AGROECOLOGY, ECOSYSTEMS, AND SUSTAINABILITY

EDITED BY **NOUREDDINE BENKEBLIA**

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CHAPTER 16

Vermont Agricultural Resilience in a Changing Climate

A Transdisciplinary and Participatory Action Research (PAR) Process

Rachel Schattman, Ernesto Méndez, Katherine Westdijk, Martha Caswell, David Conner, Christopher Koliba, Asim Zia, Stephanie Hurley, Carol Adair, Linda Berlin, and Heather Darby

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16.1 INTRODUCTION

16.1.1 Background

It is widely acknowledged that global climate change will lead to increasing global temperatures, rising sea levels, and decreasing snow and ice cover on land and over bodies of water within the next 50–100 years. Current projections from the Intergovernmental Panel on Climate Change (IPCC) range from low emissions scenarios (projected atmospheric carbon concentrations of 550 parts per million, or ppm) to high emissions scenarios (projected atmospheric carbon concentrations of 880 ppm) (Walthall et al. 2012). Increasing global temperatures will have numerous effects on both natural and human systems, including those associated with food and agriculture. Higher atmospheric temperatures will have an effect on the frequency and volume of rain events in addition to influencing plant and animal geographic ranges and interactions. While the full range of climate change implications for ecosystem and human communities is yet unknown, it is widely accepted that the emissions of today will influence how our world might change in the latter half of this century (Bernstien et al. 2007; Frumhoff et al. 2007).

Future interactions between climate change and agro-food systems can be expected to be dynamic and complex (Eriksen et al. 2009) with agricultural systems both contributing to and becoming increasingly vulnerable to the effects of climate change. Agricultural land use contributes to climate change by emitting approximately 31% of greenhouse gas (GHG) emissions globally (roughly 15 billion tons of CO_2 equivalents) (Scherr and Sthapit 2009; Smith et al. 2008), which does not include the additional emissions related to the processing, transportation, marketing, and consumption of food. On the other hand, projected changes in temperatures, precipitation regimes, and natural hazard frequencies will have an impact on the production capacity and resilience of different agricultural systems (Smith and Olesen 2010). The ability of an agroecosystem to adap and mitigate or contribute to climate change largely depends on the types of components it includes, its management regime, and external factors such as policies and markets (Smith et al. 2008; Tubiello et al. 2008).

In the northeastern United States, climate change is expected to severely affect rural populations and farming communities (Lal et al. 2011). Growers already implement farming practices tha have the potential for climate change mitigation and adaptation through sustainable agricultur (Wall and Smit 2008), but whether these practices have the greatest potential to limit risk an reduce vulnerability at the farm level remains an untested question. We refer to climate chang adaptation as a farmer's adjustment to the conditions and effects of climate change, which leads to reduction of risk at the farm level (Smith et al. 2008). Some of the climate change impacts that ar anticipated for this region, and to which farmers will be required to respond, include an increas in the number of heavy storms and floods, changes in the suitability for growing traditional crop (e.g., apples, blueberries, and cranberries), changes in insect and plant communities, and decrease in milk production due to hotter summers (Frumhoff et al. 2007; Wolfe et al. 2007). Although th IPCC has responded to criticism that there is insufficient evidence that recent upticks in disaster such as floods and droughts at a regional level are directly caused by climate change, this is primar ily due to a lack of monitoring at local scales. There is an acknowledgement that a changing climat increases vulnerability and risk associated with extreme weather and climatic events (IPCC 2012). The recent devastation of tropical storm Irene in Vermont has exposed the need for stakeholders to develop strategies that respond to extreme climatic events.

16.1.2 Research and Initiative Objectives

The Vermont Agricultural Resilience in a Changing Climate Initiative seeks to make contributions to agroecology through (a) researching and implementing a transdisciplinary, participatory action research (PAR) framework; and (b) reporting on that process with a special focus on stakeholder participation. Specifically, this work in progress is inclusive of multiple stakeholders (researchers with a wide range of foci, a professional advisory committee that includes farmers and other collaborators, farmers who cultivate a wide range of products, and policy makers). Our research approach is to work with diverse stakeholder groups to identify the best management practices (BMPs) that will (1) best help farmers adapt to climate change now and in the future; (2) provide information on how farmers can contribute to GHG mitigation; (3) work with outreach professionals to deliver information about these practices to a broad community of farmers and other professionals; (4) assess the future needs related to climate change of stakeholders in the Vermont agro-food system; and (5) create and utilize tools to inform policy and governance that are specifically related to climate change and agriculture issues.

16.1.3 Agroecology and PAR Frameworks

As a conceptual framework, agroecology has the capacity to address problems at multiple scales (plot, farm, ecosystem, region, state, global), while simultaneously engaging stakeholders and enabling interaction with broader influences, including social, ecological, and economic factors (Francis et al. 2003; Guzmán and Woodgate 2013). Climate change and its relationship to agriculture and agro-food systems is a highly complex interaction, which presents challenges to the economic viability of businesses, the ecological balance, and social well-being. We propose that agroecology can contribute to addressing some of these issues. Many of the political and social components of agroecological theory are concerned with the rural setting, specifically attempting to reconcile conceptual and social factors at the plot, field, and farm scales (Amekawa 2011). Vermont, a small rural state with a long agricultural history (Albers 2002), is an appropriate location to apply this theory. It is worth noting that an agro-food systems approach to agroecology is a relatively recent theoretical and practical application (Francis et al. 2003; Gliessman 2007; Wezel et al. 2009), and prior to current efforts, it has been identified as the weakest contribution to agroecology thus far, and with the most opportunity for contributions to be made in the future (Tomich et al. 2011).

Recent contributions to agroecological theory and practice have argued that transdisciplinary and PAR approaches are well suited to reach a better and more balanced understanding of the social, economic, and ecological forces in agricultural and agro-food systems (Méndez et al. 2013). Transdisciplinary research integrates multiple knowledge systems, including academic disciplines and nonacademic knowledge (e.g., local or indigenous), to seek solutions to complex, real-world issues and problems (Belsky 2002; Francis et al. 2003; Godemann 2008; Stokols 2006). PAR similarly emphasizes exchange and collaboration across knowledge systems, and involves a diversity of stakeholders as active participants in an iterative process that integrates research, reflection, and action. PAR seeks to provide a voice to actors, such as farmers, who have traditionally been excluded from the scientific research process (Bacon et al. 2005; Kindon et al. 2010; Méndez et al. 2013). The integration of multiple academic disciplines and nonacademic knowledge through the participation of key stakeholders is necessary to identify and address threats to ecological and human health at all levels, and to contribute to greater long-term climate change resilience in the agro-food system. The degree and implications of how and when different stakeholders participate in a PAR process represent areas of scholarship with many unanswered questions. Varying levels of participation in problem identification and data collection and analysis, and subsequent action at the community or policy level reflect stages of empowerment and have the capacity to influence the agency of different groups. Although PAR has been criticized for not sufficiently shifting the locus of power from the researcher to other stakeholders (Kindon et al. 2010), it is still rare for papers based on a PAR process to include an analysis of stakeholder participation and subsequent power relationships (Manzo and Brightbill 2010). To date, examples of this power analysis have been published primarily in literature that addresses PAR theory (Figure 16.1), as in Kindon et al. (2010) and Pretty (1995). The assumption of the participation continuum presented in Figure 16.1 is that higher levels of participation lead to greater benefit for stakeholders, and higher levels of empowerment lead to greater interest in and execution of participation. Through this chapter, we attempt to provide an in-process review of how these dynamics have evolved in our initiative and provide reflections on how these dynamics can shift in the second half of this multiyear effort.

Additionally, it is necessary to evaluate the context in which PAR processes occur and potentially compete with other parallel processes. In the case of Vermont, a state that boasts a citizen legislature, farmers and representatives of the university and membership associations are often invited to give testimony on key legislation. Additionally, several senators and representatives themselves own and operate commercial farms. This state's deep connection to agriculture sets the stage for sympathetic legislation, such as the Farm to Plate Investment Program (F2P), which was approved by the Vermont State Senate and House in 2009. One of the results of the F2P process was the development of a network of farmers, funders, service providers, researchers, and policy makers, which allows diverse parties to work together, on an annual basis, to review key problems in the Vermont food system, set goals, and measure progress on those goals. Our team is involved with the F2P process, allowing us to share ideas with individuals and organizations working on related efforts throughout the state.

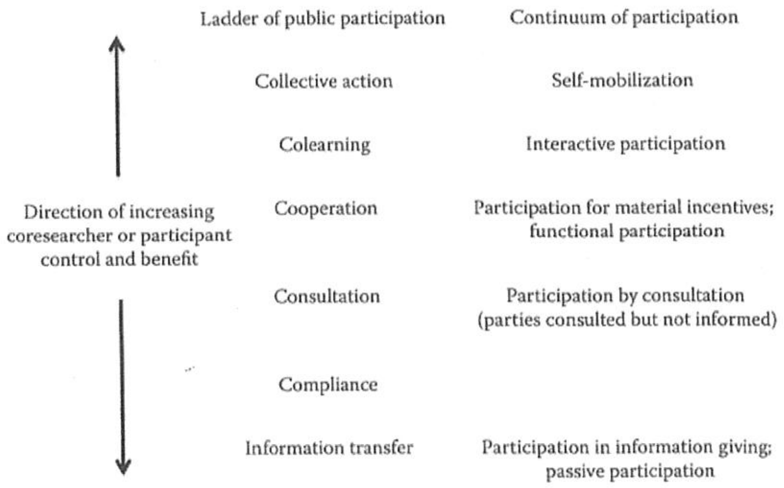

Figure 16.1 Participation continuums. (Adapted from Kindon, S., Pain, R., and Kesby, M. (eds)., *Participatory Action Research Approaches and Methods: Connecting People, Participation and Place*, Routledge, New York, 2010.)

16.2 OUR APPROACH

16.2.1 Climate Change Best Management Practices (CCBMPs)

Farmers constantly innovate in their daily practice, making decisions based on multiple factors on a daily, monthly, seasonal, and yearly basis. Much can be learned by identifying and analyzing existing agricultural management practices that have the potential to adapt to and/or mitigate climate change. *Best management practices* is a commonly used term to describe those approaches that have been tested and proven to have a positive impact on some part of an agricultural system. We identify those BMPs specifically related to addressing climate change as climate change BMPs (CCBMPs). Agroecological analysis has demonstrated how ecologically based and locally designed farming practices can increase the resilience of agroecosystems to extreme climate events. In Central America, Holt-Giménez (2006) compared the impacts of Hurricane Mitch between paired agroecologically and conventionally managed farms. Farms that had established agroecological practices (i.e., soil conservation practices and organic management) fared much better than their conventional counterparts did in terms of soil erosion, economic losses, and vegetation cover. Another study in Chiapas, Mexico, documented that increased vegetation complexity mitigated the damage in coffee farms from one hurricane (Philpott et al. 2008). In Canada, Wall and Smit (2008) documented sustainable agricultural practices that farmers had adopted as an adaptation response to climate change. These included crop and enterprise diversification, land resource management (e.g., conservation tillage and use of shelterbelts), water resource management (e.g., irrigation and use of ponds), and livestock management (e.g., intensive grazing).

One of the outcomes of this work will be to identify what qualities make a BMP a CCBMP. In other words, we are trying to answer the question: "What agricultural practices have the greatest potential to both mitigate GHGs and/or reduce the vulnerability and risk faced by farmers due to climate change?"

16.2.2 Economics of CCBMPs

No examination of CCBMPs and how farmers utilize them would be complete without an economic analysis. Understanding the costs and benefits associated with CCBMPs is particularly necessary given that the majority of farms in Vermont, and in the United States, generally earn negative net income (USDA-NASS 2007). Farmers often do not keep detailed and accurate records of their costs of production. Traditional crop or enterprise budgets are typically constructed by consulting academic experts who assign typical practices and costs to each category. However, this approach fails to represent the heterogeneity of the scales, practices, and experiences of farmers. Short-cut "rules of thumb" such as target revenues for each hour spent harvesting and packing can be dangerously misleading (Conner 2004). Cost measurement is especially difficult on diversified farms, which grow many crops at relatively small scales (Conner and Rangarajan 2009), which is of particular concern in an agroecological context where diversity and small-scale agriculture are often lauded. Knowing costs is also important in pricing decisions and in ensuring that revenues gained from the adoption of practices cover costs. The costs of the implementation of BMPs, and potentially a new suite of CCBMPs, will inform efficient resource allocation toward any future potential scenarios involving adaptation to climate change, carbon trading (i.e., climate change mitigation), or payment for ecosystem service provisions.

16.2.3 Mitigation Potential of CCBMPs

In future climate scenarios, interactions between differing agricultural management practices and projected changes in precipitation regimes and temperature will result in a diversity of potential feedback loops between climate and land use change. In this context, an important research question is whether and how current CCBMPs and conventional farming practices affect carbon and GHG balances. Depending on the diversity of the habitats and the characteristics of the plants that make up a given grower's land, such as maintaining forested areas, high-productivity or high-diversity ecosystems (e.g., Fornara and Tilman 2008), farms may store more carbon (C) to offset GHGs. However, even if a farmer's lands act as a C sink by increasing C storage in biomass and soils (taking up more carbon dioxide [CO_2] from the atmosphere than is released), their net effect on climate will be determined by trace gas emissions (methane [CH_4] and nitrous oxide [N_2O]). Both CH_4 and N_2O are more potent GHGs than CO_2, trapping 25 and 298 times more heat over 100 years than CO_2, respectively (IPCC 2007). The primary sources of N_2O are denitrification and nitrification. Losses of N_2O via denitrification are transient, driven by precipitation events that produce anoxic conditions in the topsoil, which also inhibit nitrification (Parton et al. 1996). CH_4 may also be produced in anoxic soils via microbial methanogenesis. Denitrification is considered to be the primary source of N_2O from agricultural land, but Panek et al. (2000) reported the equal contribution of both processes to total N_2O emissions. N_2O emissions from fertilized agricultural lands may range from 9 to 17 kg N_2O ha^{-1} yr^{-1} (6–11 kg N ha^{-1} yr^{-1}; Frolking et al. 1998), and emitting 1 kg of N as N_2O offsets the permanent storage of 54 kg of C. Thus, a crucial question for managing the C and GHG balances of farmlands now and in the future is how such systems affect not only C storage, but also the production of these potent GHGs.

16.2.4 Governance and Policy through Agent-Based Models

Another key component of our research focuses on better understanding the way that farmers make decisions as they relate to CCBMPs, and how this process interacts with existing or future policies related to climate change. Public policies are designed and executed using multiple sources of information, and there is a growing appreciation for the contribution of complex governance networks in these processes. We argue that computer models increase the power and capacity with which we are able to advance governance theories and frameworks. Governance is defined here as the "means by which an activity or an ensemble of activities is controlled, steered or directed" (Koliba and Zia forthcoming). Heterogeneously acting and interacting agents work within and across organizations; the description of how these actors interact is called *governance infomatics.* Understanding these complex interactions helps network managers to better understand the forces at play, and assists in solving seemingly intractable problems. This is especially relevant to climate change as a large complex problem that exists across multiple scales and involves and affects numerous networks of organizations, governing bodies, and populations.

Considering this, we have utilized an agent-based modeling (ABM) approach, which is a computer simulation experimental method for modeling the emergence of system-wide outcomes that arise from the complex interaction between landscape-level changes and institutional agent decision making (Koliba et al. 2011; Koliba and Zia forthcoming; Zia et al. 2013). In ABM, a system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. Agents may execute various behaviors appropriate for the system that they represent—for example, producing, consuming, or selling. The ABMs are premised on describing a system from the perspective of its constituent units (North and Macal 2007). Computer models of this nature can account for uncertainty and the adaptability of agents and eventually support scenario planning and the nonlinear analysis of farming practice dynamics. These kinds of simulated process-based models allow knowledge to emerge and be utilized throughout the interactive analytic process.

16.2.5 Landscape Visualization and CCBMPs

Our research group has begun to develop a series of landscape visualizations that will enable farmers and other stakeholders to envision the potential impacts and resiliencies associated with the adoption of CCBMPs at both the farm and landscape levels. Both eye-level and orthophoto (map-view) images of photo-realistic landscapes are presented to stakeholder groups to both demonstrate the spatial and visual effects of CCBMP implementation and gauge the utility of this form of imagery within PAR processes. Figures 16.2 and 16.3 show examples of the type of "existing versus proposed" landscape views that we are developing to share with stakeholders. This type of visualization has been increasingly employed in the environmental planning field as a means to communicate the distinctions between different policy, land use, and land management scenarios. Landscape visualizations have become an increasingly important component of environmental decision making and public participation processes, including in natural resource management studies (Pettit et al. 2011), in rural landscape settings (Appleton and Lovett 2003), and in public dialogues about visualizing the impacts associated with climate change (Sheppard and Meitner 2005; Sheppard et al. 2011). Landscape visualizations complement other forms of communication and have been found to be

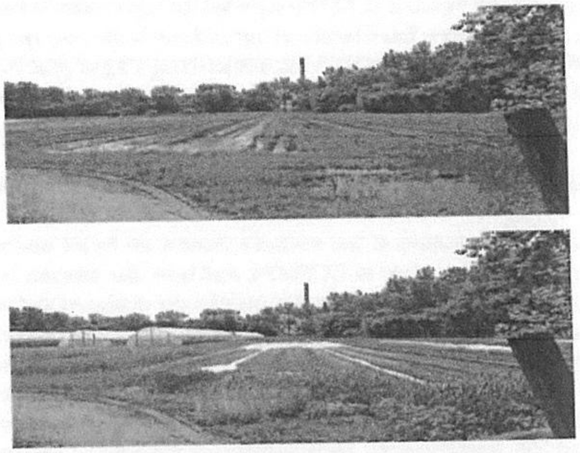

Figure 16.2 **(See color insert)** Photograph of existing vegetable field in a floodplain (*top*) and the proposed condition with hoop houses, crop diversification, and wetlands (*bottom*).

Figure 16.3 **(See color insert)** Photograph of an existing cornfield on a riverbank (*top*) and the proposed condition with riparian buffer (*bottom*).

accessible to audiences from an array of backgrounds, including laypersons (Lewis and Sheppard 2005). Lewis and Sheppard (2006) describe realistic landscape visualizations as a beneficial element in decision making, with demonstrable influences on human behavior and policy structure around climate change. With increased interfacing of landscape visualization techniques using geographic information systems (GIS) and with the recent development of numerous 3-D visualization models, researchers have had increased success in their efforts to communicate current and future land use scenarios to diverse audiences (Ghadirian and Bishop 2008; Griffon et al. 2010). Accordingly, landscape visualization is a logical component of our transdisciplinary research approach.

Figures 16.2 and 16.3 are examples of the type of visualizations of BMPs that we will present to farmers and use to guide discussions in 2014–2015. Both photos were taken in an agricultural area at the Intervale, a conserved agricultural area in Burlington, Vermont, that is highly vulnerable under current climate change scenarios. The land is a floodplain, and is therefore susceptible to flooding, erosion, and contamination from upstream sources. Figure 16.2 depicts a farm field in the Intervale in a partially flooded condition, paired with a visualization of what that same parcel could look like if it was managed with a constructed wetland and alternative drainage practices. Hoop houses that would extend the growing season for farmers are also shown. Figure 16.3 depicts a riverbank, also in the Intervale floodplain, paired with a visualization of what this area could look like with a vegetated riparian buffer and stream bank erosion-prevention BMPs added to it. The riparian buffer would both help sequester carbon and protect the farmland from erosion and flood hazards in the case of extreme weather. These images will be used to facilitate conversations between researchers, outreach professionals, landowners, and managers about the implications of using and not using BMPs and the type of impact that these practices may have under specific climate change scenarios.

16.2.6 Stakeholders and the PAR Approach

The emergence of this initiative in 2011 relied on input from key stakeholders such as the Vermont Agency of Agriculture, the VT Natural Resources Conservation Service, the University of Vermont (UVM) Extension, the Vermont Farm to Plate Network (F2P), the Vermont State Climatologist, Stone Environmental, certified crop advisors, and researchers at other US universities. The input from these key groups and individuals is formalized in our project through an advisory group. Members of the advisory committee include vegetable, dairy, livestock, and diversified farmers, representing trade organizations such as the Vermont Vegetable and Berry Grower's Association, the Farmer's Watershed Alliance (dairy farmers), and the Vermont Grass Farmer's Association (nondairy, pastured livestock farmers). We convene this group two to three times per year to ensure that our goals and potential impacts are relevant, to contribute to the interpretation of research findings, and to contribute to project assessment. We have selected our advisory group based on their interest in this project and their ability to represent farmers, agricultural service providers, researchers, and policy makers to address the impacts of climate change on agriculture in Vermont and nationwide. In addition, we conducted secondary analysis of the reports from farmers submitted through the Vermont Vegetable and Berry Growers Association's "Reports from the Field." We reviewed farmer submissions from 1998 to 2012 to determine if and when this group of farmers was talking about climate change with their peers. Their concerns and attitudes have helped inform our work.

16.3 METHODS

16.3.1 Initial Investigation, Year 1

Figure 16.4 details the progression of research and outreach in this project. What the figure does not show is the informal discussion and problem identification that took place prior to the funding

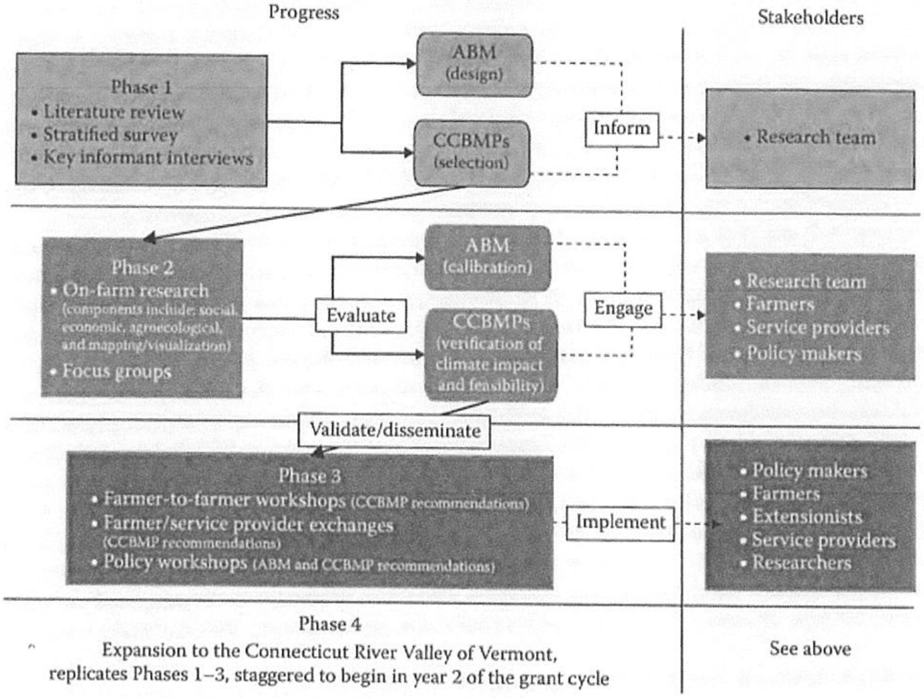

Figure 16.4 Diagrammatic representation of the proposed project, including phases, activities, and stakeholders.

of the project and the development of the research team. The discussions that led to the initiation of this work included conversations among researchers and farmers in the wake of Tropical Storm Irene and the devastation from the storm on Vermont's farms and infrastructure. Additionally, the Agroecology and Rural Livelihoods Research Group (ARLG) facilitated a daylong event in May 2012, targeted toward Vermont agricultural service providers, which attempted to capture information about how these service providers approached the topic of climate change with farmers, and how farmers differentiated between climate change and extreme weather as influential concepts. Preceding the event, we conducted a survey of Vermont agricultural service providers, which captured their initial thoughts and concerns about climate change and how farmers integrate these concerns into their decision-making processes (Schattman et al. 2012). In addition, several members of our project team are extension and outreach professionals, who work with farmers, other technical service providers, and community members on a regular basis. These team members serve as key informants, and are invaluable to our efforts because of the degree to which they represent the concerns and perspectives of these stakeholder groups.

In 2012, the research team began by identifying goals and opportunities for collaboration, identifying working norms, and conducting a literature review on BMPs related to climate change which were most applicable to farms in the northeastern United States. All principal investigators contributed to the development of a stratified survey, which was conducted in the Champlain Valley of Vermont, specifically in the Lamoille and Missisquoi watersheds. These watersheds were selected for two reasons: (1) farms located in the Lamoille watershed are representative of farms in Vermont as a state (Lovell et al. 2010a), and (2) the principal investigators who lead the ABM portion of this project are conducting additional research in the Missisquoi watershed and hoped to use this survey to enhance the depth of their investigations. The survey was tested with five farmers in the Champlain Valley of Vermont in the winter of 2013, and was revised to incorporate their feedback.

In order to ensure our survey was delivered to farmers within the specified watersheds, our group contracted the National Agriculture Statistics Service (NASS) to administer an anonymous survey. An initial postcard was sent to farms that met the location criteria. The mailing inquired about land use, ownership, and primary sources of income, and concluded by asking the participant if he or she would be willing to fill out a longer questionnaire. This screening survey was sent to 1104 farms, with a total response rate of 20%. Of those who replied, 128 responded that they would be willing to fill out the longer questionnaire. The full survey questionnaire was mailed to these respondents between April and July 2013. Of these, 48 completed surveys were returned by mail, and 31 were collected over the phone by NASS enumerators, for a total of 79 complete responses. This resulted in a confidence interval of 10.49% at a 95% confidence level.

Simultaneous to the survey, we conducted a secondary document review of Reports from the Field. These reports are submitted by growers on a semimonthly basis to the Vermont Vegetable and Berry Growers Association, who then publishes the reports through a list serve and in print through the Vermont Agency of Agriculture, Food and Market's monthly newspaper. The reports range in topics from evaluating crop varieties to commenting on the weather to markets and customers. We used a double-coding approach (Boyatzis 1998) to investigate if and when farmers were sharing their thoughts about climate change, and in what context. In addition, we coded for specific plant diseases, pests, dry and wet weather, and extreme weather events. The coding and analysis were conducted using HyperRESEARCH (Researchware Inc. 2013), a qualitative data analysis software.

In addition to the survey and document review efforts, and equally as important, Year 1 was the period in which our research team began to build relationships within our own ranks and with professional partners (including farmers), initiate outreach, and solicit additional funding to support our work. While our group is committed to a PAR process, it is exceedingly challenging to secure the funding that is needed to support the reflective and relationship-building components of this approach. We firmly emphasize that the time required to build relationships and trust within the research team and with our external partners is the foundation on which the quality of our research and outreach depends.

16.3.2 Agent-Based Models, Years 1 and 2

A multilevel ABM was developed using AnyLogic Professional Version 6.6 (AnyLogic 2013). Farmers will be modeled as farm-level agents, who will exist under the institutional jurisdictions of various town, county, regional, and state government agencies. The higher-level agents are described as institutional agents. The decision heuristics for both farm-level and institutional agents will be derived from analyzing existing datasets, focus groups, the farmer survey, interviews, and policy documentation analysis. The ABM will be built on land use datasets of the study area and will be calibrated to the observed land use and carbon emission patterns from 2000 to 2010. The calibrated models will then be used to generate and test experimental simulations for alternate policy and decision behavioral scenarios. The findings from calibrated ABMs for various scenarios will be shared with broader stakeholder groups in mediated modeling sessions. Further, emergent scenarios will be derived through stakeholder inputs and will be tested in the calibrated ABMs. The decision rules of the decision-making agents such as farmers, households, businesses, and organizations/entities will be derived/simulated based on empirical datasets. Empirical datasets are being used to calibrate these models, including the utilization of new farmer surveys and interviews, analysis of existing datasets including the US Department of Agriculture (USDA) census of agriculture, the US census, the National Land Cover Database (NLCD), and permitting data collected by the state's Agency of Agriculture.

16.3.3 On-Farm Research, Years 2 and 3

16.3.3.1 Farm Selection

Four components of this investigation require researchers to engage directly with farmers as coinvestigators. It was important to choose farmers carefully for this stage of the research, as we not only want collaborators in the research, but partners who will also support our outreach efforts. In order to select which farmers to approach, in the initial screening, we used a multistage process as follows:

1. We sourced names from key contacts, including members of our research team, as well as professional and technical services providers. The survey described in Section 16.3.1 also concluded with a question asking respondents to indicate if they were willing to partake in on-farm research, and this provided a sample of willing farmers.
2. The farmers were sorted by type of farm (vegetable, dairy, meat producers, or diversified), with a goal of 12 total participating farmers, with 3 replicate farms in each category. Maple and hay producers were included if they also produced goods in one of the four listed categories, but were excluded if not. This was because there were a limited number of BMPs that our group could address for those who exclusively produced maple and hay.
3. In order to ensure that our economic analysis would ultimately be useful to commercial producers in the Northeast, farmers were sorted by gross income in 2011 (if they were survey respondents), and those who grossed <$10,000 were excluded.
4. The BMPs employed by each farm were listed (if they were survey respondents), and cross-referenced with those BMPs of most interest to the on-farm research team. The BMPs of high priority were no-till cultivation, cover cropping, storm water runoff management, rotational grazing, and conservation buffers. These were selected based on data collected (surveys and interviews), as well as the experience, professional interest, and expertise of the principal investigators.
5. Farmers were then contacted, asked to participate, and offered compensation at an hourly rate. They were given an outline of the project that detailed the on-farm research activities proposed and an estimate of the amount of time that they would be expected to contribute to each component.

16.3.3.2 Farmer Interviews

The on-farm research portion of this project will include qualitative interviews to assess farmer and technical service provider knowledge about climate change, reasons for adopting specific BMPs, and decision-making processes. Interviews will be transcribed and analyzed using HyperRESEARCH (Researchware Inc. 2013). A double-coder, constant comparison approach to analysis will look for emergent themes, using a grounded theory approach (Charmaz 2005; Glaser 1992; Glaser and Strauss 1967; Strauss and Corbin 1990). We will also utilize structuration theory, which asserts that both the agent, or the actor, and the social or organizational structure in which that agent operates are equally important for understanding behavior and outcomes (Giddens 1984; Held and Thompson 1989). In this light, we will examine critical institutional, governmental, and organizational influences that impact the levels of risk experienced at the farm level. As an addition to the interview tool, we will use a modified version of an evaluation tool developed by Lovell et al. (2010b) to record farmer and service provider perceptions of BMPs and how these BMPs may or may not help to mitigate the risk of climate change at the farm level. This evaluation tool addresses the social/cultural, economic, and ecological aspects of BMPs. Farmers are asked to rank each aspect on a scale of −2 (extreme negative impact) to +2 (extreme positive impact), with a score of 0 being no impact or not applicable. This will help us to create a relative qualitatively analyzed ranking (Boyatzis 1998) of CCBMPs from the farmer and the technical service provider perspective, which will be critical for an intentional reflection of our investigation and will also help to inform future outreach, information sharing, and research.

16.3.3.3 Economic Analyses

The economists in our group will work directly with farmers to conduct an economic analysis of potential CCBMPs, including cost analysis and projections, with the goal of evaluating their viability and barriers for adoption by farmers in the Northeast (over a 3 year period). In addition, this activity will yield information on potential ways to improve CCBMPs and make them more attractive to farmers from an economic standpoint. We will develop cost functions for each of the identified farms and CCBMPs that show promise, using the following basic formula:

$$C_{ij} = \sum_{1}^{F} \frac{Pf * Xf}{Tf} + \sum_{1}^{V} Piv * Xiv$$

where the cost (C) of implementing mitigation or adaptation practices i on farm j in a given year is the sum of the fixed (f) costs (quantity [X] times price [P]) amortized over T years of service plus the sum of variable costs. Fixed costs include the installation of infrastructure, vegetation, and so on, with an expected service of more than 1 year. Variable costs include those with a single year of service. For each CCBMP, input and labor costs, as well as machinery and fuel use, as applicable, will be calculated. If owner-operator or family labor is used, an opportunity cost will be assigned. The measurements will constitute a series of snapshots over farms and years, with attention to the phase of adoption (new, continuing) and various farm attributes (crops, scales, tenure), in order to understand the costs of CCBMP use in a variety of settings. The data will be collected via paper or electronic forms according to the farmer's choice. Farmers will record all relevant costs each month and provide completed forms for data processing and analysis. Any revenues resulting from the adoption of CCBMPs will be recorded as well. Each year, the data will be compiled into annual cost and revenue functions for each farm with key expenses and categories highlighted (Conner and Rangarajan 2009; Conner et al. 2010).

16.3.3.4 C Sequestration and GHG Emissions

To quantify the climate change mitigation potential and begin to understand the GHG balance of specific CCBMPs, we will measure the C storage and GHG emissions of selected farms and CCBMPs. To calculate the climate change mitigation potential of CCBMPs within a given farm type, we will measure the C stored (in CO_2 equivalents [CO_2E]) in soils and aboveground biomass (AGB) and GHG emissions (CO_2, N_2O, and CH_4). The carbon storage in AGB and soils will be measured in all farm type and CCBMP combinations. Herbaceous AGB will be estimated by clipping peak standing AGB in a 0.075 m^2 area in three or four locations within each farm type. Woody AGB will be estimated using allometric equations developed for northeastern forests. Soil C will be measured in each plot to a depth of 1 m increments of 0–10, 10–20, and 20–60 cm. The bulk density will also be determined using these soil cores (drying and weighing each soil core's known soil volume prior to compositing). The soil texture in one location per farm type and CCBMP combination will be determined by the hydrometer method (0–20 cm layer only). GHG emissions will be sampled in three or four locations per farm type. On each sampling date, we will measure CH_4 and N_2O fluxes using the vented, closed chamber method (Hutchinson and Mosier 1981). CO_2 fluxes will be measured using an LI-COR 8100A soil respiration survey system with a 20 cm diameter chamber. Inorganic soil N, soil temperature, and soil moisture (gravimetric) will be measured concurrently, as GHG flux covariates. We will measure inorganic soil N (as a covariate for N_2O fluxes) by taking three or four soil cores (0–20 cm) per farm type and CCBMP combination. Cores will be composited and subsampled for 2 M KCl extraction. These extracts will be analyzed for inorganic soil N at UVM's Agricultural and Environmental Testing Lab (Lachat QuickChem FIA). Year-round measurements (as described above) will be taken across 3 years.

16.3.3.5 *Landscape Visualization*

Photo-simulated landscape visualizations using both landscape-scale (high-resolution orthophotos) and site-scale perspectives (photos at eye level) will be developed for at least one of each farm type. Adobe Photoshop and ArcMap GIS software will be used to create the scenario visualizations. These visualizations will provide more in-depth descriptions of CCBMP potential on-farm, which will complement in-depth farmer-to-farmer outreach activities. Photo simulations will be debuted at several winter farm conferences in the region in 2014, where i-clickers (survey tools) will be used to gauge stakeholder preferences in response to (1) the acceptability and practicality of the CCBMPs shown and (2) the utility of these visualizations in the knowledge-sharing pieces of a transdisciplinary research and outreach approach. In 2015, smaller focus groups will also have an opportunity to react to a library of landscape visualizations representing the different CCBMPs implemented across the four major farm types explored in this study.

16.4 SELECTED PRELIMINARY RESULTS

16.4.1 Survey

Respondents to our survey own 15,106 acres and lease an additional 1,891 acres in the area of study. The average acreage owned by a respondent is 220 acres (SD of 219), and the average acreage leased is 67 acres (SD of 62). The median acreage owned is 150 acres, and the median acreage leased is 55 acres. Table 16.1 shows that the respondents to this survey have a wide variety of management approaches, including certified organic, organic but not certified, conventional, biodynamic, and integrated pest management. Growers who identified their management practices as conventional were represented more heavily than other categories. Of greater interest is the number of respondents who reported multiple management strategies including conventional approaches paired with certified and noncertified organic practices. Our survey did not address growers' understanding of what qualifies as a noncertified organic approach.

Table 16.1 Description of Survey Respondents

Farm Management Type, $n=76$	
Certified organic	16
Certified organic and conventional	1
Conventional	34
Organic, not certified	18
Organic, not certified and conventional	2
Integrated pest management (IPM)	1
Organic, biodynamic, and nutrient-dense soil management	1
Sustainable	1
Number of Years Spent Farming, $n=76$	
<3	0
3–7	4
8–10	3
11–20	13
21–30	16
31–40	26
41–50	8
50+	6

In relation to the number of years farming, responses were categorized into decades of experience with the exception of those who have farmed for fewer than 10 years. These "beginning farmers" were separated out into three categories according to the beginning farmer typology described by Scheils (2002). This typology will be used in subsequent analysis when examining farmers' perceptions of how climate change will affect their business and livelihood.

16.4.2 Reports from the Field

Frequency reports from the secondary analysis of grower reports (Reports from the Field) indicate that growers mention climate change in passing, but without great frequency. Table 16.2 demonstrates the typical comments submitted by growers, distinguished between comments that directly reference climate change and those that address extreme weather events. Of the comments that address climate change, the two selected comments demonstrate a laissez-faire attitude that thinly veils a willingness (or perhaps a need) to test new conditions, push seasonal limits, and take risks in diversified operations. A review of these comments showed that growers were much more likely to discuss extreme weather events. While heat and dryness were associated with low plant disease pressure, excess rain was commonly linked with evidence of foliar and root diseases.

Table 16.2 Farmer Voices from Reports from the Field, 1998–2012

Topic	Year	Farmer Voices
Climate Change	1998	"There's still time to squeeze out a few bucks to lose on… a late planting of radishes, arugula, cilantro, and spinach. If September temperatures are going to be in the 80s, might as well take advantage of global warming."
	1998	"We are finally conceding to global warming and putting out 75 peach trees. If they make it and fruit 2 out of 4 years they will be worth the investment. If the winter is so cold it whacks them then maybe it will be cold enough to reduce some of the overwintering insect pests we have been seeing in large numbers the last couple of years: squash bugs, striped cucumber beetles, Colorado potato beetles, and first-generation corn borer."
Extreme Weather Events	1998	"The ice storm and wet weather caused loss of 75% of my newly planted raspberries this year (2,000 plants)… They started out great in the spring and then they started dying back probably due to severe winter injury after an open winter without snow cover."
	2000	"Fourteen inches of snow plus several days of rain have not helped our seedings of field crops, and to date we have only 2 seedings in of peas, carrots, beets, turnips, and radishes."
	2000	"On Friday evening June 5, a hail storm blew through the Connecticut Valley at high velocity. The storm raged for about 20 minutes with high winds, heavy rains, and large hail. All of our spring crops were shredded or buried in mud. We lost peas, strawberries, lettuce, tomatoes, melons, etc.. However, I haven't seen a flea beetle yet, and I don't dare complain about the few cutworms I've seen. We have postponed our first CSA (Community Supported Agriculture program) distribution for a month."
	2004	"This has been a difficult spring. First we have a couple of intense heat days in April. Then excessive wind drying things out, and May gave us 10 inches of rain and lots of grey cool cloudy weather. That was followed by 2 days of 90° weather that gets blown out by a storm that deposits 1.5 inches of rain and some trees in about an hour. When that's done we have frost warnings on June 10th and 11th. The strawberries have just plain freaked out. They are ripening the earliest in recent memory, yet we can't find a beet green or radish close to harvest. Despite my best efforts (and a second mortgage to pay for fungicides and stickers) 10 inches of rain has taken its toll… Greenhouse sales were strong, thank goodness…."

Reports on weather events included mild winters and lack of snow cover damaging overwintering plants. On the other side of the coin, growers also reported too much snow in May. High winds and hail featured in several reports, while some growers wrote during the years when the range of weather events seemed to affect farms. Other reports revealed that while some growers are susceptible to flooding, and managing too much water can be a problem, others are deeply reliant on irrigation to ensure both crop availability and quality. The key question raised by this review of the Reports from the Field is whether farmers distinguish between weather and climate, and how their decision making is influenced by their understanding of these two concepts. A review of the reports indicates that weather and the effects of climate and weather combined are of immediate concern to fruit and vegetable growers in Vermont, but long-term planning based on grower knowledge of climate change is discussed less frequently. The implications of this are related to farmers' ability to cope with changing climatic conditions. This is a line of inquiry that we will follow with additional analysis of the survey and qualitative interviews.

16.4.3 Agent-Based Model

Details of the initial ABM results can be found in a recent report by members of this project (Tsai et al. 2012). The hypothesis posed by members of this team was that financial considerations in combination with factors such as climate change and public policy are the primary influences on farmers' land use decisions. Researchers constructed six scenarios to represent the varying presence of exogenous factors (climate change, public policy, etc.) on the financial conditions of farmers. By running these scenarios through the ABM, two conclusions were reached: (1) the primary factor influencing farmers' decisions regarding land use is their financial condition, and (2) exogenous factors that reduce financial stress among farmers have the greatest potential for limiting the shrinkage of agricultural lands and the growth in forested lands in Vermont.

16.5 DISCUSSION

16.5.1 PAR Process: Taking Stock of Transdisciplinary Process Participation

Critical to the PAR process is the inclusion of stakeholders in multiple phases of the project, as well as an examination of the levels of stakeholder engagement. Figure 16.4 illustrates not only the phases of this project, but also at what stages of the work the different stakeholders are involved. As discussed previously, Kindon et al. (2010) outline a continuum of participation in PAR projects as compared with a ladder of public participation. The assumption of this continuum is that greater levels of participation lead to greater benefit for stakeholders, and that greater degrees of empowerment lead to greater interest in and execution of participation (see Figure 16.1). This is of particular interest in an agroecological framework that prioritizes the empowerment of the disenfranchised (Tomich et al. 2011). Using their framework, we have evaluated the degree of participation of each stakeholder group in our project, and identified areas in which we can improve our facilitation of stakeholder involvement.

As Table 16.3 demonstrates, not all stakeholders in this PAR effort participate equally, and by extension, not all stakeholders have parity of power within the research. It is critical to note that, while much is written about increasing the empowerment of disenfranchised groups in both agroecology (as a social movement) and PAR, an analysis of the ability or willingness to participate in decisions affecting a particular group's own condition is rarely conducted at the onset of the work. Questions can be raised about both the level of power held by stakeholders prior to the project (Stillman 2013), and the degree to which a PAR process can change the level of empowerment held by a particular stakeholder group. For example, our project focuses on the resilience and risk

Table 16.3 Stakeholder Participation Analysis Summary: A Snapshot of Years 1 of 3

Stakeholder Group	Level of Participation	Roles and Responsibilities	Team Goals for Years 2 and 3
Farmers	Participation for material incentives; functional participation	Provide on-farm research setting and time, inform research outcomes and benefit from research for management decisions, participate in advisory committee, test interview and survey instruments, and give feedback	Increase participation and investment in the project (to what rung on the ladder and how?). Empower farmers through farmer-to-farmer training on specific CCBMPs, provide input into the next iteration of our work
Technical service providers	Co-learning	Contribute to defining research goals and approach, contribute to framing the issue, key team members for outreach portion of the project	Contribute to data analysis, engage other technical assistance (TA) providers in Train the Trainer workshops, maintain relationships with researchers and farmers, provide input into the next iteration of our work
University-based researchers and extension/outreach professionals	Co-learning	Contribute to defining the research goals and approach, contribute to framing the issue, the key team members for research, and the outreach portions of the project	Complete the on-farm portion of the research, conduct analysis, deliver results to outreach professionals, and collaborate with them to provide training that places farmers and TA providers in leadership roles. Apply for additional funding for the next iteration of our work
Policy makers	Information transfer	Participate in information giving/receiving	Receive information from our project to inform future policy decisions

management among farmers, but to date the farmers involved in our project participate functionally (testing interview and survey instruments, providing feedback, and serving on the advisory committee) and for incentives (in return for providing a setting for on-farm research), but not by setting research goals and objectives. Future iterations of our efforts are structurally designed to allow for and facilitate greater degrees of farmer participation in key decision-making processes, including the direction of new research objectives. Since participation serves as a proxy for the empowerment experienced by stakeholders, attention must be paid to how participation changes through iterative PAR cycles. Greater inclusion of the knowledge and opinion of stakeholders, especially those not normally included in agenda-setting processes, benefits not only these stakeholders but the work as a whole (Stillman 2013).

This framing of agroecology and PAR requires us to pay more rigorous attention to how power is distributed in our process, and how our process interacts with notions of social justice and equity (Gatenby and Humphries 2000). It is through PAR that we can address the key ethical and moral concerns of our research. Specifically, we draw from the work of Emanuel et al. (2000), which examined many international standards for ethical research and articulated the following criteria:

> To be ethical, research must have social or scientific value, demonstrate scientific validity, be conducted using fair subject/participant selection, have a favorable risk–benefit ratio, be subject to independent review, practice informed consent of research participants, and demonstrate respect for potential and enrolled participants. (Emanuel et al., 2000, p. 2703)

Khanlou and Peter (2005) review PAR approaches in light of these criteria, and encourage us to carefully examine the following key factors: (1) whether our PAR efforts truly have emancipatory potential; (2) whether our motivating foci are based on rigorously examined scientific knowledge; and (3) that we do not select participants solely because of their level of disenfranchisement or privilege. In our work, the emancipatory potential of our efforts is grounded in the assumption that stakeholders (Kania and Kramer 2011), and researchers in particular (Francis et al. 2008; Rosenfield 1992), are constrained by narrow understandings of complex problems. By bringing together researchers and stakeholders from a variety of backgrounds and disciplines, we seek to broaden our understanding of the problem (in this instance, the effects of climate change on the agro-food system) and increase the creativity with which we conceptualize and apply solutions (Rosenfield 1992). Through the integration of economic analysis, biogeochemistry, and qualitative and policy analysis, we seek to bring scientific rigor to the community level and let further inquiry be based on the needs of the community, as identified by the community (Bacon et al. 2005).

While our transdisciplinary approach is designed to maximize the effectiveness of our research and outreach, it is not without its challenges. Kessel and Rosenfield (2008) identify many potential benefits and challenges to transdisciplinary research. Among those highlighted, we have experienced an openness and appreciation of other team members' knowledge and level of expertise, as well as a shared understanding of the problem at hand. Prior to our project, many of the participating researchers and extension educators knew one another and had a positive rapport, though most had a limited depth of knowledge about their colleagues' research. One of the first challenges that we faced was getting researchers to find the time so that team members could get to know each other and their work in more depth. Fry (2001) identifies building this rapport, deep understanding, and appreciation of other's disciplines as one of the key elements to a successful transdisciplinary research process. To facilitate this, we provided time at full team meetings for individual team members to present their work, a practice that we will continue in the second half of the project and in future iterations of the PAR process. This seemed to work well for everyone to become more familiar with the components of the research that each individual or group was working on, and it also facilitated the integration of the different approaches utilized. This is something that we will also do with farmers in order to integrate the knowledge derived from experience (rather than academic), though we are still in the process of finalizing the methods that we will use.

The challenges face by our team, which were predicted by Kessel and Rosenfield (2008), include concerns about the diffusion of work because of multiple foci and the lack of a preexisting research framework. The differences in how different stakeholders are evaluated can also present a challenge, such as the difference between how extension professionals and tenure-track faculty are evaluated by the chairs of their department or their supervisors (McDowell 2001). We address these concerns by relying on strong facilitation to keep the group informed of individual and group efforts in both research and publication, and by carefully documenting and reviewing our emerging process (Alrøe and Kristensen 2002). In addition, one of the greatest challenges to a project that is both transdisciplinary and based on PAR is the friction between scientific knowledge and local knowledge, as well as the conflict between differing goals and agendas, which can potentially derail trust and collaboration between researchers and other stakeholders, and bears special sensitivity when conducting PAR.

Finally, Khanlou and Peter (2005) encourage researchers to be attentive to the possible risks that research and its resulting social action pose to all stakeholders; to seek an ethical and independent review of the research at each iterative cycle of the PAR process; to require informed consent from stakeholders involved in the research process; and to address stakeholder concerns with the research process in a transparent and open manner.

16.5.2 Lessons Learned and Future Directions

This thoughtful analysis in each PAR process and conversation between stakeholders are needed for two reasons: (1) to increase the dialogue among parties and identify those areas where power dynamics can result in intentional or unintentional oppression (Chatterdon et al. 2010) and (2) to address the concerns that PAR processes may be biased by the social agendas of the participants (including the researchers). We subscribe to the perspective that all research is biased to varying degrees (Alrøe and Kristensen 2002). The transparency of bias is one tool that we employ to address concerns about research validity, while simultaneously developing the trust and openness between collaborators that is necessary to succeed using a PAR approach (Kessel and Rosenfield 2008). In light of this, we wish to make two points that will add to how we have understood and employed PAR in an agroecological context.

First, we acknowledge that, at its inception, this was not a farmer-generated project. Rather, it was conceived of within the context of the university, and because of this, we were required to invest time and resources into proposal writing, resources garnering, and team building. To integrate multiple stakeholder views into the initial stages of this project, we shaped our initial research goals through meetings with agricultural service providers and policy makers in Vermont (such as the Vermont Natural Resources Conservation Service) and relied heavily on the extension educators on our team. We also drew on the input of team members who are otherwise embedded in the agricultural community of our region. While the farmers themselves were not well represented at this stage in the research, PAR is an iterative process and future opportunities for defining agendas will incorporate their voices more actively. We strive to be attentive to the needs of farmers in the context of climate change, since PAR as an approach has emerged as a response to top-down, academic, and policy-driven research (Fernandez et al. 2013). Ultimately, we hope that this will guide our work, making it of real value to farmers and the public at large, in accordance with the original mission and goals of public research institutions (McDowell 2001).

Secondly, temporal factors play a significant role in our conceptualization of empowerment in a PAR process. While Table 16.3 illustrates the roles and levels of participation in our project to date, it is only as representative as a snapshot. PAR processes are long-term, committed endeavors with a multiplicity of dimensions that are designed to address complex problems such as climate change (as is the case in this project). Our ultimate hope is that we can contribute to a process following PAR principles that brings us all to a place where everyone has a more equal voice in the dialogue. To do this, methods of tracking and reporting the levels of participation, empowerment, and investment in research processes should be developed. These will lead to a deeper understanding of how the power dynamics in PAR efforts shift over time, or differ depending on who is involved at what point in the process. This could also lead to a framework for evaluating when PAR is most applicable and of value to stakeholders versus when more straightforward research approaches are appropriate. Currently, we are not aware of any precedent for assessing the levels of stakeholder participation and empowerment in PAR processes over time.

In this light, and humbly accepting that we could not do it all, we are working to build relationships, generate data, and contribute as much as we can to both Vermont agriculture and relevant policy dialogue and practice. It is our hope that our experiences and reflections on them will contribute to the efforts of others seeking to use transdisciplinary approaches to find grounded, innovative solutions for complex problems.

SUMMARY

Complex problems, such as agricultural resiliency in the face of climate change, require multistakeholder and transdisciplinary approaches. This chapter presents an innovative research and outreach effort employed in Vermont to address the challenges associated with climate change that farms may face in the near and distant future. Our research team is composed of eight faculty with a diversity of specialties including agricultural economics, agroecology, climate change science, extension, sustainable agriculture, governance, and policy. In this chapter, we present both conceptual and empirical contributions to PAR and agroecological thought, which are drawn from our experiences with the Vermont Agricultural Resilience in a Changing Climate Initiative, an in-progress, multiyear effort. This chapter discusses the successes and challenges of this approach, with special attention given to the levels of stakeholder participation and empowerment, as well as our experiences working with a highly diverse team of researchers and stakeholders on a highly complex problem. We find that a framework for evaluating change in stakeholder power and parity in PAR processes over time is needed. In addition, our approach to transdisciplinary work related to agriculture and climate change can be used as a blueprint, to be adapted and improved on by other groups. The richness of this effort comes from an integration of theory and practice, shown through our reflections.

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REFERENCES

Albers, J. 2002. *Hands on the Land: A History of the Vermont Landscape*. Cambridge: MIT Press.

Alrøe, H. F. and E. S. Kristensen. 2002. Towards a systemic research methodology in agriculture: Rethinking the role of values in science. *Agr Hum Values* 19(1):3–23.

Amekawa, Y. 2011. Agroecology and sustainable livelihoods: Towards an integrated approach to rural development. *J Sustain Agr* 35:118–162.

AnyLogic. 2013. AnyLogic multimedia simulation software, professional version 6.6. http://www.anylogic.com/ (accessed: February 12, 2014).

Appleton, K. and A. Lovett. 2003. GIS-based visualisation of rural landscapes: Defining "sufficient" realism for environmental decision-making. *Landscape Urban Plan* 65(3):117–131.

Bacon, C., E. Méndez, and M. Brown. 2005. Participatory action research and support for community development and conservation: Examples from shade coffee landscapes in Nicaragua and El Salvador. Santa Cruz, CA. http://escholarship.org/uc/item/1qv2r5d8.pdf (accessed: September 28th, 2013).

Belsky, J. M. 2002. Beyond the natural resource and environmental sociology divide: Insights from a transdisciplinary perspective. *Soc Natur Resour* 15(3):269–280.

Bernstien, L., P. Bosch, O. Canziani et al. 2007. Climate change 2007: An assessment of the Intergovernmental Panel on Climate Change. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf (accessed: December 15, 2013).

Boyatzis, R. E. 1998. *Transforming Qualitative Information: Thematic Analysis and Code Development*. Thousand Oaks, CA: Sage Publications.

Charmaz, K. 2005. Grounded theory in the 21st century: Applications for advancing social justice studies. In Y. S. Denzin and N. K. Lincoln (eds), *The Sage Handbook of Qualitative Research*, pp. 507–535. Thousand Oaks, CA: Sage Publications.

Chatterdon, R., D. Fuller, and P. Routledge. 2010. Relating action to activism: Theoretical and methodological reflections. In S. Kindon, R. Pain, and M. Kesby (eds), *Participatory Action Research Approaches and Methods: Connecting People, Participation and Place*, pp. 216–222. New York: Routledge.

Conner, D. 2004. Shortcuts to measuring crop profitability: Are they misleading? Marketing, May. http://marketingpwt.dyson.cornell.edu/SmartMarketing/pdfs/conner5-04.pdf (accessed: December 15, 2013).

Conner, D. and A. Rangarajan. 2009. Production costs of organic vegetable farms: Two case studies from Pennsylvania. *Horttechnology* 19:193–199.

Conner, D. S., K. B. Waldman, A. D. Montri, M. W. Hamm, and J. A. Biernbaum. 2010. Hoophouse contributions to economic viability: Nine Michigan case studies. *Horttechnology* 20:877–894.

Emanuel, E. J., D. Wendler, and C. Grady. 2000. What makes clinical research ethical? *J Am Med Assoc* 283:2701–2711.

Eriksen, P. J., J. S. I. Ingram, and D. M. Liverman. 2009. Food security and global environmental change: Emerging challenges. *Environ Sci Policy* 12:373–377.

Fernandez, M., V. E. Méndez, and C. Bacon. 2013. Seasonal hunger in coffee communities: integrated analysis of livelihoods, agroecology, and food sovereignty with smallholders of Mexico and Nicaragua. In Conference Paper #42, Food Sovereignty: A Critical Dialogue. International Conference Yale University. September 14–15.

Fornara, D. A. and D. Tilman. 2008. Plant functional composition influences rates of soil carbon and nitrogen accumulation. *J Ecol* 96:314–322.

Francis, C., G. Lieblein, T. A. Breland et al. 2008. Transdisciplinary research for a sustainable agriculture and food sector. *Agron J* 100:771–776.

Francis, C., G. Lieblein, S. Gliessman et al. 2003. Agroecology: The ecology of food systems. *J Sustain Agr* 22:99–118.

Frolking, S. E., J. L. Bubier, T. R. Moore et al. 1998. Relationship between ecosystem productivity and photosynthetically active radiation for northern peatlands. *Global Biogeochem Cy* 12:115–126.

Frumhoff, P. C., J. J. McCarthy, J. M. Melillo et al. 2007. An integrated climate change assessment for the northeast United States. *Mitig Adapt Strateg Glob Chang* 13:419–423.

Fry, G. L. A. 2001. Multifunctional landscapes—Towards transdisciplinary research. *Landscape Urban Plan* 57:159–168.

Gatenby, B. and M. Humphries. 2000. Feminist participatory action research: Methodological and ethical issues. *Womens Stud Int Forum* 23:89–105.

Ghadirian, P. and I. D. Bishop. 2008. Integration of augmented reality and GIS: A new approach to realistic landscape visualisation. *Landscape Urban Plan* 86:226–232.

Giddens, A. 1984. *The Constitution of Society: Outline of the Theory of Structuration*. Berkeley, CA: University of California Press.

Glaser, B. G. 1992. *Basics of Grounded Theory Analysis*. Mill Valley, CA: Sociology Press.

Glaser, B. G. and A. L. Strauss. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago: Aldine Press.

Gliessman, S. R. 2007. *Agroecology: The Ecology of Sustainable Food Systems*, 2nd edn. Boca Raton, FL: CRC Press.

Godemann, J. 2008. Knowledge integration: A key challenge for transdisciplinary cooperation. *Environ Educ Res* 14:625–641.

Griffon, S., A. Nespoulous, J. Cheylan, P. Marty, and D. Auclair. 2010. Virtual reality for cultural landscape visualization. *Virtual Real* 15:279–294.

Guzmán, E. S. and G. Woodgate. 2013. Foundations in agrarian social thought and sociological theory agroecology. *Agroecol Sustain Food Syst* 37:32–44.

Held, D. and J. B. Thompson. 1989. *Social Theory of Modern Societies: Anthony Giddens and His Critics*. New York: Cambridge University Press.

Holt-Giménez, E. 2006. *Campesino a Campesino: Voices from Latin America's Farmer to Farmer Movement for Sustainable Agriculture*. Oakland, CA: Food First Books.

Hutchinson, G. L. and A. R. Mosier. 1981. Improved soil cover method for field measurement of nitrous oxide fluxes. *Soil Sci Soc Am J* 45:311–316.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change 2007—The physical science basis: Working group I contribution to the fourth assessment report of the IPCC volume 4 of Assessment report. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf (accessed: December 15, 2014).

IPCC (Intergovernmental Panel on Climate Change). 2012. Summary for policymakers: Managing the risks of extreme events and disasters to advance climate change adaptation. http://ebooks.cambridge.org/ref/id/CBO9781139177245 (accessed: December 19, 2013).

Kania, B. J. and M. Kramer. 2011. Collective impact. Stanford Social Innovation Review. http://www.capsonoma.org/downloads/AgendaPacketV1.pdf (accessed: January 13, 2014).

Kessel, F. and P. L. Rosenfield. 2008. Toward transdisciplinary research: Historical and contemporary perspectives. *Am J Prev Med* 35:S225–234.

Khanlou, N. and E. Peter. 2005. Participatory action research: Considerations for ethical review. *Soc Sci Med* 60:2333–2340.

Kindon, S., R. Pain, and M. Kesby (eds). 2010. Participatory action research: Origins, approaches and methods. In *Participatory Action Research Approaches and Methods: Connecting People, Participation and Place*, pp. 9–18. New York: Routledge.

Koliba, C. and A. Zia. forthcoming. Governance informatics: Using computer simulation models to deepen situational awareness and governance design considerations. In E. DeSouza and K. Johnston (eds), *Policy Informatics*. Cambridge, MA: MIT Press.

Koliba, C., A. Zia, and B. Lee. 2011. Governance informatics: Utilizing computer simulation models to manage complex governance networks. *Innov J* 16:1–26.

Lal, P., J. R. R. Alavalapati, and E. D. Mercer. 2011. Socio-economic impacts of climate change on rural United States. *Mitig Adapt Strateg Glob Chang* 16:819–844.

Lewis, J. L. and S. R. J. Sheppard. 2005. Ancient values, new challenges: Indigenous spiritual perceptions of landscapes and forest management. *Soc Natur Resour* 18:907–920.

Lewis, J. L. and S. R. J. Sheppard. 2006. Culture and communication: Can landscape visualization improve forest management consultation with indigenous communities? *Landscape Urban Plan* 77:291–313.

Lovell, S. T., V. E. Méndez, D. L. Erickson, C. Nathan, and S. DeSantis. 2010a. Extent, pattern, and multifunctionality of treed habitats on farms in Vermont, USA. *Agroforest Syst* 80:153–171.

Lovell, S. T., S. DeSantis, C. A. Nathan et al. 2010b. Integrating agroecology and landscape multifunctionality in Vermont: An evolving framework to evaluate the design of agroecosystems. *Agr Syst* 103:327–341.

Manzo, L. C. and N. Brightbill. 2010. Toward a participatory ethics. In S. Kindon, R. Pain, and M. Kesby (eds), *Participatory Action Research Approaches and Methods: Connecting People, Participation and Place*, pp. 33–40. New York: Routledge.

McDowell, G. R. 2001. *Land-Grant Universities and Extension into the 21st Century: Renegotiating or Abandoning a Social Contract*. Ames, IA: Iowa State University Press.

Méndez, V., C. Bacon, and R. Cohen. 2013. Agroecology as a transdisciplinary, participatory, and action-oriented approach. *Agroecol Sustain Food Syst* 37:37–41.

North, M. J. and C. M. Macal. 2007. *Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation.* Oxford: Oxford University Press.

Panek, J. A., P. A. Matson, I. Ortiz-Monasteria, and P. Brooks. 2000. Distinguishing nitrification and denitrification sources of N_2O in a Mexican wheat system using ^{15}N. *Ecol Appl* 10:506–514.

Parton, W. J., A. R. Mosier, D. S. Ojima et al. 1996. Generalized model for N_2 and N_2O production from nitrification and denitrification. *Global Biogeochem Cy* 10:401–412.

Pettit, C. J., C. M. Raymond, B. A. Bryan, and H. Lewis. 2011. Identifying strengths and weaknesses of landscape visualisation for effective communication of future alternatives. *Landscape Urban Plan* 100:231–241.

Philpott, S. M., B. B. Lin, S. Jha, and S. J. Brines. 2008. A multi-scale assessment of hurricane impacts on agricultural landscapes based on land use and topographic features. *Agr Ecosyst Environs* 128:12–20.

Pretty, J. N. 1995. Participatory learning for sustainable agriculture. *World Dev* 23:1247–1263.

Researchware Inc. 2013. HyperRESEARCH 3.5.2. http://www.researchware.com (accessed: December 13, 2013).

Rosenfield, P. L. 1992. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Soc Sci Med* 35:1343–1357.

Schattman, R., V. E. Méndez, and K. Westdjik. 2012. Vermont farm resilience in a changing climate: Survey of Vermont agricultural service providers. http://www.uvm.edu/~agroecol/SchattmanR&VEMendez_VTServiceProviderClimateChangeSurveyReport_2012.pdf (accessed: January 3, 2014).

Scheils, P. 2002. What does the term "new farmer" mean? Growing new farmers, professional development discussion series #101. http://www.smallfarm.org/uploads/uploads/Files/GNF_PD_-What_does_the_term_new_farmer_mean.pdf (accessed: December 15, 2013).

Scherr, S. J. and S. Sthapit. 2009. *Mitigating Climate Change through Food and Land Use Change*. Washington, DC: Ecoagriculture Partners and Worldwatch Institute.

Sheppard, S. R. J. and M. Meitner. 2005. Using multi-criteria analysis and visualisation for sustainable forest management planning with stakeholder groups. *Forest Ecol Manag* 207:171–187.

Sheppard, S. R. J., A. Shaw, D. Flanders et al. 2011. Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. *Futures* 43:400–412.

Smith, P., D. Martino, Z. Çai et al. 2008. Greenhouse gas mitigation in agriculture. *Philos Trans Roy Soc B* 363:789–813.

Smith, P. and J. E. Olesen. 2010. Synergies between the mitigation of, and adaptation to, climate change in agriculture. *J Agr Sci* 148:543–552.

Stillman, L. 2013. Participatory action research and inclusive information and knowledge management for empowerment. In *Proceedings of the Sixth International Conference on Information and Communications Technologies and Development Notes—ICTD'13*, vol. 2, pp. 163–166. New York: ACM Press.

Stokols, D. 2006. Toward a science of transdisciplinary action research. *Am J Commun Psychol* 38:63–77.

Strauss, A. L. and J. M. Corbin. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Thousand Oaks, CA: Sage Publications.

Tomich, T. P., S. Brodt, H. Ferris et al. 2011. Agroecology: A review from a global-change perspective. *Annu Rev Environ Resour* 36:193–222.

Tsai, Y., A. Zia, C. Koliba et al. 2012. *Impacts of Land Managers' Decisions on Land-Use Transitions within Missisquoi Watershed Vermont: An Application of Agent-Based Modeling System*. Burlington, VT: Vermont EPSCoR.

Tubiello, F., P. G. Neofotis, and E. Fernandes. 2008. Climate change response strategies for agriculture: Challenges and opportunities for the 21st century. Paper #42, Agriculture and Rural Development Discussion. Washington, DC: The World Bank.

USDA-NASS. 2007. Census of Agriculture. http://www.agcensus.usda.gov/ (accessed November 23, 2013).

Wall, E. and B. Smit. 2008. Climate change adaptation in light of sustainable agriculture. *J Sustain Agr* 27:37–41.

Walthall, C. L., P. Hatfield, L. Backlund et al. 2012. *Climate Change and Agriculture in the United States: Effects and Adaptation*. Washington, DC: USDA. http://www.usda.gov/oce/climate_change/effects_2012/CC and Agriculture Report (02-04-2013)b.pdf (accessed: December 15, 2013).

Wezel, A., S. Bellon, T. Doré et al. 2009. Agroecology as a science, a movement and a practice. A review. *Agron Sustain Dev* 29:503–515.

Wolfe, D. W., L. Ziska, C. Petzoldt et al. 2007. Projected change in climate thresholds in the northeastern U.S.: Implications for crops, pests, livestock, and farmers. *Mitig Adapt Strateg Glob Chang* 13:555–575.

Zia, A., C. Koliba, and Y. Tian. 2013. Governance network analysis: Experimental simulations of alternate institutional designs for intergovernmental project prioritization processes. In L. Gerrits and P. K. Marks (eds), *COMPACT I: Public Administration in Complexity*, pp. 144–165. Litchfield Park, AZ: Emergent Publications.

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