any internal benefits from reductions in CO\(_2\) emissions if emission continue to rise from other sources; therefore, it will be necessary to adapt to the forecast changes. Smit [33] categorized potential climate change adaptation practices as farm
production through modified intensity and product types, land use through crop siting and tillage practices, land topography for manipulating moisture levels, irrigation strategies, and operational timing. The Intergovernmental Panel on Climate Change’s 2014 report on climate change gives similar recommendations with an emphasis on cropland management, grazing land management, and restoration of organic matter in soils [1,3]. Dunnington [27] also identifies crop diversity and research as the ways forward for Vermont’s climate adaptation. These identified strategies are clearly quite broad in scope and there are abundant BMPs within each category that agricultural can employ in the service of climate adaptation. These changes will often be incremental modifications to existing production systems, and will not always be sufficient to adapt to the more extreme climate change scenario impacts. Regardless, the adoption of these practices, even in the absence of climate change, is advisable given their other potential benefits.

Traditional farm BMPs, those positively tested and proven approaches for farm production and management, are broad in scope and have been shown to result in a wide range of internal farm improvements such as enhanced soil quality, increased vegetative cover, reduced erosion, cleaner water, increased economic viability, and generally reduced farm risk. These practices also have the potential to help farmers adapt to climate change and reduce atmospheric carbon dioxide levels [31,34]. The best practices for climate change that also serve more traditional farm needs vary from region to region, and must be determined based upon local conditions [29]. Locally relevant CCBMPs in Vermont include cover crops, riparian buffer strips, and management intensive rotational grazing (MIRG) [34]. Following identification of relevant CCBMPs in Vermont, it’s necessary to understand the factors that will influence actual adoption of these practices.
The regional and local variability of CCBMP costs and the necessity of incentive programs offering payments that maximize practice adoption necessitated that this study investigate the following research question: What is the cost to install, maintain, remove and/or incorporate CCBMPs in Vermont over the course of one growing season?

2.2. Selected Literature

A 2012 study by the USDA Economic Research Service [5] reported that many challenges associated with climate change will vary from region to region and adaptation measures must be tailored to local conditions. The necessary changes, such as CCBMPs, utilized in response to these challenges may in fact be the largest concern for United States agriculture moving forward [32].

Resistance to changing farm production practices solely in response to climate impacts may be a roadblock to adoption. One study found only 20% of farmers that experienced climatic variations consciously modified their farm operations [35]. Wall [36] stated that farmers will likely not adopt practices purely due to their climate implications, but for other risk management, environmental, and economic reasons. Widespread adoption of CCBMPs will therefore require that the practices provide not only the internal benefits of climate change risk adaptation, but more traditional economic risk management such as environmental improvements and economic profitability. This paper focuses on three key CCBMPs for Vermont that may provide both mitigation and adaptation benefits: cover cropping, MIRG, and riparian buffer strips.

2.2.1. Cover Crops

Cover cropping is one of the more common practices in use in Vermont and provides both traditional BMP benefits as well as additional internal and external climate
effects. The Vermont Natural Resources Conservation Service [37] defined cover crops as “crops including close growing grasses, legumes, and forbs for seasonal cover and other conservation purposes.” Internal benefits provided to farms that use cover crops include reduced erosion, increased soil organic matter, captured and recycled nutrients in the soil, increased biodiversity, suppressed weeds, managed soil moisture, and minimized and reduced soil compaction [37,38]. Utilizing legume cover crops also promotes biological nutrient fixation that reduced energy use and decreases reliance on greenhouse gas (GhG) intensive nitrogen fertilizers by fixing nitrogen throughout the plant’s life cycle [29]. While the farmer may experience the internal benefits of decreased fuel and nitrogen costs, the public would also receive external benefits through decreased greenhouse gas emission that work to mitigate climate change. Morton’s study [39] on the economics of cover crop biomass found that including cover crops in cropping systems has both direct and indirect economic costs and benefits that will vary based upon farm operations and characteristics. Costs to establish and maintain cover crops include inputs of seeds, and labor of ground preparation, planting, mowing or discing, and incorporation [40].

A Purdue University study estimated a cover crop cost per acre for Indiana in 1982 was $33-$39 per acre, or $79.92 - $94.45 in 2015 dollars [41]. A study in California estimated the cost at $90 - $170 per acre [40]. Cover cropping costs for larger scale corn and soybean operations tend to fall in the $30-$50 range [42]. Variations within the study likely result from differences between farm operations. A study on Vermont farmers’ Willingness-to-Accept (WTA) payments for cover crops found farmers accepted an average of $125.16 per acre [43]. The Sustainable Agriculture Research and Education
(SARE) study [42] also found that incentive payments can be an important catalyst to cover crop adoption for some farmers, but additional motivation comes from the readily apparent benefits.

2.2.2. Management Intensive Rotational Grazing

Management-intensive rotational grazing, planned rotational grazing, or simply rotational grazing, is “any grazing method that utilizes repeating periods of grazing and rest among two or more paddocks or pastures [44].” MIRG has internal advantages of wasting less forage by the animals leading to increased stocking density, decreased hay requirements, better animal temperament, and heightened farmer awareness of and ability to detect diseases or other problems, improved nutrient distribution, and greater environmental stewardship [44]. Intensively managed pastures, based on the intensity, animal numbers, and frequency of their grazing, can also provide external mitigation benefits by sequestering carbon [45]. A summary of the research on the social implications of MIRG in Wisconsin found that grazing operations are typically profitable and often provide higher profits per cow than confinement operations [46]. Additionally, a 2007 project studying Northeastern US dairy farmers that utilize rotational grazing reported higher levels of farming satisfaction, reduced stress, financial progress and improved herd health [47]. The same study also reported that income, land, and labor required were the most common barriers to adoption for farmers.

Economic costs to raise animals through incorporation of MIRG are traditionally calculated as cost per animal to produce milk or meat. This study is specifically interested in the cost per acre of the MIRG practice itself, as the climate benefits from MIRG are conferred on a per acre basis as opposed to per animal. In addition, our study
seeks to understand the specific costs associated with implementing and maintaining MIRG as a practice, as opposed to the comprehensive cost for a product. As a result, our MIRG CCBMP findings are at a different scale from typical enterprise budgets for MIRG production systems. Little research exists that documents either the cost of implementing the practice of MIRG itself or farmers’ WTA levels.

2.2.3. Riparian Buffer Strip

The third BMP we will evaluate is the buffer strip. A Riparian buffer strip, also called vegetative filter strip [48], or riparian forest buffer, is an “area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands [49].” The Natural Resources Conservation Service (NRCS) contends that these buffer strips help keep sediment, nutrients, agricultural inputs, and other pollutants from entering water bodies and reduce nutrients in shallow subsurface water flows. In addition, they provide food and habitat for wildlife, lower local water temperatures, slow flood flows, reduce erosion, and produce economic timber or wood fiber products. Increasing vegetation in previously degraded areas can also increase carbon storage. Generally, these benefits would be experienced by the public as a whole, but the farmer would also likely experience improvements, especially on farm perimeters.

Costs to establish and maintain a conservation, or forest buffer strip vary greatly depending upon size, density, and type of buffer. A 2000 study in Maryland found the costs range from $218 - $729 per acre [50], with grass buffers tending to cost less than tree variations. Additionally, a Pennsylvania Department of Environmental Protection riparian forest buffer guide found an even broader range of $385 - $4,723 per acre, including labor, with density of tree plantings being the greater driver of variability [51].
Given these large ranges, local numbers are needed to accurately assess potential costs. A study on farmers WTA levels for buffer strips found an average of $168.33 per acre [43]. However, this estimate appears to be centered upon grass based buffer strips, as opposed to tree based.

### 2.2.4. Farmer Adoption

Perceptions of MIRG, cover cropping, riparian buffer strips, and other CCBMPs along with the adoption of best management practices in general are influenced by demographics, environmental awareness and concern, income and wealth, farm characteristics, agricultural extension support, and available information [52,53]. Within extension support and information, a 2013-2014 study on the effectiveness of various cover crop educational opportunities found that self-experimentation, local workshops, and internet research were the most effective means of learning about new cover cropping methods [42].

A meta-analysis of farmer best management practices adoption literature found that information, financial, and networking variables were most capable of predicting best management practice adoption [52,53]. In Vermont, incentive levels were found to significantly impact farmer decision-making regarding BMPs [43].

Perceptions of risk and profitability are also important to BMP adoption as perceived risk is related to the perceived profitability of a BMP [54,55,56]. If there is a perceived risk that implementing a best management practice will threaten the viability of a farm, this will typically outweigh the perceived benefits of implementing that practice regardless of environmental awareness and other factors [54]. Understanding the costs of CCBMPs is necessary given the importance financial considerations play in their
adoption, as well as the reality that a majority of farmers have net negative incomes [57,62]. Specifically, the USDA Economic Research Service notes that many farms are not even profitable in the best farm income years, and the projected median farm income is -$1,558 in 2015, relatively unchanged from 2014 when the number was -$1,570 [62]. While limited enterprise budgets may exist for farm best management practices and general crop production, they may often be “rule-of-thumbed” by academic experts utilizing average costs and profits, potentially resulting in dangerously misleading estimations of total budgets and unnecessarily increased economic risk [58]. As a result, more locally specific studies are needed to determine accurate costs for establishing these practices to ensure revenues cover costs and economic risks can be adequately addressed [34]. Dunnington also identifies additional research in Vermont aimed at reducing the cost and risks for farmers in experimenting with new production practices as important for Vermont’ agricultural future [27].

Federal programs exist, such as EQIP and the Conservation Stewardship Program (CSP), that attempt to address these economic barriers to adoption of BMPs, by incentivizing BMPs through financial and technical assistance. While these programs were not designed to include climate change adaptation and mitigation, the practices they promote often provide additional internal and external climate benefits. Hypothetically, these programs pay farmers for BMP adoption at the point where a farmer’s willingness to accept (WTA) equals the government or public’s willingness to pay (WTP) [59]. WTA and WTP levels vary from farmer to farmer and must be regionally assessed to ensure cost effectiveness for both farmers and the government. WTA levels for CCBMPs in the Northeast have been established at a very limited scale, with a recent one year
study finding farmer WTA level of $125.16 per acre for cover cropping and $168.33 per acre for buffer strips [43]. The corresponding WTP levels are demonstrated through the payment levels provided through programs such as EQIP and CSP.

This research will improve regional incentive payment programs, specifically EQIP, by providing more accurate local data to inform payment levels. By comparing costs found in this study to existing EQIP payment levels, we can assess if current payment levels are high enough to properly offset practice costs to a degree that removes the economic risks faced by the farm. WTP levels can then be compared to WTA levels to assess if payment levels are high enough to maximize practice adoption, as adoption should be maximized when WTP equals WTA. In addition, CCBMP cost data will give farmers concrete financial figures to incorporate into risk and profitability calculations, which are vital considerations in practice adoption. The costs established in our study will also be directly supplied to farmers considering implementing these programs, as understanding the establishment and maintenance costs will reduce economic uncertainty moving forward.

The regional and local variability of CCBMP costs and the necessity of incentive programs offering payments that maximize practice adoption necessitated that this study investigate the following research question: What is the cost to install, maintain, remove and/or incorporate CCBMPs in Vermont over the course of one growing season? It should be noted that while this is an economic based study, the cost of CCBMPs discussed here is more of an accounting cost than a pure economic assessment as indirect impacts to farmer yields and profit such as opportunity costs are not considered.
2.3. Methods

This analysis is part of the Vermont Agricultural Resilience in a Changing Climate (VARCC) research initiative, a transdisciplinary and participatory action research based initiative that aims to identify BMPs that will help farmers adapt to the impacts of climate change. The VARCC initiative functions through a diverse team of stakeholders including farmers, agricultural service providers, researchers and community organizations to address the impacts of climate change in Vermont by focusing on evaluating and implementing on-farm climate change mitigation and adaptation practices [34]. The VARCC research initiative was conceptually divided into four phases: 1. Initial investigation including literature review, stratified survey, and key informant interviews, 2. On-farm research concerning social, economic, agroecological, and map elements of the broader research study, 3. Farmer-to-farmer workshops, policy workshops, and farmer-service provider exchanges concerning CCBMP recommendations, and 4. Expansion to the Connecticut River Valley of Vermont replicating phases 1-3.

2.3.1. Farm Selection and Data Collection Process

This study builds upon work done during phase 1 of the VARCC initiative during which the broader research team utilized survey and interview data, as well as experience, professional interest, and the expertise of the principal investigators, to identify twelve farm research participants and establish the CCBMPs of interest [34]. The twelve farms were selected due to their use or intended use of the selected CCBMPs, and included three each of vegetable, dairy, meat, or diversified producers. Nine of the twelve farms were utilizing the identified CCBMPs prior to the start of this study, while the
remaining three were not. This resulted in a clearer picture of the differences in costs to establish vs maintain the different practices. In other words, for nine of the farms, there was no change in practices regarding the utilization of CCBMPs as each farm already had the practices in place, while the 3 other farm were establishing the practices as essentially new operational components, and were as such not transitioning from a more conventional practice to another.

Institutional Review Board approval was obtained prior to engaging farmers for data collection. Sixty minute interviews were conducted with each selected farmer following farmer selection to verify consent to participate and contribute data, general study participation and establish a greater working knowledge of their CCBMP installation, maintenance and/or removal plans. Farmer input, farm enterprise budget literature, and economic theory were used to create custom data collection spreadsheets for each farm. Farmers were requested to utilize these data collection sheets to document daily labor, inputs such as soil amendments or seeds, and fuel costs along with associated activities and equipment used. Additionally, data were focused exclusively on costs of activities, materials and equipment used for the installation, maintenance, incorporation, or removal of assigned CCBMPs. Cost data were split into two categories when applicable: establishment costs, and maintenance costs. This allowed for variation in the farm’s status for each CCBMP, as some farms were in the process of establishing the practices while some were maintaining already established practices. Each farm was requested to track either cover crop, MIRG, or riparian buffer strip costs, and three farms agreed to track multiple CCBMPs.
These data were to be returned to the researchers each month via email or mail based upon farmer preference. Data collection began with the start of each farm’s respective growing season, typically April 1st, 2014, and lasted through the end of each farm’s respective growing season, from October – December 2014. Participating farmers were compensated $50 per hour for their time spent contributing to the data collection. Following completion of the growing season, each farm’s data were aggregated for the entire growing season by farmer labor hours (including planning for the season), employee or other labor hours, farmer tractor hours, employee or other tractor hours, fuel used in gallons and type, equipment purchases, and other purchases such as seeds or lime.

Labor hours were translated to labor costs at a rate of $20/h for farmers, and $12/h for employees or other workers and aggregated. Inputs including fuel at a price of $3.24/gallon for diesel and $2.50/gallon for gasoline, were combined with total labor costs to compute a total CCBMP cost for one year of installation, maintenance, incorporation, and/or removal. Analysis was then done to establish cost per acre for each practice, categorized by producer type. Additional analysis consisted of determining average practice costs across producer categories, adjustments to the data to improve comparability by removing extra equipment costs, and general farm characteristic comparisons.

2.4. Results and Discussion

All twelve participating farms returned data in some form throughout the research period. Seven of the twelve farmers returned data with moderate consistency of at least once every two months, four returned all data at the end of the season, and one returned data twice throughout the season. Eleven of the twelve participating farms returned data
of high enough quality and quantity for analysis, with the twelfth farm lacking enough detail on practice cost breakdowns. This resulted in the underrepresentation of the dairy producer category—two as opposed to the three in each other category—in data analysis.

Data results are reported in Table 1. Total costs were divided between labor, split between the farmer and other which includes employees, friends, and family, and inputs.

Five farms collected data on MIRG of total acreages between 21 and 170 acres. Four of these operations were already established prior to this season, and demonstrate snapshots of one season in already established operations. The fifth farm (Farm 1) recently changed hands, and represents a new operation as a large portion of their early season labor costs consisted of infrastructure, such as perimeter fencing installation. The established costs for the fifth farm are therefore of limited comparability to the first four, but is a useful picture of the year-one establishment costs for a MIRG operation. Table 1 shows that total yearly costs per acre for the MIRG were fairly consistent, ranging between $51.26 to $81.98 for beef cows with an average of $66.61, and cost of $20.20 for sheep. Dairy operations show slightly higher costs of $83.10 and $102.94, averaging $93.02 per acre. The separate establishment cost associated with the new MIRG operation (Farm 1), were $33.37 per acre. In total, Farm 1’s establishment plus maintenance cost was $136.31 per acre. Averaging the maintenance costs for all four beef and cow dairy MIRG operations (Farm 2a), we find an average cost per acre of $79.82. Farm 2 also utilizes subsoiling and cover cropping within their MIRG operation. The costs associated with these practices were separated from the basic MIRG operations, as seen in Table 1. While outside the scope of this study, it should be noted there may also be costs associated with changes in yield when converting from convention confinement.
livestock to MIRG grazing production. These potential increases or decreases in yield would impact farm profitability alongside the associated changes in other capital and variable expenses.

Five farms collected cover cropping data on practice areas between 0.25 and 34 acres. Four of the cover cropping operations were also on established fields, with the fifth representing a new installation from pasture to cover crop (Farm 8). Similar to MIRG, the fifth cover cropping operation is of limited comparability to the other four, but does provide a picture into the establishment costs of a new cover cropping practice. Vegetable cover cropping operations generally ranged from $90.09 to $209.68 per acre yearly for established fields, with the smallest, Farm 10 which consisted of four 1/16 acre plantings, being the most costly at $849.92 per acre.

Farm 9 purchased a grain drill during the season and was the only farm to purchase large equipment necessary for their CCBMP, removing that purchase reduced their maintenance cost per acre to $105.40, comparable to the other established cover crop operations. Farm 7 did not report fuel usage, so the $/acre in Table 1 is comparatively low. Given their tractor usage of 22.25 hours for the season, and an average gallon/h factor of 1.75 for other similar farms, an extra $10.34 per acre is warranted, for a final adjusted cost of $155.60/acre. These adjusted costs are shown in the far right column of Table 1. Additionally, farm 6 tracked cover cropping both on in-production and out-of-production fields, these data are shown separately and combined in Table 1. The newly established cover cropping operation at Farm 8 had a maintenance cost of $269.46 per acre, and an establishment cost of $298.83, and a combined cost of $568.29$ per acre. High establishment costs were driven primarily by a large number of
farmer labor costs associated with establishing a new field, including rock and debris removal, and tractor work. Using the adjusted numbers for Farms 7 and 9, the combined data for Farm 6, and removing the two outliers of Farms 8 and 10, the average cover crop maintenance cost for an established practice was $129.24/acre. Note, that Farms 8 and 10 were identified as outliers because Farm 8 is a newly established practice, and Farm 10’s utilized a different field structure. The 0.25 acres reported on by Farm 10 were the aggregation of crop beds not necessarily in proximity to one another, as opposed to the other farms that reported on larger acreages that combine all crop beds into individual fields.

The final farm, farm 11, collected data on a newly established 1.5 acre riparian, tree-based buffer strip. All work was done by hand, so the number of labor hours was relatively high as opposed to an operation utilizing a tractor. In addition, the farmer reported that all but 2 hours of other labor time was spent on the establishment of the practice. Therefore, the $807.33 per acre per year represents the cost to establish the riparian buffer strip, as opposed to the cost to maintain it.
### Table 1. Annual Climate Change Best Management Practice Costs

<table>
<thead>
<tr>
<th>Farm</th>
<th>Total Labor (Farmer/Other) (hours)</th>
<th>Labor Costs ($)</th>
<th>Input Costs ($)</th>
<th>Total Cost ($)</th>
<th>Area (Acres)</th>
<th>$/Acre</th>
<th>Adjusted $/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm 3</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Farm 1(a)</td>
<td>350.00/33.40</td>
<td>6586.00</td>
<td>3968.16</td>
<td>10554.16</td>
<td>127.00</td>
<td>83.10</td>
<td>83.10</td>
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<tr>
<td>Farm 1(b)</td>
<td>122.00/72.00</td>
<td>3,304.00</td>
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<td>3602.85</td>
<td>35.00</td>
<td>102.94</td>
<td>102.94</td>
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<td>Farm 2a</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm 2b</td>
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<td></td>
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<td>Farm 2c</td>
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</tr>
<tr>
<td>Farm 4</td>
<td>24.50/0.55</td>
<td>623.60</td>
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<tr>
<td>Farm 2a</td>
<td>418.75/175.50</td>
<td>10481.00</td>
<td>23.00/23.00</td>
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<td>170.00</td>
<td>73.73</td>
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<tr>
<td>Farm 2b</td>
<td>446.20/180.50</td>
<td>3602.85</td>
<td>1167.91</td>
<td>10554.16</td>
<td>127.00</td>
<td>83.10</td>
<td>83.10</td>
</tr>
<tr>
<td>Farm 2c</td>
<td>456.70/180.50</td>
<td>13937.14</td>
<td>170.00</td>
<td>81.98</td>
<td>35.00</td>
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### MIRG (Meat Cattle)

<table>
<thead>
<tr>
<th>Farm</th>
<th>Total Labor (Farmer/Other) (hours)</th>
<th>Labor Costs ($)</th>
<th>Input Costs ($)</th>
<th>Total Cost ($)</th>
<th>Area (Acres)</th>
<th>$/Acre</th>
<th>Adjusted $/acre</th>
</tr>
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<tbody>
<tr>
<td>Farm 4</td>
<td></td>
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</tr>
<tr>
<td>Farm 5</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Farm 6a</td>
<td>7.16/38.40</td>
<td>604.00</td>
<td>1377.88</td>
<td>1981.88</td>
<td>22</td>
<td>90.09</td>
<td>90.09</td>
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<tr>
<td>Farm 6b</td>
<td>14.50/23.05</td>
<td>566.60</td>
<td>1760.12</td>
<td>2326.72</td>
<td>12</td>
<td>193.89</td>
<td>193.89</td>
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<tr>
<td>Farm 6c</td>
<td>21.66/61.45</td>
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<td>4308.60</td>
<td>34</td>
<td>126.72</td>
<td>126.72</td>
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<tr>
<td>Farm 9</td>
<td>2.00/15.00</td>
<td>220.00</td>
<td>1589.60</td>
<td>1809.60</td>
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<td>Farm 10</td>
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<td>212.48</td>
<td>0.25</td>
<td>849.92</td>
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</tbody>
</table>

### Cover Crop (Vegetables)

<table>
<thead>
<tr>
<th>Farm</th>
<th>Total Labor (Farmer/Other) (hours)</th>
<th>Labor Costs ($)</th>
<th>Input Costs ($)</th>
<th>Total Cost ($)</th>
<th>Area (Acres)</th>
<th>$/Acre</th>
<th>Adjusted $/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm 7</td>
<td>25.25/22.75</td>
<td>778.00</td>
<td>994.00</td>
<td>1772.00</td>
<td>12.2</td>
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<td>155.60</td>
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<td>Farm 8(a)</td>
<td>47.10/20.00</td>
<td>942.00</td>
<td>499.6</td>
<td>1441.60</td>
<td>5.35</td>
<td>269.46</td>
<td>269.46</td>
</tr>
<tr>
<td>Farm 8(b)</td>
<td>21.25/14.00</td>
<td>593.00</td>
<td>1005.72</td>
<td>1598.72</td>
<td>5.35</td>
<td>298.83</td>
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</tr>
</tbody>
</table>

### Cover Crop (Diversified)

<table>
<thead>
<tr>
<th>Farm</th>
<th>Total Labor (Farmer/Other) (hours)</th>
<th>Labor Costs ($)</th>
<th>Input Costs ($)</th>
<th>Total Cost ($)</th>
<th>Area (Acres)</th>
<th>$/Acre</th>
<th>Adjusted $/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm 11(a)</td>
<td>16.00/26.00</td>
<td>632.00</td>
<td>555.00</td>
<td>1211.00</td>
<td>1.5</td>
<td>807.33</td>
<td>807.33</td>
</tr>
</tbody>
</table>

Notes: Farm 3 Farmer labor is all employees paid at a rate of $15/hr, and other includes work contracted out at a rate of $40/h. Farm 2a does not include cover cropping and subsoiling. Farm 2b includes cover cropping for 4.5 acres of total area, and Farm 2c includes both cover cropping on the 4.5 acres and subsoiling on 1.5 acres of total area. Farm 6a was the portion of the acreage in production for the season, Farm 6b is out of production for the season, and Farm 6c is the aggregation of both. \(\text{\(a\)}\) denotes costs associated with regular maintenance activities for newly established CCBMPs. \(\text{\(b\)}\) denotes costs associated with establishing a new CCBMP.

Generally, farms with already established CCBMPs showed a lower cost of utilizing that CCBMP, whereas new installations displayed higher costs per acre for maintenance after establishment was completed. Furthermore, while not statistically significant due to the small sample size, both cover cropping and MIRG tended to show that larger acreages tended to result in lower costs per acre than smaller acreages, with the possible exception of Farm 4.
The average beef and cow dairy MIRG maintenance cost of $79.82 per acre, sheep MIRG cost of $20.02 per acre, and average cover cropping maintenance cost of $129.24 per acre represent an annual budget of labor, fuel, seed, and other input costs necessary for implementing, maintaining, and removing or incorporating CCBMPs on farms already using those practices. The found average cover cropping cost falls within the numbers found in the literature of $80-$170 per acre, while MIRG costs were unable to be compared due to methodological differences. MIRG for sheep was also shown to be much lower than cow operations, primarily due to the dramatically lower labor costs resulting from less frequent animal rotations and larger paddocks.

The cost to establish a new MIRG practice (Farm 1-$33.37 per acre) cover cropped field (Farm 8-$298.83 per acre), and riparian zone (Farm 11 - $807.33 per acre) demonstrates the logical expectation that establishing a new practice will require addition upfront costs. Furthermore, the first year of maintaining these practices after establishment was shown to be higher than for farms with already established practices. The buffer strip establishment cost also falls within the broad range identified in the literature of $385 - $4,723. Furthermore, for riparian buffer zones there may be relative yield reductions due to a reduction of land in production if previously in-production land is converted to the riparian buffer strip. This cost was not calculated for this study as it does not fit within the explicit cost of maintenance or establishment costs, but would be calculated on a cost per lost acre basis. The farm studied here did not take any land out of production to establish the riparian buffer.
2.4.1. Cost per acre compared to Incentive Program Payments

This study addressed the research question: What is the cost to install, maintain, remove and/or incorporate CCBMPs in Vermont over the course of one growing season? Results show that the average cost for cover cropping for diversified or vegetable operations is $129.24 per acre, MIRG for cow dairy and meat production is $79.82 per acre, and a tree based riparian buffer strip cost $807.33 per acre in Vermont. While these numbers alone are useful financials for farmers calculating their potential profitability for an upcoming growing season, they can also be compared to incentive program payments to determine if adequate payment levels are in place to maximize adoption. This is done by comparing our established costs to government WTP levels. Costs shown to be higher than WTP would indicate payments are not high enough to fully compensate farmers for practice use, increasing farm risk through potentially reduced profits. WTP, costs, and WTA levels can then be compared to determine if farmers will, on average, accept established payment levels from incentive programs.

This study found the average cost of cover cropping to be $129.24 per acre for farms that had been using cover crops in previous seasons. WTP levels, established through assessment of 2015 EQIP payments [59], were $79.45 per acre, and Miller (2014) reported farmer’s WTA was $125.16 per acre. Comparing practice cost to WTP levels, we see that per acre, costs are $49.79 – approximately 40% - higher than WTP levels, indicating payments offered are below the level necessary to maximize farmer adoption by covering practice expenses. Farmer WTA for cover cropping was $45.71 higher than existing WTP as well, but $4.08 higher than costs. The difference between
both the WTA and costs, and WTP levels shows that existing cover cropping payments do not fully cover the costs of implementing the practice.

MIRG costs in this study were found to average $79.82 per acre, while comparable WTP levels are $23.91 per acre. Comparing the two shows that MIRG costs $55.91 – approximately 70% - higher than existing WTP levels. Similar to the cover cropping scenario, existing incentive program (EQIP) payments does not adequately compensate farmers for implementing this practice. No studies were found detailing WTA levels for MIRG, so a comparison between WTP, costs, and WTA was not possible.

Furthermore, establishment costs for a riparian buffer strip were found to be $807.33 per acre. WTP was $763.68, and Miller found WTA to be $168.33 for this practice. The comparison between costs and WTP for this practice indicates a relatively more adequate payment level, with a difference of $43.65 per acre, approximately 5.4% higher. Here, costs and WTP levels are much higher than WTA levels of farmers. This disconnect likely exists due to variations in riparian buffer strip planting and type characteristics, as demonstrated by the large range in past cost estimates.

<table>
<thead>
<tr>
<th>Practice</th>
<th>WTA ($ per acre)</th>
<th>WTP ($ per acre)</th>
<th>Average Cost ($ per acre)</th>
<th>WTP - Cost ($ per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover Crop</td>
<td>125.16</td>
<td>79.45*</td>
<td>129.24</td>
<td>-49.79</td>
</tr>
<tr>
<td>MIRG</td>
<td>N/A</td>
<td>23.91**</td>
<td>79.82</td>
<td>-55.91</td>
</tr>
<tr>
<td>Buffer Strip</td>
<td>168.33</td>
<td>763.68***</td>
<td>807.33</td>
<td>-43.65</td>
</tr>
</tbody>
</table>

Notes* WTP levels are established through assessing EQIP Payments from 2015 (EQIP 2015).* cover cropping practice of HU-Nitrogen Fixing Cover used. **closest practice to this specific MIRG practice is prescribed grazing, intensive. ***closest practice to this specific buffer planting is tree/shrub establishment, averaged between 110 and 300 per acre. † WTA levels were reported in Miller, 2014.
2.5. Conclusion

2.5.1. Implications and Recommendations

The costs found in this study to install and maintain MIRG, cover cropping, and riparian buffer strips demonstrate to Northeastern and specifically Vermont farmers the unique costs associated with CCBMPs they may be considering adopting. A 2013-2014 study on the effectiveness of various cover crop educational opportunities found that self experimentation, local workshops, and internet research were the most effective means of learning about new cover cropping methods [42]. Baumgart-Getz, Prokopy, & Floress also found that information and networking variables were useful for predicting best management practice adoption [52]. Therefore, we recommend that local Extension systems incorporate the costs and implementation of CCBMPs into online educational materials and workshops to provide the necessary information to potential practice adopters and generally maximize adoption. Understanding these specifically defined costs will help alleviate farmer perceptions of unknown risks and profitability, two vital barriers to BMP adoption [54,55,56].

CCBMPs like covering cropping and MIRG provide external, public benefits through the mitigating climate change by way of increasing carbon soil sequestration and reducing fossil fuel use. Therefore, under adoption results in agricultural systems contributing to climate change to a greater degree than is necessary. In addition, CCBMPs provide internal benefits that result in more adaptive farms by keeping soil in place, reducing flooding impacts, keeping weeds controlled, managing nutrients, and decreasing imported fertility and feed. Therefore, under-adoption results in a more
vulnerable farming population in a changing climate. The costs found in this study should inform policy makers of the true cost of implementing these important practices. Specifically, incentive levels warrant increases for high intensity cover cropping, and high intensity grazing, as the current payment levels are likely resulting in under-adoption given that costs outpace current payment levels by 40-70%. Including the specific internal or external benefits farmers and society receive in this calculation would reduce this difference, as the current calculation is total costs as opposed to net costs (Costs – benefits), and there are certainly numerous benefits associated with each practice. However, given the one year research period for this project, it was not possible to measure specific quantitative on-farm benefits as this would require baseline data from farm operations prior to CCBMP adoption. This would be necessary to allow for differentiation between pre and post farm characteristics.

Large scale adoption of these three CCBMPs may also have unknown implications on the global scale in terms of external benefits. If these practices were to be widely adopted at the regional or national level, and result in general decreased yields, this could result in national crop shortfalls. These shortfalls may then require the import of outside crops, offsetting some of the decreases in emissions and the associated societal benefits. While this issue is outside the scope of this analysis, it is an important consideration when considering national or global adoption of these practices.

Additional specific policy recommendations for increasing MIRG adoption include revenue assurance for farmers who are converting from conventional or confined livestock or dairy operations to MIRG practices over a three or five year period and zero or very low interest loans for conversion costs. While the farms assessed here were not
undergoing conversions from one practice to the other, this does represent a notable cost and risk for farmers. Incentive payment programs should also more explicitly incorporate external ecosystem service benefits, such as carbon sequestration, into their payment calculations.

2.5.2. Strengths and Limitations

The primary strength of this study is the data collection method used. With several exceptions, data were collected from each farmer on a daily basis and aggregated to annual costs. When farmers were unable to track on a daily basis using our customized data tracking logs, other existing daily or weekly record keeping materials used by the farmers were relocated to our tracking method. This yielded an accurate picture of inputs, fuel, and labor required for each documented practice over the course of one season.

The costs documented in this study represent the cost to establish and/or maintain CCBMPs. It should be noted that these costs are not intended to reflect the total cost of producing dairy, meat, or vegetable crops; additional feed, veterinary services, regulatory testing, land rent, and other business expenses were not included. This approach was logical for this study as we were interested in the cost of specific practices within larger production systems, as opposed to the total end cost for products themselves. Similar to cover cropping being a select practice within vegetable operations, the utilization of MIRG is only part of the broader process of raising livestock. Specific to MIRG, the focus of the reporting is $/acre instead of a more traditional $/animal. As a result, dollars per acre found for MIRG practices are difficult to compare to existing studies on MIRG that follow a traditional production system enterprise budget approach. In addition, this study did not incorporate potential increases or decreases in yield resulting from
incorporation of these best practices. If practice adoption were to increase profits to a notable degree, the gap between costs and WTP levels may be less importance for farmer adoption.

An additional limitation of our study was the comparability between farms for the different CCBMPs. The farms we worked with offer a picture of Vermont agriculture, that which includes a variety of operations that utilize differing practices. For example, our researched farms plant different mixes of cover crop seeds that cost different amounts, reducing the direct cost comparability between farms. However, the process of averaging these inherently variable costs produces a useful average cost for each practice, except in the case of riparian buffer strips and sheep MIRG. Results of this study showed a relatively narrow range of practice costs for MIRG and cover cropping when the logical outliers were excluded as described previously, indicating established costs are likely relevant to other similar farms within Vermont. However, caution should be taken when generalizing these results, as twelve farms does represent a small sample size. This is especially true in regard to the sheep farm MIRG practice and riparian buffer zone practice, as each had only one sample to draw conclusions from.

2.5.3. Future Research

Future research should establish costs associated with additional CCBMPs, as well as verifying the costs found here for other areas of the Northeastern United States. Specifically, no-till land management practices and stormwater management practices should be prioritized. WTA levels should also be assessed for stormwater management system practices and MIRG. Additionally, further research should be conducted on the
adequacy of CCBMP incentive payment levels by comparing WTA and WTP levels once established.

This study does not include the comparative calculated benefits of these CCBMPs. The 12 participating farmers qualitatively discussed why they were using these practices, and anecdotally provided their perceptions of the public and private benefits of each. However, the associated internal and external benefits of these practices were not incorporated in this study given the one year scope of research. It would not have been possible to establish baselines prior to CCBMP establishment. However, future research should work with farms to measure the private benefits before and after practice establishment, while also measuring GhG emissions to demonstrate public benefits. Specifically, research on private benefits should include potential profit changes from practice adoption. Increases in farmer profits from CCBMP practice adoption would demonstrate a win-win situation for farmers as they would not only receive payments through programs like EQIP, but they would generate better economic returns independent from incentive programs. Potential situations like this would be important inclusions in extension service advisory services provided to farmers.

In addition, the long vs short term impacts to carbon sequestration of these practices may be somewhat variable, resulting in fluctuating public benefits. For example, while there would be benefits to short-term carbon sequestration from utilizing cover cropping, if these practices were removed in the future, sequestered carbon would potentially return to the atmosphere. Future research should look into the timescale issue of various CCBMP’s impact on carbon sequestration if practices are either continued or removed.
2.5. Acknowledgements

This work was part of the Vermont Agricultural Resilience in a Changing Climate (VARCC) initiative and the Agroecology and Rural Livelihoods (ARL) Group. Funding was provided by the University of Vermont’s Food Systems Transdisciplinary Research Initiative. Most important, many thanks are extended to the twelve farmers who painstakingly tracked data over an entire season. This study would not have been possible without the financial and administrative support supplied by the VARCC and ARL, and the data collection the farmers undertook.

2.6. References


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CHAPTER 3: FACTORS INFLUENCING CONSUMER PERCEPTIONS OF RAW MILK SAFETY IN VERMONT

3.1. Introduction

Raw milk refers to goat, cow, or sheep’s milk that has not been pasteurized. Raw milk is typically not homogenized and retains the milk fat present upon milking. The production of raw milk has been part of Vermont’s agricultural system for hundreds of years (Rural Vermont, 2014), and a recent survey report states over 53,000 gallons of raw milk from 76 farms was sold from November 1, 2012 through October 31, 2013 amounting to 373,018$ (Rural Vermont, 2014). Rural Vermont’s survey also found that the average price for a gallon of raw cow or goat milk in Vermont was $7 and $10 per gallon, respectively, a significant price premium compared to the average price of pasteurized cow’s milk in January 2014 of just above $3.50 per gallon (US BLS, 2015). The Vermont legislature also recently increased the ability of consumers to obtain raw milk by passing Act No. 149 (S.70), which allows for the delivery of raw milk to customers at farmers’ markets (Vermont General Assembly, 2014).

3.1.1. Perceptions of Raw Milk

Consumption of raw milk in Vermont is a contentious issue given the potential for raw milk to carry foodborne pathogens. Experts from the U.S. Food and Drug Administration (FDA, 2014), American Academy of Pediatrics (Brady et al., 2014), Centers for Disease Control and Prevention (CDC, 2014), and Vermont Department of Health (VT Dept. of Health, 2014) all hold the position that raw milk may be harmful to your health, derived almost exclusively from considerations of microbiological food safety. Specifically, the potential for the presence of disease-causing pathogens such as
E-coli, Salmonella, Campylobacter, and Listeria is of great concern (Claeys et al., 2013). The academic side of the discussion on the safety of consuming raw milk also focuses almost exclusively on these microbiological risks (Oliver, Boor, Murphy, & Murinda, 2009; Claeys et al., 2013).

In contrast to the perceptions of raw milk held by a majority of public health experts and those researching food safety in academia, raw milk advocacy groups say raw milk, produced under sanitary conditions, is both safe to drink and possesses many more health benefits than pasteurized milk (A Campaign for Real Milk, 2014). Proponents also argue that raw milk is safe because it “contains many components that kill pathogens and strengthen the immune system” (A Campaign for Real Milk, 2014). While the perceptions and positions of these groups are well documented in academic literature, research concerning those who actually consume raw milk is limited.

Motivations for consuming raw milk vary widely and diverge from the centralized focus on microbiological safety. Broadly speaking, consumers of unpasteurized food products, such as raw milk, could be called “post-Pasteurians,” those who resist the “hyper hygienic” dream of Pasteurians, and may be concerned with broader issues such as antibiotic resistance, and believe that microbes are not only a part of life but may also enhance life (Paxson, 2008). Such consumers likely support a complex idea of small-scale, labor-intensive, artisanal farming, and may hold a broad critique of mass food production (Berg, 2008). More specifically, the taste of raw milk, perceived increased health benefits over pasteurized milk, cultivated relationships with family farmers, and support for local and sustainable farms appear in the literature as important motivations for consumers of raw milk (Leamy, Heiss, and Roche, 2014; Katafiasz & Bartlett, 2012;
Bell, 2010). Understanding why consumers and experts perceive a product differently is vital to understanding the debate surrounding raw milk. In addition, this understanding informs how the perceptions of raw milk consumers interact with those of public health or academic experts.

3.1.2. Differing Perceptions of Risk

Differing perceptions of a potentially dangerous food product is not uncommon, and risk tends to be a central issue motivating these differences. Literature regarding the quantification of perceived risk has shown that experts and the general public perceive risks differently (Slovic, 1987; Slovic, 1999; Ueland et al., 2012). Risk experts tend to define risk through measures of harm or mortality, while the public tends to define risk through broader measures such as uncertainty, dread, catastrophic potential, controllability, and equity (Slovic, 1999; Ueland et al., 2012). Slovic (1987) further asserts that for the public, connections exist between these various risk characteristics, such as something voluntary being perceived as controllable, or something highly uncontrollable being perceived as a high risk to future generations, and that these connections can manifest themselves in public perceptions of risk. Furthermore, food risk research has shown that food products perceived to be highly beneficial are also perceived to have low risk (Ueland et al., 2012). Differing perceptions of risk are further complicated in that evidence is also often not enough to remedy disagreements due to strongly held initial beliefs about a product (Slovic, 1987).

The raw milk discussion clearly fits within Slovic’s (1987) conceptual analysis of the differences between experts and the public regarding risk. For this study’s purposes,
the food safety of raw milk is the dominant risk analyzed. Risk, or food safety, in the eyes of the public is not some simple concept influenced only by directly perceived danger such as the potential for foodborne illness. The degree of perceived risk is influenced by a broad set of factors. This study seeks to understand which factors related to raw milk, including production methods, perceived benefits, and demographic variables, interact with consumer perceptions of raw milk safety. For example, consumers may judge raw milk’s risk as reduced because the degree of risk is perceived as controllable, through the proxy of knowing the farmer who produced the raw milk.

3.1.3. Raw Milk and Sustainable Agriculture

Limited research exists regarding the broad factors influencing perceptions of raw milk safety. As a result, literature concerning the broader issues of raw milk, and similar food products, along with logical reasoning were used to guide which factors would be assessed in this study. Existing literature on raw milk consumption motivations often have similarities with studies on motivations for the support of sustainable agriculture. Sustainable agriculture is defined as an agricultural system of social and environmental values, in which food is produced without depleting nonrenewable resources or polluting the natural environment, and where rural communities are vibrant, lives of all those included in the agricultural system are rich, and food produced is wholesome (Earles & Williams, 2005). In other words, sustainable agriculture produces healthy food through environmental and socially embedded production methods. Raw milk is certainly perceived as a healthy food by those that consume it, and the motivations for raw milk consumption of increased social relationships, small-scale production, support for local farms, and broad turn away from conventional production techniques can all be classified
as socially or environmentally embedded elements of a sustainable agriculture system. (Leamy, Heiss, and Roche, 2014; Katafiasz & Bartlett, 2012; Bell, 2010; Paxson 2008; Berg, 2008).

Raw milk consumers may broadly associate raw milk with sustainable agriculture given the parallels between the embedded traits of sustainable agriculture and the motivations behind raw milk consumption. Limited research exists that explicitly assesses this link between perceptions of sustainable agriculture and raw milk, and this topic will be analyzed briefly in this report to inform the broader issue of factors influencing raw milk safety perceptions. Given the potential relationship between perceptions of raw milk and sustainable agriculture, research regarding factors influencing perceptions of sustainable agriculture products was used in determining which factors to investigate in this study. It should be noted that this study makes no statement regarding the actual sustainability of raw milk.

3.2. Conceptual Model

The conceptual model used to inform this paper’s final analysis draws from existing research on perceptions and motivations of raw milk consumption, sustainable agriculture products, raw milk cheese, beef, and risk perception. Local and organic production methods (Tobin, Thomson, & LaBorde, 2012; Berlin, Lockeretz, & Bell, 2009; Nganje, Hughner, & Patterson 2014), humane animal treatment (Harper & Makatouni, 2002), and food supply control (Leamy, Heiss, & Roche, 2014; Katafiasz & Bartlett, 2012; Bell, 2010) are four elements of sustainable agriculture that have been identified in academic literature as impacting perceptions of food safety. These four production traits make up the first four factors in the conceptual model. Note that while
the term “natural” appears in some literature concerning motivations for sustainable agriculture, this factor was not considered in this study due to a lack of agreed upon or legal definition. The fifth and sixth factors, taste and perceived nutritional value, appear frequently in the existing raw milk literature as the strongest motivations for consumption (Bell 2010; Katafiasz & Bartlett, 2012; Leamy 2014). Trust in information supplied by health officials (Slovic 1999; Katafiasz & Bartlett, 2012) and personal experiences with a food product (Tonsor, Schroeder, & Pennings, 2009) appear in the academic literature concerning raw milk cheese and perceptions of beef safety as influencing consumer perceptions of food safety, and are factors seven and eight. Demographic variables were also selected as potential factors for the conceptual model, including income, education, gender, rurality, age, and the presence of children in the household. Combined, this results in a conceptual model consisting of 14 potential factors influencing perceptions of raw milk safety.

Previous research on factors impacting food safety risk perceptions of beef split potential factors into five dimensions: reliance on observable attributes, reliance on credence attributes, trust in industry, grocery and government, trust in researchers and consumer groups, and trust in doctors (Tonsor, Schroeder, & Pennings, 2009). This framework was used to further categorize the conceptual model and associated factors within this study. Here, potential factors are categorized into credence, observable, and trust-based indicators as outlined in Table 3. Demographic variables are categorized separately.
Table 3. Raw Milk Conceptual Model for Analysis

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Factors/Attributes</th>
<th>Variables</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credence</td>
<td>Organic impact on food safety</td>
<td>Reported perception that these traits are more or less safe than their conventional counterpart. Aggregated to represent one variable of sustainable agriculture.</td>
<td>Tobin, Thomson &amp; LaBorde 2012; Berlin, Lockertet, Bell, 2009; Berlin, Lockertet, Bell, 2009; Nganje, Hughner, &amp; Patterson, 2014</td>
</tr>
<tr>
<td></td>
<td>Local production impact on food safety</td>
<td>Sustainable agriculture traits influence on food safety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Humane livestock production impact on food safety</td>
<td></td>
<td>Harper &amp; Makatouni, 2002</td>
</tr>
<tr>
<td></td>
<td>Knowing a farmers impact on food safety</td>
<td></td>
<td>Ueland et al., 2012</td>
</tr>
<tr>
<td>Credence or Observable</td>
<td>Health benefits of raw milk compared to pasteurized milk</td>
<td>Perception that raw milk is more or less healthy than pasteurized milk</td>
<td>Oliver, Boor, Murphy, &amp; Murinda, 2009</td>
</tr>
<tr>
<td>Observable</td>
<td>Flavor of raw milk compared to pasteurized milk</td>
<td>Perception that raw milk tastes better or worse than pasteurized milk</td>
<td>Bell 2010; Katafiasz &amp; Bartlett 2012; Leamy, Heiss, Roche, 2014</td>
</tr>
<tr>
<td></td>
<td>Personal experience with raw milk illness or lack thereof</td>
<td>Whether or not individual has been exposed to illness perceived to be from raw milk</td>
<td>Tonsor, Schroeder, &amp; Pennings, 2009</td>
</tr>
<tr>
<td>Trust</td>
<td>Trust in information from health officials</td>
<td>Level of trust in information coming from health officials</td>
<td>Colonna, Durham, &amp; Meunier-Goddik, 2011</td>
</tr>
<tr>
<td>Demographics</td>
<td>Children</td>
<td>Presence of children in the house or not</td>
<td>Logical Reasoning</td>
</tr>
<tr>
<td></td>
<td>Income</td>
<td>Reported income</td>
<td>Logical Reasoning</td>
</tr>
<tr>
<td></td>
<td>Rurality</td>
<td>Reported residence in urban or rural areas</td>
<td>Logical Reasoning</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>Male or Female</td>
<td>Logical Reasoning</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>Reported level of education</td>
<td>Logical Reasoning</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>Reported Age</td>
<td>Logical Reasoning</td>
</tr>
</tbody>
</table>

Utilizing this conceptual model, this study seeks to answer the following research questions: 1) do perceptions of raw milk safety correlate with the consumption of raw milk?; 2) do Vermonter’s perceive selected sustainable agriculture practices as being safer than conventional practices?; 3) which factors and demographic variables influence perceptions of raw milk safety, and to what extent? Results illustrate the specific factors correlating with, and potentially influencing, perceptions of raw milk risk and safety.
Understanding these factors will allow public health experts to have more empathetic, informed, and productive outreach and discussions with raw milk consumers and producers.

3.3. Methods

3.3.1. Research Question #1

Research Question (RQ) #1 asked: do perceptions of raw milk safety correlate with the consumption of raw milk? Understanding this first question was necessary to establish the need for assessing factors that influence perceptions of raw milk safety. If raw milk safety perceptions did not correlate with consumption of raw milk, then the remaining research questions were of limited importance.

RQ #1 was analyzed by testing the following null hypothesis: $H_0$: There is no correlation between Vermonter’s perception of raw milk safety and whether or not Vermonters have obtained raw milk. The associated alternative hypothesis is $H_1$: There is a correlation between Vermonter’s perception of raw milk safety and whether or not Vermonters have obtained raw milk. This test used the independent dummy variable of raw milk safety perception (safe: 1 or dangerous: 0), and the dependent dummy variable of obtained raw milk (yes: 1 or no: 0) in a Chi-squared test. The null was rejected and alternative accepted if the p-value fell below .05, at a 95% confidence interval.

3.3.2. Research Question #2

RQ #2 asked: do Vermonter’s perceive selected sustainable agriculture practices as being safer than conventional practices? This second research question sought to examine the relationship between the four sustainable agriculture factors of local, organic, known farmer, and certified humane and perceived safety. To answer this
question, four hypotheses were developed and basic descriptive statistical frequencies were determined (Table 4). Basic univariate, ordinal statistics established from the results of survey questions one through four (Appendix I) identified the percentage of respondents who perceive food produced locally, organically, humanely, or by a known farmer to be safer than conventional, not-local, not certified humane, or from an unknown farmer, respectively. If these sustainable agriculture factors were perceived as being safer than their counterparts, they justified further analysis in RQ #3.

Table 4. RQ #2 Hypotheses, Perceptions of Sustainable Agriculture’s Impact on Food Safety

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>H2: Vermonters Perceive locally produced food to be safer than food not produced locally</th>
<th>H3: Vermonters Perceive organically produced food to be safer than food produced conventionally</th>
<th>H4: Vermonters Perceive food coming from a farm that is certified as following humane animal treatment practices, as being safer than non-certified farms</th>
<th>H5: Vermonters Perceive food that is produced by a known farmer to be safer than food produced by an unknown farmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis testing method</td>
<td>Descriptive Statistics</td>
<td>Descriptive Statistics</td>
<td>Descriptive Statistics</td>
<td></td>
</tr>
</tbody>
</table>

3.3.3. Research Question #3

RQ #3 asked: which factors and demographic variables influence perceptions of raw milk safety, and to what extent? A multi-regression analysis was run to determine how a change of one unit in the identified statistically significant independent variables impacted the dependent variable of raw milk safety perception. The four independent variables associated with sustainable agriculture practices were analyzed alongside the four remaining survey question variables, and six demographic variables. The first steps in running the regression analysis were to determine the correct statistical regression test and the correct model. The Probit test was selected for the regression analysis since the
dependent variable of raw milk safety perceptions is binary. To determine if the appropriate model, including all 14 potential independent variables, was selected, a specification f-test was run on the whole model. A small p value would indicate the model is correct, with a large p value indicating different parameters or kinds of analysis should be used. If deemed an inaccurate model, a t-test was performed on each of the 14 potential independent variables to determine those that were statistically insignificant (t-stat less than 1). A separate f-test was also run to determine if the four independent variables of sustainable agriculture production methods are jointly significant. A restricted model was then run with all variables having an absolute value t-stat greater than or equal to 1 or p-value less than .10. An f-test was then run to determine the appropriateness of utilizing the restricted model. If a large f-stat was found, the restricted variables from the full model was kept in the final model, and the restricted model would be used as the final model if a low f-stat was determined. Upon model selection, the Probit regression was run to determine the parameter’s magnitude and statistical significance.

3.3.4. Survey Data Collection

Ten survey questions, along with demographic questions, were included in the 2014 Vermonter Poll, a cross-sectional, statistically representative survey of Vermont residents to assess the 14 factors included in the conceptual model. Data was collected by the Center for Rural Studies at the University of Vermont. The survey was conducted between the hours of 9:00 a.m. and 9:00 p.m. beginning on March 10, 2014 and ending on March 25, 2014. The telephone polling was conducted from the University of Vermont using computer-aided telephone interviewing (CATI). A random sample for the
poll was drawn from a list of Vermont telephone numbers, which is updated quarterly and included listed and unlisted telephone numbers. Cellular phone numbers were not included in the sampling frame. Only Vermont residents over the age of eighteen were interviewed. The poll included questions on a variety of issues related to public policy in the state of Vermont. In total, 2,013 households were successfully contacted, yielding 576 complete responses; therefore, 28.6 percent of these calls resulted in a completed survey. Based on a group of this size, the results have a margin of error of plus or minus 4.5 percent with a confidence interval of 95 percent.

A majority of the ten survey questions were developed as Likert-type questions. Eight of the questions are based on the eight factors identified earlier in the conceptual model, shown in Table 3. Two additional questions were included about the respondents’ perception of the safety or danger of raw milk and if they had obtained raw milk in the past year. Data were analyzed using the data software SPSS, version 21. Descriptive statistics showed the basic results of each of the ten questions, with more detailed analysis conducted for the three research questions.

3.4. Results

General survey results indicate that 15.6% of respondents (89 of 571) had obtained raw milk within the last year. Perceptions of raw milk safety were found to be variable, with 13.8% of respondents reported consuming raw milk to be very safe with 23.6% reporting somewhat safe. 5.8%, and 27.4% of participants reported it as very dangerous and somewhat dangerous, respectively. Interestingly, 40 of 574 (6.9%) of respondents reported that consuming raw milk has resulted in themselves or someone they know getting sick. 10.2% of respondents thought raw milk tastes worse than
pasteurized milk, while 30.1% thought the opposite (46.6% don’t know). Furthermore, 32.5% believe raw milk to be slightly or much less healthy than pasteurized milk, while 28.6% thought it was slightly or much more healthy (23.5% don’t know). Full survey results are displayed in Appendix II.

3.4.1. RQ #1 Results

RQ #1 asked: do perceptions of raw milk safety correlate with the consumption of raw milk? Findings indicate that there is a significant positive relationship between perceptions of food safety and consumption of raw milk. Individuals obtaining raw milk was generally correlated with perceptions of raw milk being more safe than dangerous. Based on this result, it’s clear that the perception of raw milk safety is an important factor in decisions to obtain raw milk, or vise-versa, if you purchase raw milk, you perceive it as safe. Interestingly, 11 respondents perceived raw milk as being more dangerous than safe yet still reported obtaining raw milk within the past year. To reach this conclusion, analysis was run on null hypothesis H10: There is no correlation between Vermonter’s perception of raw milk safety and whether or not Vermonters have obtained raw milk. Results from the Chi-square test, namely a p-value of .000, indicate that it is appropriate to reject the null hypothesis of there being no correlation, and accept the alternative hypothesis of H1: There is a correlation between Vermonter’s perception of raw milk safety and whether or not Vermonters have obtained raw milk.

3.4.2. RQ #2 Results

RQ #2 asked: do Vermonter’s perceive selected sustainable agriculture practices as being safer than conventional practices? Results indicate that Vermonters overwhelming perceive each practice of local, organic, certified humane food from
known farmers as being safer than the counterparts of non-local, conventional, non-certified humane food from unknown farmers (Table 6). The factor of local production garnered the highest perception of safety, with 75.4% of respondents reporting locally produced food as much more or slightly more safe that non-local production. Additionally, the factor of organic production had a notably higher percentage of respondents that perceives the practices being equally safe, 27.5%. The known farmer and certified humane factors received similar response rates regarding their perceived safety, approximately 71.0%. These results were established through analysis of Survey Questions 1-4, which show that it is appropriate to accept hypotheses 2-5: that Vermonters perceive locally, organically, certified humane food from known farmers as safer than food produced non-locally, non-organically, without humane certification, and from unknown farmers. Given the clear perception that these four factors are related to food safety, it is logical to include them in the preliminary model for our regression analysis in RQ #3.

Table 5. Survey Question Responses, Sustainable Agriculture Perceptions

<table>
<thead>
<tr>
<th>Survey Questions†</th>
<th>% of respondents reporting the sustainable agricultural practice as being much less or slightly less safe</th>
<th>% of respondents reporting the sustainable agricultural practice as being much more or slightly more safe</th>
<th>% of respondents reporting the sustainable agricultural practice as being the same level of safety as the counterpart practice</th>
<th>% Don’t</th>
<th>% Refused</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Local</td>
<td>1.3%</td>
<td>75.4%</td>
<td>16.4%</td>
<td>6.5%</td>
<td>0.3%</td>
</tr>
<tr>
<td>2. Organic</td>
<td>3.8%</td>
<td>66.6%</td>
<td>27.5%</td>
<td>5.9%</td>
<td>0.0%</td>
</tr>
<tr>
<td>3. Known Farmer</td>
<td>4.0%</td>
<td>71.0%</td>
<td>18.1%</td>
<td>8.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>4. Certified Humane</td>
<td>1.7%</td>
<td>71.7%</td>
<td>19.2%</td>
<td>9.9%</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

Note. † Full survey questions can be found in Appendix I. The four factors of local, organic, known farmer, and certified humane were compared vs each’s inverse practice of not-local, conventional, unknown farmer, and non-certified humane.
3.4.3. RQ #3 Results

RQ #3 asked: which factors and demographic variables influence perceptions of raw milk safety, and to what extent? Three factors, believing raw milk has better taste, perceiving increased health benefits of raw milk, and having children at home, positively impact the perceptions of raw milk safety. Perceived health benefits had the highest influence on safety perceptions, with presence of children, and taste, respectively displaying a smaller, yet still significant, impact on perceptions of safety. Knowing the farmer, personal experience with perceived raw milk illness, and rurality were not statistically significant factors (p values pf .221,.226 and .254 respectively), but had the next three highest levels of significance.

The 14 factors from the conceptual model were all included in the preliminary model to be tested. The results of the 14-independent variable specification f-test on the preliminary model were an f-stat of 5.079 and p-value of .000. However, only three of fourteen parameters were found to be statistically significant within the model: taste, health benefits, and presence of children in the house. Rurality, knowing a farmer, and perceived experience with illness were technically not statistically significant, but had t-values greater than 1, so they were also included in the restricted model. An f-test of the restricted model, containing the six parameters, resulted in an f-stat of 12.789. Given the larger f-stat of the restricted model, the original model was used as the final model.

Results of the binary Probit regression test performed on the final model are shown in Table 7. Note that the dependent variable was raw milk perceived safe (1) or dangerous (0). Statistically significant results were observed for taste, health benefits, and children in the house.
Table 6. RQ #3, Probit Regression Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Beta Value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>-.186</td>
<td>.673</td>
</tr>
<tr>
<td>Organic</td>
<td>.291</td>
<td>.514</td>
</tr>
<tr>
<td>Know Farmer</td>
<td>-.547</td>
<td>.221</td>
</tr>
<tr>
<td>Certified Humane</td>
<td>.469</td>
<td>.278</td>
</tr>
<tr>
<td>Taste</td>
<td>.836</td>
<td>.052</td>
</tr>
<tr>
<td>Health Benefits</td>
<td>2.098</td>
<td>.000</td>
</tr>
<tr>
<td>Personal Experience</td>
<td>.871</td>
<td>.226</td>
</tr>
<tr>
<td>Trust</td>
<td>-.138</td>
<td>.733</td>
</tr>
<tr>
<td>Kids In the House</td>
<td>1.073</td>
<td>.043</td>
</tr>
<tr>
<td>Income</td>
<td>-.340</td>
<td>.460</td>
</tr>
<tr>
<td>Education</td>
<td>.077</td>
<td>.851</td>
</tr>
<tr>
<td>Gender</td>
<td>-.415</td>
<td>.314</td>
</tr>
<tr>
<td>Rurality</td>
<td>.471</td>
<td>.254</td>
</tr>
</tbody>
</table>

3.5. Discussion

The intent of this study was three-fold: assess the link between perceptions of raw milk safety and consumption of raw milk, determine potential factors that may influence those perceptions of raw milk safety, and gauge the magnitude of influence for each factor. As expected given the multitude of research studies concerning raw milk’s microbiological safety, there was a strong positive relationship between perceptions of raw milk safety and consumption of raw milk. Higher perceived safety was a stronger indicator of consumption, while individuals that perceived raw milk as more dangerous tended to not consume raw milk, with the exception of 11 respondents, as results from RQ #1 demonstrated.

It was necessary to develop a conceptual framework for determining the potential factors influencing perceptions of raw milk safety given the lack of quantitative research in this area. One interesting result of the development of the conceptual framework was the determination that a large majority of Vermonter’s perceive organic (66.6%), local (75.4%), certified humane (71.7%), and food from a known farmer (71.0%) as slightly or much more safe than counterpart conventional practices. When
comparing the results of the regression analysis to the indicator categories in the conceptual framework, the factors with the least significance primarily trust or credence based indicators, or factors of which utility is difficult to ascertain for certain for a consumer. Specifically, local, organic, and trust in info from health officials were highly insignificant, while education was also. This indicates that observable indicators may have the strongest relationships with raw milk safety. The outlier here is perceived health benefits. This may be a result of consumers perceiving direct health benefits from the consumption of raw milk, transforming health benefits from a credence to observable indicator.

The perception of potential health benefits was the single most influential factor on perceptions of raw milk safety. The presence of children in the household and taste were also influential as shown by the Probit regression. Consistent with Slovic’s (1987) framework of inverse relationships between perceived benefits and risk, consumers appear to associate the most tangible perceived aspects of raw milk, such as taste and health benefits, with reduced risk or increased safety. Of interest in the regression results, is that all sustainable agriculture practices had no statistically significant influence on perceptions of raw milk safety when demographics, quality perceptions and behaviors are controlled for.

Findings illustrate that consumers are influenced by a complex suite of factors when forming their perceptions of raw milk safety-beyond the sole consideration of microbiological risk. The scope of the discussion around raw milk should be expanded by the public health world to include the diverse motivations behind the formation of safety perceptions and raw milk’s consumption. The sole focus on microbiological
safety, without consideration for the factors underpinning perceptions of that safety, and lack of consideration for other factors impacting raw milk consumption, likely diminishes the public’s trust in the message from health officials. Public health experts should take this into account when conducting outreach to raw milk consumers and producers, validating these underlying factors to ensure the most effective communication and productive discussion. Future research should assess the effectiveness of communications strategies around raw milk that incorporate factors beyond safety.

The public should also be aware that perceived benefits of raw milk, such as enhanced health benefits or better taste, do not necessarily mean raw milk is fundamentally safe. While benefits of raw milk certainly exist, the microbiological food safety risks are also real, and not eliminated by those benefits. Decisions to consume raw milk, which are at least partially informed by perceptions of raw milk’s safety, need to be made with a true understanding of the potential benefits and risks.

3.6. Conclusion

Vermonter’s appear to be continuing the trend of consuming raw milk at an increasing rate. These results indicate that in 2014, 15.6% of resident’s obtained raw milk in the past year. This in an increase from a previous study in 2013 (Leamy, Heiss, & Roche, 2014) that found the number to be 11.6%. This trend progresses despite the continuing message from health experts that raw milk is generally an unsafe product to consume (FDA, 2014; Brady et al., 2014; CDC, 2014; VT Dept. of Health, 2014). This study sought to understand what factors may be influencing Vermonter’s perception of raw milk safety given the strong and sole focus on safety by the public health community. Results from this study indicate that observable indicator factors have the greatest
influence on perceptions of raw milk safety. Specifically, the factors of perceived health benefits, presence of children in the household, and taste were found to influence perceptions of safety to the highest degree.

Perceptions of sustainable agricultural practices impact on food safety were not found to influence perceptions of raw milk safety. This is of note because existing studies on the motivations for raw milk consumption (Leamy, Heiss, & Roche, 2014; Paxson, 2008; Berg, 2008) identify social and environmentally embedded production methods as driving factors for consumption. This indicates that while sustainable agricultural practices don’t necessarily influence perceptions of raw milk safety significantly, they do influence general decisions to consume raw milk. Future research should study the connection between raw milk and sustainable agriculture more broadly, as opposed to this study’s narrow focus on raw milk’s safety. While it was determined that sustainable agriculture factors do not impact perceptions of raw milk’s safety, it would be of interest to understand the quantifiable impact of these and additional factors on perceptions of raw milk in general.

Furthermore, current Vermont law requires that consumers be informed of the potential dangers of raw milk consumption at time of purchase, so it stands to reason that they are at least aware of the potential dangers. This raises the question of if consumers are to some degree willing to ingest a risky product because of the social, environmental, or economic benefits that are embedded within that product, likely through the practices used to create that product. Future research should study to what degree consumers are willing to assume various levels of food risk to create public or private benefits.
While findings of this study come from a well-established and sound survey, care should be taken when generalizing these findings. Vermont has a relatively large rural population, agricultural base, and dairy production, likely leading to a larger percent of residents consuming raw milk, and unique perceptions of agricultural production practices’ impact on food safety.
3.7. References


Vermont General Assembly. (2014). *Act 149 (S.70).* Retrieved from

http://legislature.vermont.gov/bill/status/2014/S.70
CHAPTER 4: COMPREHENSIVE CONCLUSION

The research reported in this thesis ultimately sought to increase understanding of some of the key factors related to the perceptions and adoption of sustainable agriculture practices and products. Through use of CCBMPs to assess farmer adoption of sustainable agriculture practices, and raw milk to assess consumer perception of a perceived sustainable agriculture product, a narrow window into this topic was opened.

Sustainable agriculture provides a means to mitigate the future negative effects of climate change and industrialized agriculture, and adapt to the already present impacts. These benefits can be maximized through increased practice adoption by taking local economic conditions into account when developing incentive programs. Understanding the demand for products produced with use of sustainable agriculture practices is also important to maximizing associated benefits. The issue of raw milk illustrates that even potentially dangerous food products are being consumed by the public, in large part due to their embedded benefits. Considerations of safety are important for consumers, but social and environmental benefits also motivate consumption. The public may even be willing to assume some degree of risk to ensure continued provision of those benefits.

A review of the literature, and results from recent research show that economic considerations are of central importance to the farmer adoption of sustainable agriculture practices, such as CCBMPs. Furthermore, incentive programs play an important role in promoting these practices. However, as the CCBMPs element results of this research indicate, local costs for these practices must be aligned with program payments to ensure maximum adoption. While it is hard to justify the generalization of this study’s first article’s results upon other region’s incentive payment programs, it does raise the
question of if these programs are providing high enough incentive levels to maximize adoption. Future research should assess this issue in other regions, and with additional practices. Local, farmer based cost studies should be used to inform payment levels, and these costs should be incorporated into extension outreach and educational materials.

The consumer side of sustainable agriculture focuses upon the products produced through sustainable agriculture as opposed to the practices. Results of the raw milk component of this study indicate that perceptions of product safety, especially of potentially dangerous food products, significantly relates to consumer perceptions of those products. While this finding is quite logical, of more importance is the underlying complexity that goes into the formation of these consumer perceptions. These perceptions of safety are influenced by a range of factors, primarily those that are observable. Specifically, the factors of perceived health benefits, presence of children in the household, and taste were found to be related to perceptions of safety most significantly in the case of raw milk. Furthermore, it appears that these perceived benefits of raw milk inversely impact perceptions of safety, as Slovic’s (1987, 1990) theories would suggest. For example, the perception that raw milk taste better than pasteurized milk causes that consumer to perceive raw milk as less dangerous.

Unexpectedly, perceptions of sustainable agricultural practices impact on food safety were not found to influence perceptions of raw milk safety as potentially indicated by previous raw milk literature. Existing studies on the motivations for raw milk consumption (Leamy, Heiss, & Roche, 2014; Paxson, 2008; Berg, 2008) identify social and environmentally embedded production methods as driving factors for consumption. Specially, local, small-scale, labor-intensive, artisanal, perceived increased health
benefits over pasteurized milk, cultivated relationships with family farmers, and support for local and sustainable farm were all noted as motivations for consuming raw milk ((Leamy, Heiss, and Roche, 2014; Katafiasz & Bartlett, 2012; Bell, 2010, Berg, 2008). This result indicates that while safety considerations of potentially dangerous food products are important to consumers, numerous other environmental, social, and economic factors also impact public perceptions of those food products. Caution should be taken when generalizing these results to sustainable agriculture products as a whole, as raw milk is a unique case given it microbiological characteristics. Safety perceptions would likely play less of a role in less potentially dangerous food products.

Despite public health official warnings, Vermonters continue to consume raw milk at an increasing pace. Clearly, these consumers don’t want to get food poisoning from E. coli, campylobacter, or the various other potential pathogens, but drink it anyways. Results of this study show that perceptions of safety are a consideration for consumers, but that these perceptions are impacted by factors beyond that microbiological risk. Furthermore, consumers are to some degree likely willing to ingest a risky product because of the social and environmental benefits that practices behind that product provide. While this issue is certainly complicated by the conflicting messages regarding raw milk’s safety, it stands to reason that the public is generally aware of the risks associated with raw milk given the requirements that these risks be provided to consumers at time of purchase. Future research should study to what degree the public is willing to assume risk when consumption provides various social and environmental public benefits, and experiential or health related personal benefits.
CHAPTER 5: COMPREHENSIVE BIBLIOGRAPHY


Intergovernmental Panel on Climate Change. (2014). Mitigation of Climate Change. *Contribution of Working Group III to the Fifth Assessment Report of the*


APPENDICES

APPENDIX I. Raw Milk Survey Questions

1. Consider the relationship between food safety and the location of the farm where the food was produced. Compared to food from a farm that is not local, food from a local farm is
   a. Much less safe
   b. Slightly less safe
   c. The same
   d. Slightly more safe
   e. Much more safe
   f. Don’t Know
   g. Refused

2. Consider the relationship between food safety and how a food was grown. Compared to food from a conventional farm, food from an organic farm is
   a. Much less safe
   b. Slightly less safe
   c. The same
   d. Slightly more safe
   e. Much more safe
   f. Don’t Know
   g. Refused

3. Consider the relationship between food safety and the treatment of animals. Compared to food from a farm that is not certified as following humane animal treatment practices, food from a farm that is certified as following humane animal treatment practices is
   a. Much less safe
   b. Slightly less safe
   c. The same
   d. Slightly more safe
   e. Much more safe
   f. Don’t Know
   g. Refused

4. Consider the relationship between knowing a farmer and food safety. Compared to food that comes from a farmer you do not have any knowledge of, food from a farmer you know of personally is
   a. Much less safe
   b. Slightly less safe
c. The same
d. Slightly more safe
e. Much more safe
f. Don’t Know
g. Refused

5. Consider information from health professionals such as the Vermont Department of Health or the Center for Disease Control and Prevention. Which of the following statements best describes how much you trust or distrust this information
   a. I don’t trust any of the information
   b. I trust a small amount of the information
   c. I generally trust or distrust an equal amount of the information
   d. I trust a large amount of the information
   e. I trust all of the information
   f. Don’t Know
g. Refused

The next questions ask about your perceptions of raw milk. Raw milk is milk that has not been rapidly heated to a specific temperature and then cooled.

6. Have you obtained raw milk in the past year?
   a. Yes
   b. No
   c. Maybe
   d. Don’t know
   e. Refused

7. Consider the attribute of taste in your food buying decisions. Compared to pasteurized milk, raw milk tastes
   a. Much worse
   b. Slightly worse
   c. The same
   d. Slightly better
   e. Much better
   f. Don’t know
   g. Refused

8. Consider the health benefits of both raw and pasteurized milk. Compared to pasteurized milk, consuming raw milk is
   a. Much less healthy
   b. Slightly less healthy
   c. The same
d. Slightly more healthy
e. Much more healthy
f. Don’t know
g. Refused

9. How safe or dangerous do you think consuming raw milk is?
   a. Very safe
   b. Somewhat safe
c. The same
d. Somewhat dangerous
e. Very dangerous
f. Don’t know
g. Refused

10. Has consuming raw milk ever resulted in you or someone you know getting sick?
    a. Yes, myself
    b. Yes, someone I know
c. Maybe
d. No
e. Don’t Know
f. Refused
APPENDIX II. Raw Milk Survey Results

Survey results are indicated in bold to the left of each question’s response options.

1. Consider the relationship between food safety and the location of the farm where the food was produced. Compared to food from a farm that is not local, food from a local farm is
   a. (0.3%) Much less safe
   b. (1.0%) Slightly less safe
   c. (16.4%) The same
   d. (30.6%) Slightly more safe
   e. (44.7%) Much more safe
   f. (6.5%) Don’t Know
   g. (0.3) Refused

2. Consider the relationship between food safety and how a food was grown. Compared to food from a conventional farm, food from an organic farm is
   a. (0.7%) Much less safe
   b. (3.1%) Slightly less safe
   c. (23.7%) The same
   d. (27.4%) Slightly more safe
   e. (39.2%) Much more safe
   f. (5.9%) Don’t Know
   g. Refused

3. Consider the relationship between food safety and the treatment of animals. Compared to food from a farm that is not certified as following humane animal treatment practices, food from a farm that is certified as following humane animal treatment practices is
   a. (2.1%) Much less safe
   b. (1.9%) Slightly less safe
   c. (12.1%) The same
   d. (20.7%) Slightly more safe
   e. (50.3%) Much more safe
   f. (9.9%) Don’t Know
   g. (1.0%) Refused

4. Consider the relationship between knowing a farmer and food safety. Compared to food that comes from a farmer you do not have any knowledge of, food from a farmer you know of personally is
   a. (0.5%) Much less safe
   b. (1.2%) Slightly less safe
   c. (17.4%) The same
d.  (22.6%) Slightly more safe
e.  (29.1%) Much more safe
f.  (8.0%) Don’t Know
g.  (1.0%) Refused

5. Consider information from health professionals such as the Vermont Department of Health or the Center for Disease Control and Prevention. Which of the following statements best describes how much you trust or distrust this information
   a.  (2.3%) I don’t trust any of the information
   b.  (14.3%) I trust a small amount of the information
c.  (29.1%) I generally trust or distrust an equal amount of the information
d.  (43.1%) I trust a large amount of the information
e.  (8.2%) I trust all of the information
f.  (2.4%) Don’t Know
g.  (0.5%) Refused

6. Have you obtained raw milk in the past year?
   a.  (15.6%) Yes
   b.  (83.2%) No
c.  (0.2%) Maybe
d.  (0.7%) Don’t know
e.  (0.4%) Refused

7. Consider the attribute of taste in your food buying decisions. Compared to pasteurized milk, raw milk tastes
   a.  (5.7%) Much worse
   b.  (4.5%) Slightly worse
   c.  (12.0%) The same
d.  (12.9%) Slightly better
e.  (17.2%) Much better
f.  (46.6%) Don’t know
g.  (1.0%) Refused

8. Consider the health benefits of both raw and pasteurized milk. Compared to pasteurized milk, consuming raw milk is
   a.  (8.5%) Much less healthy
   b.  (24.0%) Slightly less healthy
c.  (14.5%) The same
d.  (15.9%) Slightly more healthy
e.  (12.7%) Much more healthy
f.  (23.5%) Don’t know
9. How safe or dangerous do you think consuming raw milk is?
   a. (13.8%) Very safe
   b. (23.6%) Somewhat safe
   c. (13.3%) The same
   d. (27.4%) Somewhat dangerous
   e. (5.8%) Very dangerous
   f. (15.6%) Don’t know
   g. (0.5%) Refused

10. Has consuming raw milk ever resulted in you or someone you know getting sick?
    a. (0.3%) Yes, myself
    b. (6.6%) Yes, someone I know
    c. (0.9%) Maybe
    d. (85.7%) No
    e. (6.3%) Don’t Know
    f. (0.2%) Refused