THREE ESSAYS ON DECISION-MAKING IN CONTEXTS OF CHANGE AND UNCERTAINTY

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by

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The undersigned, appointed by the dean of Graduate School, have examined the dissertation entitled

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DEDICATION

There is a popular African proverb that says, “It takes a village…,” and in truth the contributions of many people have been critical to the success of my academic program. I would like to thank my parents, Dr. Friday and Dr. Dorka Bekee; my siblings, Bariture and Barivure; Dr. Martin and Mrs. Ebitari Fregene; Prof. Tosan Fregene; Mr. Nelson Kogbara and family; and my uncles, aunts, and cousins; for their love, sacrifices, and prayers throughout this journey. I am also grateful for many dear friends that have become family.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Today's world is characterized by various changing conditions and increased unpredictability, ranging from environmental upheavals to technological advancements. This dissertation is an attempt to advance our understanding of the processes and actions of decision-makers that aid in moderating harm and exploiting beneficial windows of opportunities in either anticipatory or reactive manners. Adopting a multidisciplinary approach, the first essay examines the issue of rural household resilience. This essay synthesizes some of the main contributions from various subfields and proposes a typology (i.e., a systematic classification of related concepts) to organize knowledge in this arena, as well as to guide future research and review efforts. The second essay assesses the resilience capacities of agro-pastoralists in the Altiplano region of Bolivia. The Bolivian Altiplano is characterized by climate variability and change. The households in this region are constantly engaging in a range of resilience-building activities, and this study investigates the effectiveness of those efforts. The third essay focuses on issues relating to the adoption of smart farm networks. Due to the rise in threats that transcend farm boundaries, management practices at the landscape or community level—aided by computing and communications technology—are often required to respond adequately. This study employs a translational research process to examine the views of commodity crop farmers in the United States on the use of digital technologies in collaborative contexts. Taken together, the essays in this dissertation contribute to the discussion and examination of decision-making in the contexts of change and uncertainty.

CHAPTER 1. INTRODUCTION

The actions of agents are based on observations of their environment. Such observations could for instance be made through biological sensory processes in the case of humans. However, observations are often incomplete or noisy and agents resort to decision-making processes to determine their actions (Kochenderfer 2015). The decision-making process of actors is not necessarily straightforward. The outcomes of choices are not always known, and decisions may sometimes have to be made in collaborative environments with multiple agents. Furthermore, decision-makers often have to deal with various scenarios of change.

The process of decision-making becomes more complex when such changes lie at the intersection of human-nature relationships. With respect to the dynamics between humans and their environment, Constantino and Weber (2021) put it succinctly:

> "Not only are key variables and probability distributions unknown (parametric uncertainty), but the underlying generative model is changing and complex (structural uncertainty), which objective function (and in turn whose interests) to be prioritized is unclear (ethical uncertainty), and future trajectories are numerous" (p. 152).

Take climate change for example. In addition to influencing the behavior and distribution of organisms, climatic changes also have genetic effects on many species (Frank and Hoffmann, 2010). Additionally, climate change could have various detrimental effects on humans such as reduction in food supply (e.g., through weather shocks),

increasing risks to human health (e.g., through heat waves), and impeding several other development outcomes (NOAA 2021; Ayers and Dodman 2010).

Although it is vital to investigate the impact of these changing conditions, and valuable to document the ways in which humans experience them, it is also important to advance our understanding of the adaptive actions of people (Moser and Ekstrom 2010). Unraveling such processes and actions will help inform decision-making which will ultimately assist with moderating harm and exploiting beneficial windows of opportunities in the face of increased unpredictability.

Similarly, when it comes to decisions about adoption of new technologies, there is considerable uncertainty since new innovations are not completely known or understood in advance (Chavas and Nauges 2020). For instance, with respect to a new agricultural technology, farmers will have to deal with the uncertainty surrounding the suitability of the technology to their operations, uncertainty about how best to use it, and uncertainty about future earnings (Chavas and Nauges 2020). These uncertainties have resulted in low and slow adoption of new agricultural technologies in some regions, thereby frustrating technology development and promotion efforts (Yigezu et al. 2018). However, processes such as learning—whether from one's own experience or the experience of others—can help reduce the imperfect knowledge that acts as a barrier to technology adoption (Pannell et al. 2006; Marra et al. 2003; Foster and Rosenzweig, 1995).

Thus, investigating the processes and actions that agents adopt to help them take advantage of opportunities, or to cope with, manage, or adjust to hazards—especially in the face of increasing volatilities—is of necessity. This dissertation is therefore an attempt

to advance the discussion and examination of decision-making in the contexts of change and uncertainty. The three essays presented in this dissertation explore conditions and attributes that help decision-makers limit the adverse effects of perturbations on their wellbeing or take advantage of opportunities, in either anticipatory or reactive manners. The structure of the rest of this dissertation is as follows.

Chapter 2 examines the issue of rural household resilience. Due to the increase in both the frequency and severity of shocks and stressors that rural households are faced with, a vast array of studies has emerged in recent times on matters relating to their resilience. Scholarship in this field has benefitted from insights from multiple disciplines including applied economics, disaster risk management, and human ecology, to name a few. These diverse contributions, although beneficial and necessary, have led to what appears to be discrepancies in the research arena. Using a bibliometric approach and thematic clustering, the chapter sheds light on the research landscape of rural household resilience. Furthermore, this essay synthesizes some of the main contributions from various subfields and offers a systematic way for studies to approach the subject matter. From issues such as the objective and subjective dimensions of resilience characterization and measurement, to the degree of integration of the broader social ecological systems within which households exist, the systematic classification of related concepts carried out in this essay helps to organize knowledge, as well as aims to provide a guiding framework for future research and review efforts.

Chapter 3 of this dissertation builds on the chapter before it by empirically investigating the resilience of rural households in the Altiplano region of Bolivia.

Specifically, this essay seeks to assess the resilience capacities of agro-pastoralists to environmental shocks. The Bolivian Altiplano is characterized by climate variability and change. The households in this region are constantly engaging in resilience-building activities and there is need for the effectiveness of such efforts to be evaluated. This essay employs a structural equation model to assess various factors such as the sociodemographic characteristics and livelihood strategies of households, as well as households' perceptions (e.g., self-assessments of their capabilities). By integrating both objective and subjective measurements, this study takes advantage of the value inherent in both approaches by accounting for the tangible (or directly observable/measurable) elements of resilience like household assets and income, as well as the intangible elements like household agency, risk perception, and other psychosocial factors that shape the responses of households.

Chapter 4 of this dissertation focuses on issues relating to the adoption of smart farm networks. Due to natural phenomena like global warming and climate change, agricultural production is increasingly faced with threats that transcend farm boundaries. Management practices at the landscape or community level—aided by computing and communications technology—are often required to adequately respond to these new challenges. However, behavioral and social factors act as barriers to farmers harnessing all the potential gains inherent in technological solutions. This study employs a translational research process to examine the drivers of adoption of smart farm networks among commodity crop farmers in the United States. The study utilizes focus groups and questionnaires to bring to the fore farmers' views on the use of digital technologies in

collaborative contexts. This essay sheds light on the concerns farmers have relating to smart and connected farm networks, including their perceptions about potential features of the network, as well as their attitudes towards other stakeholders involved in the management and utilization of such innovations. Furthermore, the participatory approach adopted for this study helps provide insights into the process of developing innovations that are both actionable and trusted by potential end users.

Chapter 5 concludes the dissertation.

References

Ayers, J. and Dodman, D., 2010. Climate change adaptation and development I: the state of the debate. *Progress in Development Studies*, *10*(2), pp.161-168.

Chavas, J.P. and Nauges, C., 2020. Uncertainty, learning, and technology adoption in agriculture. *Applied Economic Perspectives and Policy*, *42*(1), pp.42-53.

Constantino, S.M. and Weber, E.U., 2021. Decision-making under the deep uncertainty of climate change: The psychological and political agency of narratives. *Current opinion in psychology*, *42*, pp.151-159.

Franks, S.J. and Hoffmann, A.A., 2012. Genetics of climate change adaptation. *Annual Review of Genetics*, *46*, pp.185-208.

Foster, A.D. and Rosenzweig, M.R., 1995. Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy*, *103*(6), pp.1176-1209.

Marra, M., Pannell, D.J. and Ghadim, A.A., 2003. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?. *Agricultural Systems*, *75*(2-3), pp.215-234.

Moser, S.C. and Ekstrom, J.A., 2010. A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences*, *107*(51), pp.22026-22031.

National Oceanic and Atmospheric Administration. 2021. Climate change impacts. https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts (Accessed May 2, 2023)

Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F. and Wilkinson, R., 2006. Understanding and promoting adoption of conservation practices by rural landholders. *Australian journal of experimental agriculture*, *46*(11), pp.1407-1424.

Kochenderfer, M.J., 2015. *Decision making under uncertainty: theory and application*. MIT press.

Smit, B. and Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), pp.282-292.

Yigezu, Y.A., Mugera, A., El-Shater, T., Aw-Hassan, A., Piggin, C., Haddad, A., Khalil, Y. and Loss, S., 2018. Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. *Technological Forecasting and Social Change*, *134*, pp.199-206.

CHAPTER 2. RESILIENCE OF RURAL HOUSEHOLDS: INSIGHTS FROM A MULTIDISCIPLINARY LITERATURE[1]

2.1. Introduction

Rural households are faced with various shocks that adversely affect their welfare and are, therefore, constantly negotiating ways to mitigate risks and respond to the changing conditions around them (Chambers and Conway 1992). Such perturbations could range from environmental upheavals (e.g., floods or droughts) to economic turmoil (e.g., price fluctuations) or social disruptions (e.g., political conflicts or changes in government policy). It is important to note that these disturbances are not usually one-dimensional (e.g., solely environmental). They have various qualitative and time dimensions, and they elicit either ex ante or ex post responses from households (Valdivia 2004).

In general, resilience is considered to be the capacity of individuals, groups, or systems to limit vulnerability to various shocks and stressors in either an anticipatory or reactive manner, without jeopardizing long-term viability (Awazi, Tchamba, and Avana 2019; Serfilippi and Ramnath 2018; Tanner et al. 2015;). However, directing the focus of resilience studies to humans and their livelihoods puts people at the center of the discussion and takes into consideration the capabilities and agency people possess (Tanner et al. 2015).

[1]This chapter is modified Bekee, B. and Valdivia, C., 2023. Resilience of Rural Households: Insights from a Multidisciplinary Literature. *Sustainability*, *15*(6), p.5500.

It has since been noted that the household is often the appropriate unit of analysis in rural areas for crucial decisions such as consumption and labor supply (Wheelock and Oughton 1996). Specifically with regard to social-ecological analysis, the household's operations represent a more significant unit than the individual (Ruiz-Ballesteros and Ramos-Ballesteros 2019). In addition, the household provides the relevant social, cultural, and historical context within which individuals are situated, as well as offers a suitable lens for examining a variety of motivations that influence the observed actions of individuals [6,8]. Therefore, from a rural household perspective, resilience can be viewed as comprising the various characteristics, actions, and strategies that positively moderate the relationship between shocks and development outcomes (Constas, Frankenberger, and Hoddinott 2014).

Due to the increase in both the frequency and severity of the shocks and stressors that households face, a vast array of studies has emerged on the issue of rural household resilience in recent times. Researchers from a wide range of fields including applied economics, disaster risk reduction/management, human ecology, and human geography, among others, have embraced the task of investigating this important subject. However, this increased interest and scrutiny from practitioners and scholars has resulted in a lack of consensus in its definition and measurement, among other aspects, as well as in our ability to synthesize findings and recommendations (Douxchamps et al. 2017; Serfilippi and Ramnath 2018).

Sometimes, the extent of the divergence noticed in the literature makes one wonder if it is the same concept being studied or whether it is just a case of different

dimensions of resilience being examined (Ansah, Gardebroek, and Ihle 2019), or even more, if resilience is so remarkably contextual that it leaves little to no room for the cross-comparability of studies. This paper is an attempt to address some of these concerns and to offer a systematic approach to further carry out research on the subject matter.

2.1.1. Aims of This Study

With variations in resilience conceptualizations, as well as in the resulting approaches to investigating how rural households can build resilience (Serfilippi and Ramnath 2018; Barrett et al. 2021), it is important to synthesize existing knowledge in this subfield to better direct future studies. In the words of Elinor Ostrom,

> "Without a common taxonomy of core variables, research conducted by scholars from multiple disciplines tends to focus on variables of major interest to their own disciplines without recording, measuring, controlling for, or even thinking of other variables that might account for the patterns of interactions and outcomes observed" (Ostrom 2007, 15186).

The study of rural household resilience benefits from insights from multiple disciplines. However, there has been limited scrutiny on the issue from a more holistic point of view. This study aims to fill that gap and highlights the complementary nature of research from different fields. The present study does not attempt to take on the ambitious goal of laying out all the relevant pieces to consider in an inquiry of rural household resilience. Additionally, the goal of this paper is not to carry out a quantitative systematic review of the literature. It has been pointed out that such a task would be of

limited utility due to the significantly non-representative nature of wellbeing indicators, shocks, and study regions about the topic found in the literature (Barrett et al. 2021).

Rather, this paper conducts a more general knowledge synthesis and offers a systematic classification of existing knowledge on the subject from several subfields. In this regard, a major objective of this paper is to produce a typology that captures different elements of these research strands and offers a framework that can be applied across various settings. Such a task is necessary since resilience has been pointed out to be an arena for generating integrative science and interdisciplinary collaboration in promoting a more sustainable development for humanity (Folke 2006). Furthermore, such a typology can be useful in guiding subsequent (systematic) review efforts in the field of rural household resilience, as well as help build a pipeline of studies that produce evidence that can be replicated across a range of settings.

2.2. Methodology

This study begins by providing a broad overview of knowledge on rural household resilience from different disciplines. Several reviews along different dimensions of resilience relating to rural households have already been carried out in the literature. For example, Serfilippi and Ramnath (2018) provide an overview of competing resilience definitions used by researchers and development organizations. Additionally, they compare resilience with vulnerability and sustainability; evaluate some of the common frameworks employed in the analysis of resilience; and present a list of indicators that could help in its measurement. Douxchamps et al. (Douxchamps et al. 2017) conduct a

similar review and focus more on the existing resilience assessment tools that have been created for the context of climate change and agricultural development. On the other hand, Ansah et al. (Ansah, Gardebroek, and Ihle 2019) provide a review of resilience concepts, methodologies, and empirical evidence strictly from a food security perspective.

More recently, and more closely related with some of the goals of this present work, Barrett et al. (Barrett et al. 2021) carry out a scoping review and examine how resilience has been conceptualized in the international development literature. They probe the accompanying analyses that follow such theoretical underpinnings, as well as the purposes, findings, limitations, and implications of empirical studies on the subject matter. They consider both the individual and household level studies and focus on low- and middle-income countries.

The review carried out in this study is distinct in some of its objectives and approach. It begins by conducting a bibliometric analysis to intentionally uncover the breadth and nature of disciplinary contributions to the study of rural household resilience. Bibliometric analyses are often employed to analyze the pattern and context of knowledge production in a subject area (Qin et al. 2020). They are also helpful in identifying subdomains of research fields. The keywords used in the bibliometric search were informed by the literature and additional suggestions were received from other researchers in the field. Search strings included phrases like {resilien*[2] capacit*},

[2] (The wildcard symbol (*) represents zero or more non-space characters. This ensures that all words beginning with the suggested phrase are captured)

{livelihood* resilien*}, {resilient household*}, {development resilien*} {livelihood* adaptat*}, {socio-ecological/socio-environmental resilien*}, {socio-ecological/socio-environmental adapt*}, etc. The systematic search was conducted in Scopus database between January and February 2021 and the resulting analysis was carried out using Microsoft Excel and VOSViewer 1.6.11. (Additional details of the bibliometric analysis and output are available from the authors upon request).

Following the bibliometric review, a qualitative thematic clustering was carried out. The goal was to provide a general overview of the field of rural household resilience. For this, results from the bibliometric analysis were complemented with a "snowball" reference selection. That is, other relevant articles not captured by the systematic search (e.g., due to different keywords provided by the authors) were also incorporated into the document reviewed for this study. For instance, articles that lend insights into the theoretical/conceptual underpinnings of a research strand were included in the discussions, even if they did not constitute a part of the database for the bibliometric analysis.

The themes used for the clustering were informed by elements of resilience studies found in the literature. Specifically, studies were broadly grouped based on the major outcomes of interest in those studies and by how resilience is both conceptualized and operationalized. The paper then culminates by offering a typology and discussing various issues that future studies on rural household resilience should carefully consider. The proposed typology is informed by practical considerations involved in conducting a

study on the resilience of rural households, such as deliberations surrounding how resilience is framed and made operational for a study.

2.3. Overview of the Literature

The research landscape on resilience of rural households is vibrant and has been experiencing exponential growth over the past decade. The dates of publications spanned about three decades, with the earliest work published in 1992. However, among all the articles used in this study, only three were published in the 90's. Over 95 percent of the articles were published from 2010 onwards, signaling the increased appeal of household resilience to researchers.

About 3000 authors contributed to the documents used in this analysis. The individually most cited authors were Berkes F., Twyman C., and Stringer L. C., with 615, 419 and 306 citations, respectively. The most cited work in the database was by Berkes and Jolly (2002), titled: "Adapting to climate change: Social-ecological resilience in a Canadian western arctic community." There were over 70 journals with at least three publications, and with over 2000 citations and 38 articles, *Ecology and Society* was top-ranked (Table 2.1). However, *Global Environmental Change* and *World Development* had the greatest link strengths (i.e., in terms of cross-citations from other journals) with 57 and 56, respectively (Figure 2.1).

Resilience, climate change, adaptation, vulnerability, adaptive capacity, livelihoods, and food security were found to be the most commonly used author keywords in the database used for the bibliometric analysis. Figure 2.2 below displays the co-

occurrence network of author keywords. The figure reveals some of the common themes that have received greater attention in the field ranging from specific livelihood practices/strategies (e.g., agroforestry, migration) to countries/regions (e.g., Bangladesh, Africa) and shocks/stressors (e.g., climate change, floods).

Table 2.1. Most impactful journals

Journal	Total Link Strength	No. of Publications	Citations
Global Environmental Change	57	25	1476
World Development	56	18	289
Ecology and Society	40	38	2101
International Journal of Disaster Risk	32	25	299
Land Use Policy	28	21	254
Regional Environmental Change	26	21	378
Geoforum	24	6	282
Environmental Science and Policy	22	9	309
Sustainability	21	31	141
Food Security	18	8	89

These results from the bibliometric analysis help to highlight the multidisciplinary nature of research on rural household resilience. This article then proceeds by providing a brief overview of the literature to shed light on some of the major insights and theories that are informing and being produced by research studies. For this paper, academic work on the subject matter is broadly grouped into two research strands: the *Human Systems Research Strand* and the S*ocial-Ecological Systems Research Strand*, and, where applicable, corresponding sub-themes under a strand are referred to as *Clusters*.

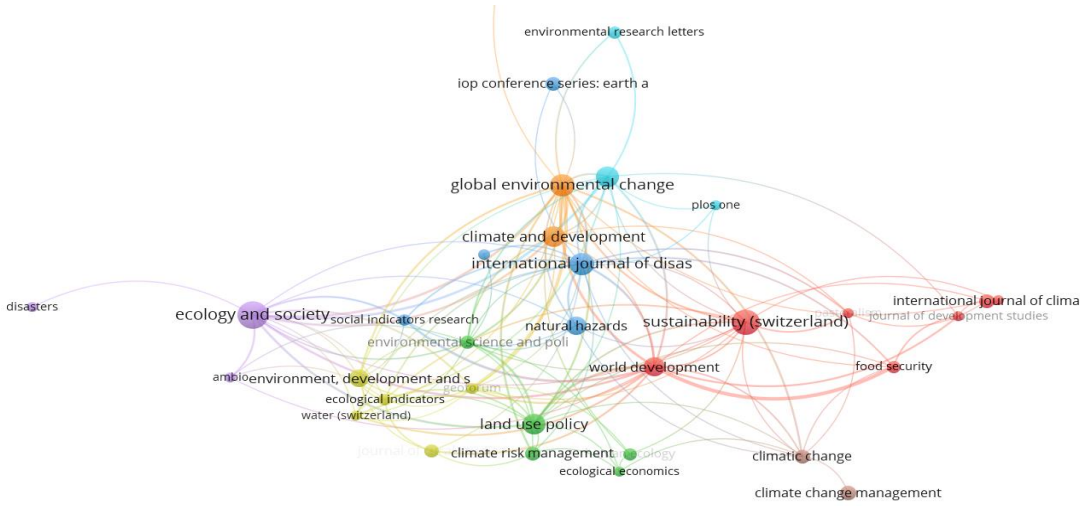


Figure 2.1: Citation networks by publication source. The circle size is weighted by number of articles (Note: Only journals with at least five citations were utilized for the citation network analysis.).

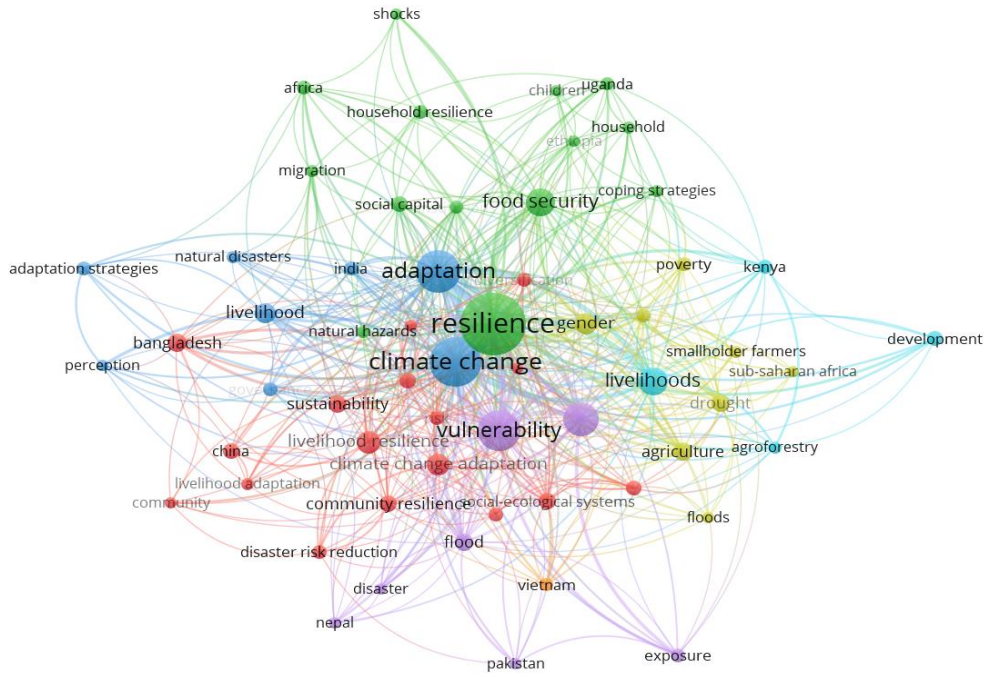


Figure 2.2. Author keyword co-occurrence. The circle size is weighted by the number of occurrences. (Note: Only keywords with at least eight occurrences were utilized.).

It should, however, be noted that the groupings delineated in this overview are not necessarily mutually exclusive, as it is common for studies to incorporate elements of the various research classes—albeit to different degrees. The goal of such a classification is simply to illuminate different aspects researchers take into consideration when investigating rural household resilience, and to provide a framework that highlights elements of the different approaches. These groupings then provide a springboard for which the typology emerges. The article proceeds by briefly describing these broad approaches:

2.3.1. Human Systems Research Strand

2.3.1.1. Cluster 1

In general, this research cluster considers resilience as a set of conditions or attributes that enable households to achieve resilience and attempts to quantitatively measure the concept for research purposes, as well as for the monitoring and evaluation of development projects (Smith and Frankenberger 2018). Resilience is often linked to outcomes such as food and nutrition security, asset accumulation, health status, and other observable measures of household wellbeing.

A major line of scholarship within this research cluster adopts the concept of *development resilience*, defined as "the capacity over time of a person, household or other aggregate unit to avoid poverty in the face of various stressors and in the wake of myriad shocks" (Barrett and Constas 2014, 14626). Resilient units are those that maintain this high capacity over time. In many instances, an asset-based approach is often favored over

income- or expenditure-based poverty measures in this cluster (Carter and Barrett 2006). Assets are broadly considered to be "state/stock variables used to generate income" (Barrett, Garg, and McBride 2016, 305), and they include "productive and financial wealth, as well as social, geographic and market access positions that confer economic advantage" (Carter and Barrett 2006, 179).

The theoretical underpinning for this research theme is that of stochastic welfare dynamics or poverty traps/dynamics, with insights from the literatures on risk and vulnerability (Cissé and Barrett 2018). It is argued that in light of initial ability and asset levels, poverty can become self-reinforcing due to structural and behavioral mechanisms such as market failures, social exclusion, underinvestment in higher-return assets/inefficient investments, etc., and these cause low living standards to persist (Barrett and Carter 2013).

Wellbeing outcomes—which are subject to random shocks but determined by choices that are constrained by nature, human institutions, and resource availability— fall within certain ranges (or *stable states*) that are not expected to change over time without interventions (Barrett and Constas 2014). Since the concept of development is normative by nature, it is argued that resilience in this context implies preventing a movement to lower undesirable states for those that are currently nonpoor, as well as enabling a transition to better wellbeing regimes for the current poor (Barrett and Constas 2014). In this subdomain, resilience has also been interpreted as the (non)persistence of shocks, i.e., how long a household experiences the effects of a shock (Knippenberg, Jensen, and Constas 2019).

Some other bodies of work are also prominent in this subfield, such as that of the Resilience Analysis and Policies team at the Food and Agricultural Organization (FAO) through the introduction of the Resilience Index Measurement and Analysis (RIMA) tool (and subsequently, RIMA-II). Consistent with its organizational mandate, the FAO RIMA approach directs its focus to the food systems, and specifically to the food security status of the household (FAO 2016). This interest on household food security has been the focus of several studies (Otchere and Handa 2022; Brück, d'Errico, and Pietrelli 2019; d'Errico, Grazioli, and Pietrelli 2018). However, other scholars have adopted the approach and used it in other non-food security contexts (Haile, Seyoum, and Azmeraw 2021).

The RIMA-II and other similar frameworks (Smith and Frankenberger 2018) attempt to capture the possible pathways through which households may be able to moderate the impact of a shock on their wellbeing. Pillars of resilience are constructed using time-variant and time-invariant characteristics and activities. In general, the pillars of resilience are taken to be absorptive, adaptive, and transformative capacities (Béné et al. 2012), and indicators that reflect these capacities are then chosen. However, RIMA-II uses a practical classification based on its food security outcome of interest, thus resulting to unique resilience pillars such as access to basic services, assets, social safety nets, sensitivity, and adaptive capacity (FAO 2016).

2.3.1.2. Cluster 2

Within the human systems research strand, a theme around the subjective dimension of resilience has emerged over time. Scholars in this field argue that there is often an assumption of a consensus on "desired states" (Tanner et al. 2015)—which are

usually defined by the prevailing power dynamics—or that a desired state even exists, and such thinking is sometimes viewed as "*akin to 'imposed rationality' that is alien to the practice of ordinary people*" (Brown 2014, 109).

Accordingly, calls have been made to complement standard objective indices with subjective measures in resilience studies, as it is believed that people can self-evaluate their capacities, capabilities, and limits (Jones and Tanner 2017). Likewise, the existing variation in resilience conceptualizations and the value-laden nature of some of its constituent objective indicators have been argued to give further grounds to the potential of subjective approaches (Jones and Tanner 2017). Furthermore, it is stated that subjective measures may prove to be better at capturing less-tangible features of resilience such as entitlement and power (Jones and d'Errico 2019), or even courage, optimism, and faith (Shah, Angeles, and Harris 2017).

For instance, a subjective approach to resilience highlights people's differences in perceiving risks, which could shape their resulting anticipatory actions (Tanner et al. 2015). Risk attitudes—which comprises of the "perceptions about the probability and severity of risk associated with change as well as the costs and benefits associated with adapting" (Cinner and Barnes 2019, 54)—are considered to be subjective and socially constructed, and impose a limit to adaptation actions of decision-makers (Adger et al. 2009). Similarly, perceptions of the riskiness of possible responses following the event of a shock are also believed to shape resulting behavior (Béné et al. 2019).

Additionally, people's perception of their ability to handle hazards has been shown to influence their adaptation responses to adverse events (Béné et al. 2016). For example,

it was found that the decisions of some households in Bangladesh to remain or leave their community in the face of environmental disasters was partly due to their self-confidence and belief in their ability to bounce back (Béné, Frankenberger, and Nelson 2015). It is posited that some other factors such as strong occupational identity or place attachment can as well limit people's ability to re-imagine themselves in other roles (Cinner and Barnes 2019). This could prevent them from exploring alternative livelihood strategies, thereby undermining their overall resilience.

In essence, this research cluster has emanated to help capture aspects of resilience that objective indicators may miss or inadequately account for. Studies in this cluster often highlight the role of cultural and societal norms and values in shaping the response of individuals and groups, and ultimately, their resilience.

2.3.2. Social-Ecological Systems Research Strand

Studies in this research strand are characterized by their presentation of the intricately interconnected nature of human and natural systems. Social-ecological systems (SES) are complex and comprise multiple subsystems and internal variables that interact to produce outcomes that feed right back into these (and other) subsystems and their components (Ostrom 2009). In addition, these systems are adaptive, i.e., they tend to evolve in their "genetics, behaviors, or spatial distributions" based on the outcomes of the interactions that occur within them (Folke 2006).

It has been pointed out that adaptive systems are process-dependent and organic, often with multiple *stable states* (or regimes); while regime shifts—changes to alternative

states with different structures and functions—are the consequences of the erosion of resilience being often caused by human actions (Folke 2006; Scheffer et al. 2001). Studies adopting the SES approach attempt to illuminate the manner in which human activities alter and are affected by the structure and function of ecosystems (Cinner and Barnes 2019). Some of these feedbacks and non-linear dynamics can result in the deepening of undesirable states, thereby leading to a *social-ecological trap* i.e., a situation whereby poverty and environmental degradation are perpetuated by reinforcing social-ecological dynamics (Enfors 2013; Cinner 2011).

Furthermore, an SES approach often helps in pinpointing the identity of the system in question and measuring thresholds of its elements. The elements of such an identity include: *Components*—the human and non-human actors*; relationships*—the interaction among the components*; innovation*—the elements of the system that lead to change*; and continuity*—the elements that embody memory and help maintain the system (Robinson and Berkes 2010; Cumming et al. 2005). These identity elements do not necessarily represent all the variables influencing the system but taking them out of the system would lead it to a qualitatively different state (Robinson and Berkes 2010).

It has been noted that the delineation between social and ecological systems is often arbitrary and artificial, since humans exist in nature (Berkes, Folke, and Colding 2000). Therefore, a lens that is solely focused on the adaptive abilities of the social system may not be sufficient to guarantee desired sustainability outcomes. It has also been observed that the actions of decisionmakers taken in response to change and uncertainty could well undermine the ability of the ecosystem to sustain such adaptation strategies

(Folke 2006). Thus, studies in the SES research strand emphasize the linkages across subsystems, making them better positioned to reveal the long-term implications of shocks and resulting responses on household resilience.

The SES perspective helps to capture how changes in environmental variables relate to changes in the human system dynamics. The focal point here is often about sustaining the productivity and functioning of natural resource systems, as well as household wellbeing and social institutions. Such inquiries could range from examining the complex interactions between the economic decision-making of farming households and soil fertility in the face of environmental shocks (Stephens et al. 2012), to assessing the potential for the livelihood transformation of households and the prevention of social breakdown in the presence of climate change (Hellin et al. 2018).

The SES research strand has also played a vital role in expanding our understanding of transformation in the resilience discourse. The intensity of shocks and stressors could be strong enough to warrant an alteration in the qualitative state of the system through the introduction and/or loss of state variables. Research in this field illuminates the changes in the structure and function of a system that can occur, and the factors that can prevent or facilitate such changes—e.g., when transformation is desired and deliberately pursued (O'Brien 2012). Such insights can be beneficial within the rural household context in that the conditions that create for longer lasting resilience can be identified. For instance, a household may need to explore an entirely new livelihood direction (as opposed to say, trying new farming practices) and understanding the requisite behavioral

shifts, technological innovations and institutional reforms to achieve this will be paramount (Béné et al. 2012; O'Brien 2012).

In a nutshell, we have employed the broad groupings of the Human Systems and the SES Research Strands to collate different aspects of scholarship on rural household resilience. The overview of the literature that has been discussed so far provides the setting for the rest of this paper. Following the bibliometric analysis and thematic clustering, we develop a systematic mapping of knowledge on the subject matter. In the section that follows, we propose a typology that is informed by various elements found in the research strands presented above.

2.4. A Typology of Studies on Rural Household Resilience

Since the landscape of research on the resilience of rural households has agreeably been referred to as being in an "*early, somewhat noisy and disjointed stage*" (Barrett et al. 2021, 19), it therefore becomes instructive to construct a typology for this subfield of resilience. Typologies help to organize knowledge in a subject area by systematically classifying related concepts and help to guide further research (Allmendinger 2002). This evolving knowledge domain of rural household resilience, with significant contributions from a wide range of disciplines, is ripe for an attempt at integrating some of the diverse approaches presently found in the literature.

Below, a typology is proposed (Figure 2.3), which will hopefully facilitate stronger multidisciplinary efforts geared towards a more robust understanding of the resilience of rural households. This mapping is not a mere extension of the classification discussed in

the previous section. Rather, it is the outcome of dissecting the research strands and clusters into integral parts and grouping them under related strata—such as is done for a taxonomical classification. The typology is also informed by some of the practical considerations that go into conducting a study on rural household resilience. The intent of such a system of categorization is to assist researchers in recognizing the options available at different stages of the research endeavor, as well as to enable them to clearly disclose the choices they are making—choices which are hopefully based on the best fit or purpose of the study.

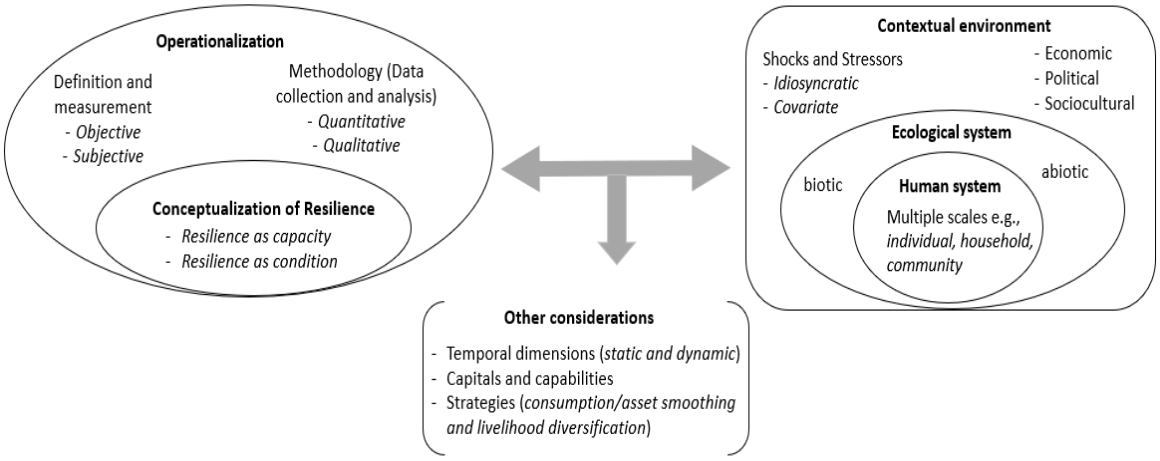


Figure 2.3. A typology of studies on rural household resilience.

As advised in the literature, the place to start when attempting to investigate the resilience of rural households is to address the question: "*Resilience of what, to what, and for whom*?" (Lebel et al. 2006). As the focus of this treatise is rural households, the researcher may need to be explicit about the shocks and/or stressors that threaten the outcome of interest—and these hazards may be covariate (widely experienced) and/or idiosyncratic (individualized) in nature (Constas et al. 2014; Constas, Frankenberger, and

Hoddinott 2014). Similarly, there is need to recognize the economic, political, sociocultural, and ecological contexts within which the households are situated, and to consider how these enable or limit their resilience. It is also imperative to be clear and consistent about how resilience is being conceptualized and subsequently operationalized. The sub-sections that follow revolve around these issues.

2.4.1. Resilience Conceptualization

A few dominant approaches to conceptualizing resilience are currently found in the literature. They are broadly classified by Barrett et al. (2021) as: *resilience as capacity; resilience as a normative condition;* and *resilience as a return to equilibrium.*

The *resilience as capacity* (or combination of capacities) approach considers resilience to be a multidimensional set of features that enable a household to limit the adverse wellbeing effects of shocks and stressors. As pointed out earlier, the constituent pillars of resilience in this approach are usually taken to be *absorptive*, *adaptive*, and *transformative* capacities—or any other combination of similar capacities (e.g., in the FAO RIMA framework). This approach endeavors to incorporate a wide range of indicators from social and ecological systems that limit households' vulnerabilities or enhance rapid recovery. Here, resilience is seen as an *ability* to withstand, recover from, or alter the structure and function of a system in the presence of shocks in a way that promotes longer-term resilience.

On the other hand, the other two categories in the Barrett et al. grouping take resilience to be a *condition*, or a qualitative state, that is either normatively determined

or defined in reference to a pre-existing state. The approach that treats *resilience as a normative condition* anchors the concept to wellbeing standards that have been normatively defined. That is, thresholds for a standard of living indicator (e.g., minimum levels of food consumption or asset stock) are used as a reference point in assessing whether households are resilient or not.

Conversely, the *resilience as a return to equilibrium* approach focuses on a household's recovery from a shock to its ex-ante state. That is, it considers the success of households in bouncing back to their pre-shock status. In principle, these two classifications could be viewed as variants of a *resilience as a condition* (or *resilience as an outcome*) approach. The main difference between the two sub-approaches is a consideration of whether the initial state of the household was desirable in the first place.

From the ongoing discussion, it appears as though fundamentally, the approaches to seeing resilience as either a *capacity* or a *condition* are directly linked, in that the condition of resilience is simply a reflection of an underlying capacity (or capacities). It can be argued that the magnitude of loss in the event of a shock and the speed and extent of recovery are in essence connected to the capacities of the household. As Christopher Béné (2020, 811) puts it: "resilience capacities are *input* to the resilience process, while resilience per se is the (intermediary) *outcome*, contributing to the longer-term final outcome (which itself is measured in terms of wellbeing)."

In this vein, the degree to which the distinctions in resilience conceptualization matter may be limited to how they inform the resulting operationalization of resilience in studies. Therefore, a researcher's interest in either assessing the multiple capacities that

enable rural households to be resilient, or in assessing the likelihood of those households (re-)achieving some established standard of living will ultimately determine the analytical approach to be adopted.

2.4.2. Resilience Operationalization

In addition, the researcher will need to make decisions as to what extent the views or perceptions of the population being assessed ought to be reflected in the studies. That is, judgements are needed about whether, and to what degree, resilience ought to be defined and/or evaluated by experts and external agents (*objective approach*), or by the subjects themselves (*subjective approach*). In addressing this issue, Jones (Jones 2019, 4) proposed that the objective and subjective measurement approaches lie on a continuum and stated that "*when it comes to resilience measurement, it is crucial to recognize that subjectivity and objectivity are neither binary nor mutually exclusive*" (p. 4).

This view suggests that the two methods may be seen as being complementary to one another and evaluators may best be served if consideration is given to the two approaches. That is, it will be wise for researchers embarking on an investigative journey on the resilience of rural households to be armed with a toolkit of both objective and subjective measurements. However, final decisions should ultimately be informed by the suitability of the preferred approach to help them arrive at the goal of their inquiry. Nevertheless, such a conclusion may only be arrived at after adequately considering the pros and cons of each approach.

Some of the factors to consider in making this decision include the bounded rationality of a single set of stakeholders; the practicability of minimizing the various cognitive and response biases such as priming and extreme response bias (as in for subjective approaches); the desire for comparisons across households or studies (e.g., the impact of interpersonal or cross-cultural differences in standardized questions); the time and resource constraint of the study (e.g., the amount and types of data required for objective approaches); the ability to identify indicators that accurately reflect the vulnerability contexts and capabilities of households; etc.

When employing subjective approaches, it is important to remember that people's interpretations of what resilience is to them or how they assess resilience may be dependent on several factors including cultural and personal elements. However, there are tools and techniques that can be utilized to reduce the worries associated with how people subjectively assess themselves and their experiences (OECD 2013). For instance, anchoring vignettes have been shown to be helpful in measuring complicated concepts and in correcting for differing interpretations of identical questions (King et al. 2004). In illustrating how this tool can be applied to a resilience context, Jones (Jones 2019) discusses how evaluators may begin by describing a hypothetical person's experience with a shock and then asking the respondents to rate the made-up scenario before rating their own situation using the same response scale. This strategy provides a basis for benchmarking individual responses, as well as helps in controlling for cross-cultural differences.

Furthermore, the choice of indicators and analytical method (if applicable to the study) should also be carefully determined since measurement decisions have sometimes been shown to influence the conclusions on wellbeing outcomes. For instance, working with the same longitudinal survey data, Vaitla et al. (2020) discovered that conclusions about food security status were sensitive to the cut-off points used by the researchers. That is, the threshold that the researchers used to specify whether a household was food secure or not influenced the conclusions from the analysis. In addition, the study showed that drivers of resilience differed depending on the choice of food security measure (i.e., the suggested causes of food insecurity when researchers used the Food Consumption Score measure were different from when the reduced Coping Strategy Index was utilized). The authors concluded that the two measures employed in the study capture "overlapping but not identical aspects of food security" (Vaitla et al. 2020, 147).

In a different study, Upton, Constenla and Barrett (2022) compared the performance of three of the dominant resilience analytical methods using the same data. They found that each method marked different households as resilient or least resilient, and differences were also observed in the predictive abilities of households' wellbeing states over time. The authors concluded by stating, "*it remains unclear what these [methods] really measure nor what descriptive, inferential, or predictive benefits they yield [beyond more established wellbeing measures] …The approaches presently in play are all, at best, imperfect, and at worst deeply flawed*" (Upton, Constenla-Villoslada, and Barrett 2022, 13, 14).

Sadly, as attested to in the foregoing discussions, the observed sensitivities to the indicators and methodologies employed in resilience analyses reduces the confidence we have in the findings from studies on rural household resilience. However, heeding certain guidelines can help bring researchers closer to carrying out investigations that produce more reliable conclusions. One of such pertinent recommendations include utilizing higher frequency data for empirical studies—in contrast to the overwhelming use of cross-sectional data presently found in the literature (e.g., Barrett et al. (Barrett et al. 2021) find that only 16% of the quantitative studies in their review used panel data).

In addition, researchers should employ approaches that are best suited for the question at hand. For instance, a composite index-based analytical approach may not be the most ideal empirical method if the goal of the study is to identify what variable—e.g., a particular household asset or community infrastructure—will be most impactful in building resilience (Upton, Constenla-Villoslada, and Barrett 2022). Finally, it is crucial for researchers to be aware of and transparent about the assumptions and limitations of their chosen analytical approaches.

2.4.3. Systems Perspective

Another point of importance when carrying out a study on rural household resilience is the consideration of the relevant subsystems required to satisfactorily describe or assess resilience. In addition to the characteristics and assets of households, some studies appropriately consider the various social, economic, and institutional structures and processes that enhance resilience. However, the wellbeing of rural

households and the long-term viability of their livelihoods cannot be addressed without an appreciation of the intertwined social-ecological systems within which these households exist—especially if their livelihoods are directly supported by these systems. To what extent the investigator explicitly factors this interconnectedness into the inquiry will depend on the objective of the study.

Even if the goal of the study is not specifically to describe or analyze the relationships between these interlinked systems, it will be valuable for researchers to account for them in some way. For instance, a study that seeks to identify which households are more resilient to certain shocks, or one that aims to describe the impact of a hazardous event on specific wellbeing outcomes, may not need to detail the feedback loop between human and natural systems. Even if the shocks being considered are not weather-related (e.g., sociopolitical shocks like conflict), it may still be helpful to point out how ecosystem properties influence households' wellbeing, especially if their productive operations are somewhat dependent on natural capital.

On the other hand, if the study at hand is interested in the long-term sustainability of nature-based livelihood activities in which households in a given region participate, then it will be crucial to acknowledge the linkages between various human and natural subsystems and recognize that there will be feedbacks across multiple scales and time periods. Because of the sheer number of relevant variables in both the biosphere and social system and all the interplays among them, and because these systems are adaptive in nature—so much so that one cannot fully predict how they will behave in future—it may be practically impossible to outline all the interactions that take place within these

systems. Nevertheless, it will still be valuable to identify some of the most important system attributes in an investigative effort on rural household resilience.

Quinlan et al. (2016) suggest the possibility of simplifying our understanding of social-ecological systems resilience, while simultaneously retaining the richness of a systems perspective. As an example, using a meta-framing of resilience principles, they propose that consideration could be given to the system structure and/or the system dynamics. The structure of the system deals with the organization or the presence of links between components of the system, while system dynamics has to do with the complex interactions of (fast) variables within the system (Quinlan et al. 2016; Biggs et al. 2012). Identification of such important system elements and connectivity does not only contribute to the richness of resilience thinking from a household perspective but will ultimately help to guide their decision-making processes.

In another instance, Ruiz-Ballesteros and Ramos-Ballesteros (2019) link the practices of households in the Agua Blanca community of Ecuador with the evolution and current state of their socioecological system. The authors consider how factors such as demographic behavior, household economy, household participation in the community, local knowledge, place attachment, and future outlook influence the dynamics and resilience of the SES. These examples illustrate how the need to streamline systems perspective into a research study could possibly be achieved.

2.4.4. Other Considerations

Considering multiple time periods in resilience enquiries is essential in resilience analyses since resilience is a time- and event-dependent concept. Some authors have even hinted at the need for high frequency data for resilience analyses, such as statistics that are collected monthly (Knippenberg, Jensen, and Constas 2019). However, collecting quality and extensive time-series data can be very expensive on a practical basis. Notwithstanding, by the very nature of resilience as a concept, at least two points in time (i.e., ex ante and ex post) should guide the investigation. It is almost impossible to think of resilience without reference to different time periods, even if it is just a recollection of a household's asset level before and after a shock, or a projection of its wellbeing state into the future.

On a different note, when thinking of capitals, researchers should avoid the trap of limiting the indicators they choose to just the tangible assets available to households. It is important to incorporate the notion of *access* to various resources, as well as to see capitals as the basis of agents' *power* to act, adapt and transform their situation (Bebbington 1999). As Bebbington notes, "People's assets are not merely *means* through which they make a living: they also give *meaning* to the person's world… This meaning will then be one of several influences in subsequent decisions people make about their livelihood strategies" (Bebbington 1999, 2022). Such meanings, as well as people's values and ideologies (or *cultural capital* in general) have been shown to shape governance mechanisms or institutions (Tanner et al. 2015; von Heland and Folke 2014), which in turn constrain or enhance resilience efforts (Folke 2016; Walker et al. 2009).

Similarly, thought should be given to the various risk- and loss-management strategies employed by rural households (i.e., strategies employed to reduce ex-ante possibility of a loss or to mitigate ex-post consequences). Because of the missing and imperfect markets in many rural areas, households often tend to have a diversified portfolio of livelihood activities, as well as engage in consumption/asset smoothing (Valdivia 2004; Morduch 1995). The specific alternative mechanisms that households adopt are often shaped by the economic, political, and sociocultural environment in which they find themselves, which ought to be given sufficient attention by researchers as well. The level of importance of these contextual variables has made some authors advise that even if the focus is the household wellbeing, development interventions should not be targeted at the household level alone, but should be directed at institutions, infrastructure, and higher system levels as well (Béné, Frankenberger, and Nelson 2015).

2.5. Conclusions

Scholars from multiple disciplines have been actively engaged in increasing our understanding of resilience as it relates to rural households, whether it is by examining the effects of stressors and shocks on household wellbeing, or assessing the ways households respond to these threats, or evaluating the outcomes of these responses. Such diverse contributions, although beneficial and necessary, could sometimes lead to some confusion in the research arena. Additionally, academic work on the issue is usually confined to disciplinary boundaries, resulting in variations in how resilience is framed and analyzed, which has in turn often led to contrasting results in resilience analyses. Such

discrepancies have warranted a more integrative approach in studying rural household resilience.

This article synthesizes some of the major elements embedded in various research strands in the literature and offers a systematic way for studies to approach the subject matter. This treatise aims to encourage scholars to employ a multidisciplinary lens in their research endeavors, a move that will hopefully result in a more robust understanding of resilience within the rural household context. The typology presented in this paper allows for different theories to inform studies on rural household resilience. This is especially useful because it has been argued that it may not be desirable to have a unified theory of resilience in the field of development since it is doubtful that such conformity will meet the practical demands of various stakeholders (Barrett et al. 2021).

As a result, scholars investigating the resilience of rural households can adopt the characterization of resilience that is most useful to the goals of their enquiry, whether their focal interest is the state of resilience or the capacities that make this possible. It does not currently appear that there is a one-size-fits-all approach to resilience conceptualization and measurement. Nevertheless, the selected resilience measures for a study should be consistent with the preferred conceptualization. Furthermore, as sometimes pointed out in the literature but not always heeded, resilience within the context of rural household is not an end goal by itself. Specific wellbeing indicators ought to be the final outcomes of interest—such as the food security, health, or livelihoods of households—and these should be clearly indicated in studies.

Researchers should also endeavor to integrate elements of objective and subjective approaches in their characterization and/or evaluation of resilience in a manner that advances the objective of the study. This fusion of approaches is needed so that studies can maintain scientific objectivity, while adequately reflecting the experiences of rural households (since resilience ultimately centers around households' qualitative states). In addition, the types of data and the analytical methods that are best suited for the research questions at hand should be the guiding factor for researchers, as opposed to convenience, funding source, existing structure of collaborative networks, or methodological allegiance.

Finally, the need for systematically synthesizing findings from studies on rural household resilience is becoming ripe. Scholars who seek to embark on this worthy task can find a framework such as the one presented in this paper to be a helpful tool. Researchers may choose to use certain elements of the typology in this paper as the basis for collating previous studies. Furthermore, this framework can also inform the generation of a stream of comparable future studies in this subfield—studies that integrate insights and approaches from multiple disciplines—thus fast-tracking our cumulative scientific understanding of rural household resilience.

References

Adger, W. Neil, Suraje Dessai, Marisa Goulden, Mike Hulme, Irene Lorenzoni, Donald R. Nelson, Lars Otto Naess, Johanna Wolf, and Anita Wreford. 2009. "Are There Social Limits to Adaptation to Climate Change?" *Climatic Change* 93: 335–54.

Allmendinger, Philip. 2002. "Towards a Post-Positivist Typology of Planning Theory." *Planning Theory* 1 (1): 77–99.

Ansah, Isaac Gershon Kodwo, Cornelis Gardebroek, and Rico Ihle. 2019. "Resilience and Household Food Security: A Review of Concepts, Methodological Approaches and Empirical Evidence." *Food Security* 11 (6): 1187–1203. https://doi.org/10.1007/s12571-019-00968-1.

Awazi, Nyong Princely, Martin Ngankam Tchamba, and Tientcheu Marie-Louise Avana. 2019. "Climate Change Resiliency Choices of Small-Scale Farmers in Cameroon: Determinants and Policy Implications." *Journal of Environmental Management* 250 (November): 109560. https://doi.org/10.1016/j.jenvman.2019.109560.

Barrett, Christopher B., and Michael R. Carter. 2013. "The Economics of Poverty Traps and Persistent Poverty: Empirical and Policy Implications." *The Journal of Development Studies* 49 (7): 976–90.

Barrett, Christopher B., and Mark A. Constas. 2014. "Toward a Theory of Resilience for International Development Applications." *Proceedings of the National Academy of Sciences* 111 (40): 14625–30. https://doi.org/10.1073/pnas.1320880111.

Barrett, Christopher B., Teevrat Garg, and Linden McBride. 2016. “Well-Being Dynamics and Poverty Traps.” *Annual Review of Resource Economics* 8 (1): 303–27. https://doi.org/10.1146/annurev-resource-100815-095235.

Barrett, Christopher B., Kate Ghezzi-Kopel, John Hoddinott, Nima Homami, Elizabeth Tennant, Joanna Upton, and Tong Wu. 2021. “A Scoping Review of the Development Resilience Literature: Theory, Methods and Evidence.” *World Development* 146 (October): 105612. https://doi.org/10.1016/j.worlddev.2021.105612.

Bebbington, Anthony. 1999. “Capitals and Capabilities: A Framework for Analyzing Peasant Viability, Rural Livelihoods and Poverty.” *World Development* 27 (12): 2021–44. https://doi.org/10.1016/S0305-750X(99)00104-7.

Béné, Christophe. 2020. “Resilience of Local Food Systems and Links to Food Security–A Review of Some Important Concepts in the Context of COVID-19 and Other Shocks.” *Food Security* 12 (4): 805–22.

Béné, Christophe, Ramatu M. Al-Hassan, Oscar Amarasinghe, Patrick Fong, Joseph Ocran, Edward Onumah, Rusiata Ratuniata, Truong Van Tuyen, J. Allister McGregor, and David J. Mills. 2016. “Is Resilience Socially Constructed? Empirical Evidence from Fiji, Ghana, Sri Lanka, and Vietnam.” *Global Environmental Change* 38: 153–70.

Béné, Christophe, Tim Frankenberger, and Suzanne Nelson. 2015. “Design, Monitoring and Evaluation of Resilience Interventions: Conceptual and Empirical Considerations.”

Béné, Christophe, Timothy Frankenberger, Tiffany Griffin, Mark Langworthy, Monica Mueller, and Stephanie Martin. 2019. "'Perception Matters': New Insights into the Subjective Dimension of Resilience in the Context of Humanitarian and Food Security Crises." *Progress in Development Studies* 19 (3): 186–210.

Béné, Christophe, Rachel Godfrey Wood, Andrew Newsham, and Mark Davies. 2012. "Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes." *IDS Working Papers* 2012 (405): 1–61.

Berkes, Fikret, Carl Folke, and Johan Colding. 2000. *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press.

Biggs, Reinette, Maja Schlüter, Duan Biggs, Erin L. Bohensky, Shauna BurnSilver, Georgina Cundill, Vasilis Dakos, et al. 2012. "Toward Principles for Enhancing the Resilience of Ecosystem Services." *Annual Review of Environment and Resources* 37 (1): 421–48. https://doi.org/10.1146/annurev-environ-051211-123836.

Brown, Katrina. 2014. "Global Environmental Change I: A Social Turn for Resilience?" *Progress in Human Geography* 38 (1): 107–17. https://doi.org/10.1177/0309132513498837.

Brück, Tilman, Marco d'Errico, and Rebecca Pietrelli. 2019. "The Effects of Violent Conflict on Household Resilience and Food Security: Evidence from the 2014 Gaza Conflict." *World Development* 119: 203–23.

Carter, Michael R., and Christopher B. Barrett. 2006. “The Economics of Poverty Traps and Persistent Poverty: An Asset-Based Approach.” *Journal of Development Studies* 42 (2): 178–99. https://doi.org/10.1080/00220380500405261.

Chambers, R., and G.R. Conway. 1992. “Sustainable Rural Livelihoods: Practical Concepts for the 21st Century.” *IDS Discussion Paper* 296.

Cinner, Joshua E. 2011. “Social-Ecological Traps in Reef Fisheries.” *Global Environmental Change* 21: 835–39.

Cinner, Joshua E., and Michele L. Barnes. 2019. “Social Dimensions of Resilience in Social-Ecological Systems.” *One Earth* 1 (1): 51–56. https://doi.org/10.1016/j.oneear.2019.08.003.

Cissé, Jennifer Denno, and Christopher B. Barrett. 2018. “Estimating Development Resilience: A Conditional Moments-Based Approach.” *Journal of Development Economics* 135: 272–84.

Constas, Mark, Timothy Frankenberger, and John Hoddinott. 2014. “Resilience Measurement Principles: Toward an Agenda for Measurement Design.” Technical Working Series 1. Food Security Information Network (FSIN) - Resilience Measurement Technical Working Group. Rome: World Food Programme and Food and Agriculture Organization. https://www.fsinplatform.org/sites/default/files/paragraphs/documents/FSIN_TechnicalSeries_1.pdf.

Constas, Mark, Timothy Frankenberger, John Hoddinott, Nancy Mock, Donato Romano, Christophe Béné, and Daniel Maxwell. 2014. “A Common Analytical Model for

Resilience Measurement: Causal Framework and Methodological Options. Resilience Measurement Technical Working Group, FSiN Technical Series Paper, 2. Rome." Technical Working Series 2. Food Security Information Network (FSIN) - Resilience Measurement Technical Working Group. Rome: World Food Programme and Food and Agriculture Organization.

Cumming, Graeme S., Grenville Barnes, Stephen Perz, Marianne Schmink, Kathryn E. Sieving, Jane Southworth, Michael Binford, Robert D. Holt, Claudia Stickler, and Tracy Van Holt. 2005. "An Exploratory Framework for the Empirical Measurement of Resilience." *Ecosystems* 8: 975–87.

Douxchamps, Sabine, Liza Debevec, Meredith Giordano, and Jennie Barron. 2017. "Monitoring and Evaluation of Climate Resilience for Agricultural Development–A Review of Currently Available Tools." *World Development Perspectives* 5: 10–23.

Enfors, Elin. 2013. "Social–Ecological Traps and Transformations in Dryland Agro-Ecosystems: Using Water System Innovations to Change the Trajectory of Development." *Global Environmental Change* 23 (1): 51–60.

Errico, Marco d', Francesca Grazioli, and Rebecca Pietrelli. 2018. "Cross-Country Evidence of the Relationship between Resilience and the Subjective Perception of Well-Being and Social Inclusion: Evidence from the Regions of Matam (Senegal) and the Triangle of Hope (Mauritania)." *Journal of International Development* 30 (8): 1339–68.

FAO. 2016. "RIMA-II: Resilience Index Measurement and Analysis – II." Food and Agriculture Organization. https://www.fao.org/3/i5665e/i5665e.pdf.

Folke, Carl. 2006. “Resilience: The Emergence of a Perspective for Social–Ecological Systems Analyses.” *Global Environmental Change*, Resilience, Vulnerability, and Adaptation: A Cross-Cutting Theme of the International Human Dimensions Programme on Global Environmental Change, 16 (3): 253–67. https://doi.org/10.1016/j.gloenvcha.2006.04.002.

———. 2016. “Resilience (Republished).” *Ecology and Society* 21 (4): art44. https://doi.org/10.5751/ES-09088-210444.

Haile, Dereje, Abrham Seyoum, and Alemu Azmeraw. 2021. “Does Building the Resilience of Rural Households Reduce Multidimensional Poverty? Analysis of Panel Data in Ethiopia.” *Scientific African* 12: e00788.

Heland, Jacob von, and Carl Folke. 2014. “A Social Contract with the Ancestors—Culture and Ecosystem Services in Southern Madagascar.” *Global Environmental Change* 24 (January): 251–64. https://doi.org/10.1016/j.gloenvcha.2013.11.003.

Hellin, Jon, Blake D. Ratner, Ruth Meinzen-Dick, and Santiago Lopez-Ridaura. 2018. “Increasing Social-Ecological Resilience within Small-Scale Agriculture in Conflict-Affected Guatemala.” *Ecology and Society* 23 (3).

Jones, Lindsey. 2019. “Resilience Isn’t the Same for All: Comparing Subjective and Objective Approaches to Resilience Measurement.” *WIREs Climate Change* 10 (1). https://doi.org/10.1002/wcc.552.

Jones, Lindsey, and Marco d’Errico. 2019. “Whose Resilience Matters? Like-for-like Comparison of Objective and Subjective Evaluations of Resilience.” *World*

Development 124 (December): 104632. https://doi.org/10.1016/j.worlddev.2019.104632.

Jones, Lindsey, and Thomas Tanner. 2017. "'Subjective Resilience': Using Perceptions to Quantify Household Resilience to Climate Extremes and Disasters." *Regional Environmental Change* 17: 229–43.

King, Gary, Christopher J. L. Murray, Joshua A. Salomon, and Ajay Tandon. 2004. "Enhancing the Validity and Cross-Cultural Comparability of Measurement in Survey Research." *American Political Science Review* 98 (1): 191–207. https://doi.org/10.1017/S000305540400108X.

Knippenberg, Erwin, Nathaniel Jensen, and Mark Constas. 2019. "Quantifying Household Resilience with High Frequency Data: Temporal Dynamics and Methodological Options." *World Development* 121 (September): 1–15. https://doi.org/10.1016/j.worlddev.2019.04.010.

Lebel, Louis, John M. Anderies, Bruce Campbell, Carl Folke, Steve Hatfield-Dodds, Terry P. Hughes, and James Wilson. 2006. "Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems." *Ecology and Society* 11 (1).

Mase, Amber Saylor, Nicholas L. Babin, Linda Stalker Prokopy, and Kenneth D. Genskow. 2015. "Trust in Sources of Soil and Water Quality Information: Implications for Environmental Outreach and Education." *JAWRA Journal of the American Water Resources Association* 51 (6): 1656–66. https://doi.org/10.1111/1752-1688.12349.

Morduch, Jonathan. 1995. “Income Smoothing and Consumption Smoothing.” *Journal of Economic Perspectives* 9 (3): 103–14.

O’Brien, Karen. 2012. “Global Environmental Change II: From Adaptation to Deliberate Transformation.” *Progress in Human Geography* 36 (5): 667–76.

OECD. 2013. *OECD Guidelines on Measuring Subjective Well-Being*. OECD. https://doi.org/10.1787/9789264191655-en.

Ostrom, Elinor. 2007. “A Diagnostic Approach for Going beyond Panaceas.” *Proceedings of the National Academy of Sciences* 104 (39): 15181–87. https://doi.org/10.1073/pnas.0702288104.

———. 2009. “A General Framework for Analyzing Sustainability of Social-Ecological Systems.” *Science* 325 (5939): 419–22. https://doi.org/10.1126/science.1172133.

Otchere, Frank, and Sudhanshu Handa. 2022. “Building Resilience through Social Protection: Evidence from Malawi.” *The Journal of Development Studies* 58 (10): 1958–80.

Qin, Hua, Martha Bass, Jessica D. Ulrich-Schad, David Matarrita-Cascante, Christine Sanders, and Barituka Bekee. 2020. “Community, Natural Resources, and Sustainability: Overview of an Interdisciplinary and International Literature.” *Sustainability* 12 (3): 1061.

Quinlan, Allyson E., Marta Berbés-Blázquez, L. Jamila Haider, and Garry D. Peterson. 2016. “Measuring and Assessing Resilience: Broadening Understanding through Multiple Disciplinary Perspectives.” *Journal of Applied Ecology* 53 (3): 677–87. https://doi.org/10.1111/1365-2664.12550.

Robinson, Lance W., and Fikret Berkes. 2010. “Applying Resilience Thinking to Questions of Policy for Pastoralist Systems: Lessons from the Gabra of Northern Kenya.” *Human Ecology* 38 (3): 335–50. https://doi.org/10.1007/s10745-010-9327-1.

Ruiz-Ballesteros, Esteban, and Paulino Ramos-Ballesteros. 2019. “Social-Ecological Resilience as Practice: A Household Perspective from Agua Blanca (Ecuador).” *Sustainability* 11 (20): 5697. https://doi.org/10.3390/su11205697.

Scheffer, Marten, Steve Carpenter, Jonathan A. Foley, Carl Folke, and Brian Walker. 2001. “Catastrophic Shifts in Ecosystems.” *Nature* 413 (6856): 591–96.

Serfilippi, Elena, and Gayatri Ramnath. 2018. “Resilience Measurement and Conceptual Frameworks: A Review of the Literature.” *Annals of Public and Cooperative Economics* 89 (4): 645–64. https://doi.org/10.1111/apce.12202.

Shah, Sameer H., Leonora C. Angeles, and Leila M. Harris. 2017. “Worlding the Intangibility of Resilience: The Case of Rice Farmers and Water-Related Risk in the Philippines.” *World Development* 98: 400–412.

Smith, Lisa C., and Timothy R. Frankenberger. 2018. “Does Resilience Capacity Reduce the Negative Impact of Shocks on Household Food Security? Evidence from the 2014 Floods in Northern Bangladesh.” *World Development* 102: 358–76.

Stephens, Emma C., Charles F. Nicholson, Douglas R. Brown, David Parsons, Christopher B. Barrett, Johannes Lehmann, David Mbugua, Solomon Ngoze, Alice N. Pell, and Susan J. Riha. 2012. “Modeling the Impact of Natural Resource-Based Poverty Traps on Food Security in Kenya: The Crops, Livestock and Soils in Smallholder Economic Systems (CLASSES) Model.” *Food Security* 4 (3): 423–39.

Tanner, Thomas, David Lewis, David Wrathall, Robin Bronen, Nick Cradock-Henry, Saleemul Huq, Chris Lawless, Raphael Nawrotzki, Vivek Prasad, and Md Ashiqur Rahman. 2015. “Livelihood Resilience in the Face of Climate Change.” *Nature Climate Change* 5 (1): 23–26.

Upton, Joanna, Susana Constenla-Villoslada, and Christopher B. Barrett. 2022. “Caveat Utilitor: A Comparative Assessment of Resilience Measurement Approaches.” *Journal of Development Economics* 157 (June): 102873. https://doi.org/10.1016/j.jdeveco.2022.102873.

Vaitla, Bapu, Jennifer Denno Cissé, Joanna Upton, Girmay Tesfay, Nigussie Abadi, and Daniel Maxwell. 2020. “How the Choice of Food Security Indicators Affects the Assessment of Resilience—an Example from Northern Ethiopia.” *Food Security* 12 (1): 137–50. https://doi.org/10.1007/s12571-019-00989-w.

Valdivia, Corinne. 2004. “Andean Livelihood Strategies and the Livestock Portfolio.” *Culture & Agriculture* 26 (1–2): 69–79.

Walker, Brian H., Nick Abel, John M. Anderies, and Paul Ryan. 2009. “Resilience, Adaptability, and Transformability in the Goulburn-Broken Catchment, Australia.” *Ecology and Society* 14 (1). https://www.jstor.org/stable/26268056.

Wallace, Claire. 2002. “Household Strategies: Their Conceptual Relevance and Analytical Scope in Social Research.” *Sociology* 36 (2): 275–92.

Wheelock, Jane, and Elizabeth Oughton. 1996. “The Household as a Focus for Research.” *Journal of Economic Issues* 30 (1): 143–59.

CHAPTER 3. ASSESSING THE RESILIENCE OF RURAL HOUSEHOLDS TO ENVIRONMENTAL SHOCKS: INTEGRATING OBJECTIVE AND SUBJECTIVE APPROACHES

3.1. Introduction

3.1.1. Resilience in today's world

The world is currently grappling with several development and existential threats such as poverty, inequality, climate change, environmental degradation, conflict, and injustice (United Nations[3]). Due to the acute and persistent nature of these global challenges, the United Nations issued an urgent call to action for all countries, and in 2015 adopted the Sustainable Development Goals as a "shared blueprint for peace and prosperity for people and the planet, now and into the future."[4] By rightly encompassing the three pillars of sustainability—i.e., the economic, social and environmental dimensions—these broad goals, with their specific targets and indicators, paint a picture of the sustainable future we desire. Still, in contexts of uncertainty and change—which characterizes the world we now live in—resilience becomes one of the critical factors for sustainability (Lebel et al. 2006).

Resilience is a cross-cutting theme that has received a lot of attention from policy makers and researchers, as well as international development and humanitarian organizations alike. However, one must note that in resilience discourse, the focal point could be directed to different units of analysis including economic systems (Briguglio et al., 2009), ecosystems (Mäler, 2008), urban communities (Zeng et al. 2022), rural

[3] https://www.un.org/sustainabledevelopment/sustainable-development-goals/
[4] https://sdgs.un.org/goals

communities (Kim et al. 2020), etc. Thus, it becomes imperative when conducting any investigation on resilience to ask the question: *Resilience of what, to what, and of whom?* (Lebel et al., 2006). This study examines the resilience of rural households to various environmental shocks.

3.1.2. Resilience Measurements and Perceptions

There has been considerable evolution in resilience thinking within the social sciences over time. For instance, in addition to the ability of a system to absorb change while maintaining its core structure, successive Intergovernmental Panel on Climate Change Assessment Reports have expanded the definition of resilience to include the capacity to adapt and the capacity to transform (Jones, 2019). At this point, there is considerable agreement among scholars that resilience is a combination of multiple capacities (Béné et al., 2015).

Resilience capacity can be described as "a set of conditions, attributes and skills that enable households to achieve resilience in the face of shocks" (Smith and Frankenberger, 2018). Furthermore, it is posited that resilience by itself is not a final goal; rather it is a means to an end (Béné et al., 2015). That is, resilience is an intermediate outcome leading to the achievement of targeted goals such as improved measures of wellbeing. Resilience is a dynamic concept and resilience measurements should therefore be able to capture the various pathways to wellbeing in the presence of shocks (d'Errico and Giuseppe, 2018). However, the definitional and conceptual variation across fields and organizations poses a challenge in measuring the concept (Schipper and Langston, 2015).

In general, there has been a tendency to rely on “objectivity” in resilience analyses i.e., measurement metrics are often externally determined through expert solicitation or based on academic literature (Jones 2019). However, despite the operational benefits of this approach, several limitations have been pointed out, such as the dual challenge of identifying all the relevant indicators and weighting them appropriately (Jones and Tanner, 2017).

Consequently, calls have been made for subjective approaches to be utilized in resilience studies (Maxwell et al., 2015; Jones and Tanner, 2017; Jones et al. 2018), since it is argued that people are cognizant of their capacities and limits (Jones and Tanner, 2017). It is also asserted that subjective factors of resilience provide insights into the reasons, the timing, and the nature of people’s behavioral responses to shocks or stressors (Béné et al. 2019). A subjective approach to resilience measurement (or “subjective resilience”) entails the cognitive and affective self-assessments of the capabilities and capacities of actors and their social systems (Jones and Tanner, 2017). Complementing psychosocial factors with the more tangible dimensions of resilience in research efforts is expected to provide further insights into the drivers and components of resilience (Béné et al. 2019). Accordingly, there has been a rise in studies that employ more subjective tools in the measurement of resilience (e.g., Nguyen and James, 2013; Jones and d’Errico, 2019).

Although subjective approaches allow individuals to factor less tangible and non-material elements of resilience such as courage, optimism, and faith into their internal judgements (Shah et al., 2017), subjective measures are not free of shortcomings either.

For example, subjective measures may be influenced by several cognitive biases e.g., recall bias or acquiescence bias[5]. There are therefore gains to be made by combining objective and subjective approaches. Jones (2019) however proposes that objectivity and subjectivity in resilience analyses are neither binary nor mutually exclusive, but existing measurement efforts can rather be thought of as lying on a spectrum[6].

In light of the above discussions, the research questions for this paper are: "*What are the various pathways that contribute to the resilience of rural households in the Altiplano region of Bolivia in the presence of changing environmental conditions? What is the relationship between these resilience pillars and household wellbeing?*" Specifically, this paper seeks to assess factors that contribute to the resilience capacity of rural households to environmental shocks, taking into consideration both objectively and subjectively defined/evaluated criteria. The study utilizes qualitative measures not common in quantitative resilience analyses.

3.2. Conceptual Approach

The analysis conducted in this study is informed by a few conceptual models that attempt to link perceptions and actions. It has been noted that during the design of interventions aimed at eliciting household action, the households' perspectives on their

[5] Recall bias is a situation where respondents do not accurately remember an experience/event that happened in the past or omit details when reporting them; while acquiescence bias (or agreement bias) is when respondents disproportionately agree to statements without it being a true reflection of their views.

[6] Jones (2019) develops an objectivity-subjectivity continuum and presents quadrants of this continuum: *objectively defined and objectively evaluated*; *objectively defined and subjectively evaluated*; *subjectively defined and objectively evaluated*; and *subjectively defined and subjectively evaluated.*

response capacity are often ignored—despite the recognized influence of normative values and perceptions on the responses of households (Elrick-Barr et al. 2017). For instance, irrespective of an awareness of potential risk, people have to feel like their material or immaterial values (e.g., food security, health, or livelihood) are at stake for them to act (Kroemker and Mosler, 2002).

Moreover, in the field of adaptation, it has been observed that physical, institutional, and economic factors may often not be as constraining as when households systematically misestimate their own adaptive ability (Grothman and Patt, 2005). For example, it has been shown that overestimating capability ("illusions of control") negatively affects the investments households make in adaptive actions (Elrick-barr et al. 2017); while underestimating one's capability can undermine adaptation since motivation alone is an insufficient determinant of action (Kroemker and Mosler, 2002).

In light of the importance of social narratives of capability, Grothmann and Patt (2005) develop a socio-cognitive Model of Private Proactive Adaptation to Climate Change (MPPACC) (Figure 1) based on the Protection Motivation Theory (Rogers, 1983) to explain why some people show more adaptive behavior than others. MPPACC highlights two key perceptual processes: risk appraisal and adaptation appraisal—which are also referred to as threat appraisal and coping appraisal (Grothmann and Reusswig 2006). Risk appraisal involves assessing the probability and damage potential of threats under the assumption of no change to current behavior; whereas coping appraisal comprises of an evaluation of one's ability to avert being harmed by the threat, along with the costs of such action.

The model discusses the elements of these perceptions, as well as describes the two potential outcomes of these appraisal processes—protective responses (e.g., those that prevent damage) and non-protective responses or avoidant maladaptation (e.g., denial or wishful thinking). According to Grothmann and Reuswigg (2006, p. 105), "coping appraisal takes place in time after the threat appraisal process, and only starts if a specific threshold of threat appraisal is passed," and it is coping appraisal that determines whether an accompanying response is protective or non-protective—as threat appraisal may only provide the motivational energy for the response.

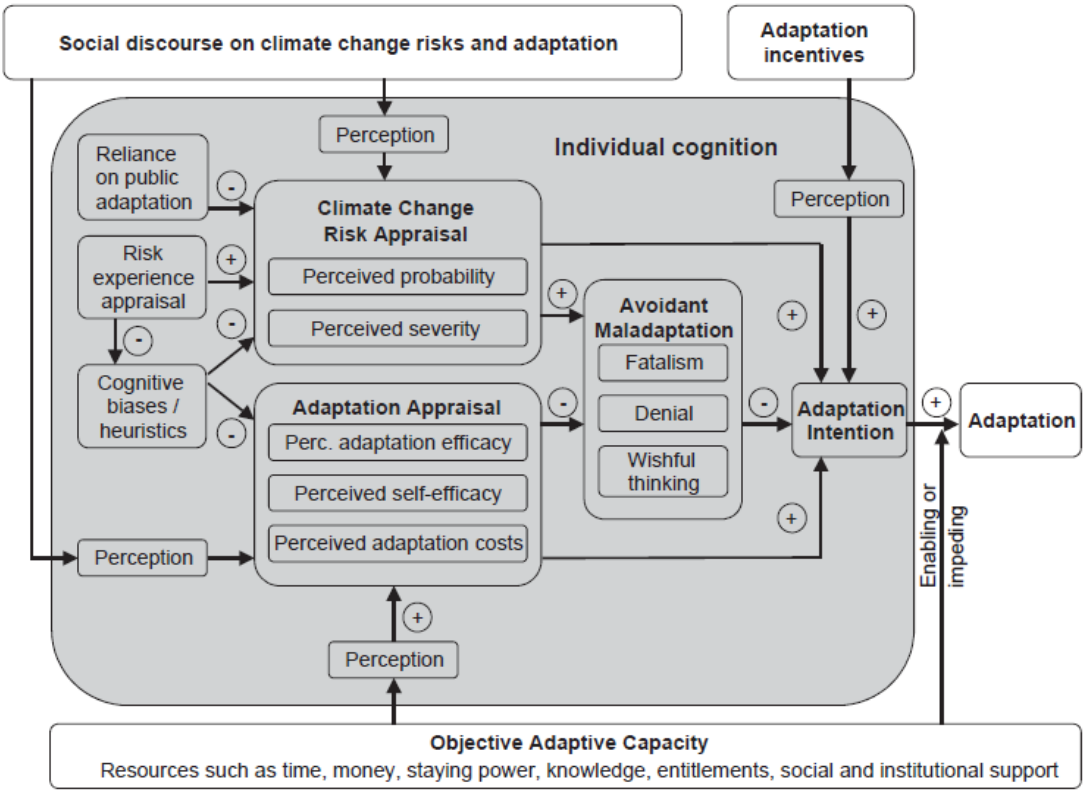


Figure 3.1. Process Model of Private Proactive Adaptation to Climate Change (culled from Grothmann and Patt 2005).

With respect to resilience more specifically, Béné et al. (2019) offer a conceptual framework that attempts to highlight the role of psycho-social factors and subjective mechanisms in building resilience (Figure 2). They argue that resilience comprises of *tangible* and *less-tangible* components. The "tangible/directly measurable" component of resilience include elements such as income, assets, knowledge, livelihood strategies, and access to services which have been largely inferred in the literature as responsible for the resilience outcomes of households.

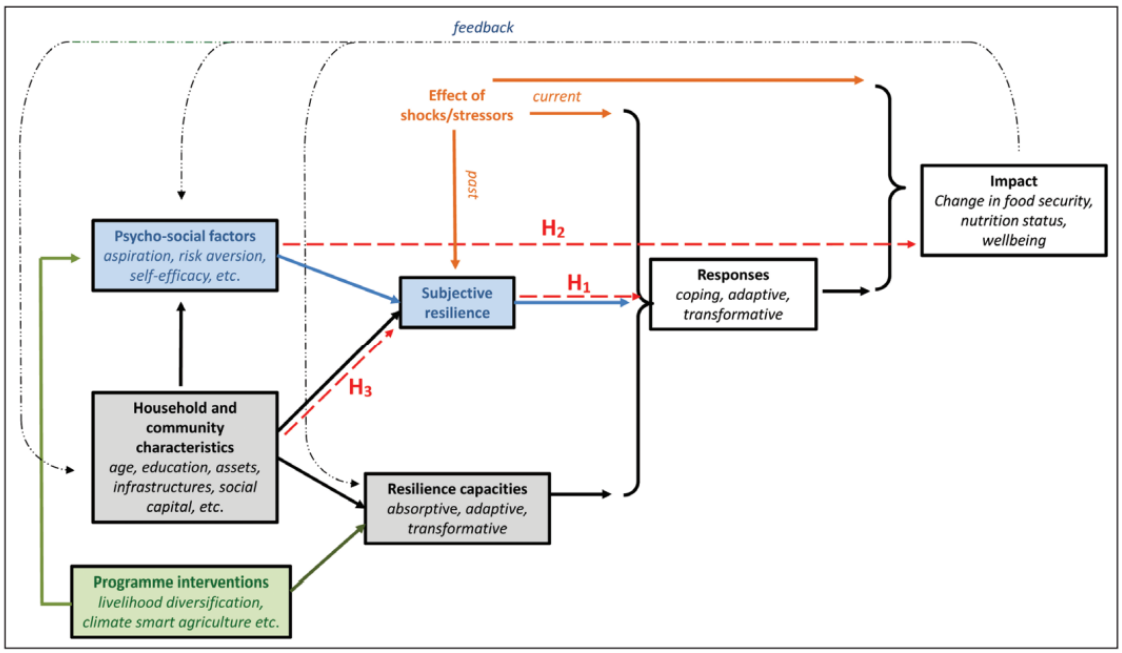


Figure 3.2. Conceptual framework representing the tangible and less-tangible components of resilience (Culled from Béné et al. 2019).

On the other hand, the subjective component of resilience, which is crucial in household decision-making, is made up of psychosocial elements such as risk aversion, self-efficacy, self-esteem, cultural identity, and motivation—but also incorporates elements of the tangible component of resilience, since we would expect the

socioeconomic realities of households to influence their perceived capabilities and capacities. Furthermore, the authors note that the tangible elements operate at the individual, household, or community levels, while intangible elements operate primarily at the individual level (although aggregated perceptions at higher scales may also shape decisions).

The inclusion of measures such as perception of control in resilience analysis helps address some of the issues highlighted in early resilience studies, such as their failure to consider issues of agency and power (e.g., Davidson 2010). Indeed, households' appraisal of their capacity helps unveil the agency of the relevant actors. Notwithstanding, it is worth pointing out that households' evaluation of their ability to respond to current or future risks may (should) be viewed as an important *component* of subjective resilience—not a direct proxy for resilience—as there are other elements of subjective resilience including an evaluation of what resilience is to the respondents, as well as self-assessments of what factors may contribute to their resilience.

3.3. Data and Methodology

3.3.1. Data

The data used for this analysis comes from a survey of randomly chosen households in Umala and Ancoraimes municipalities of the Bolivian Altiplano through the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program Project. The regions were selected to provide a variety of institutional,

geographic, and economic activities. Each household responded to over 100 questions relating to various aspects of their lives. The survey aimed at identifying the livelihood strategies, capitals, and practices of the people of that region; as well as collecting residents' views of the risks posed by various hazards and their perceptions of control to them. This study makes use of 220 households in seven of those communities with varying landscapes and livelihood strategies.

3.3.2. Study Context

The Altiplano region is found in west-central South America and occupies parts of Chile, Bolivia, Peru, and Argentina. The Altiplano region has a diversity of landscapes supporting rural livelihoods, from grasslands sustaining pastoralists raising alpacas and llamas, to agropastoral systems incorporating multiple crops and animals (Valdivia et al. 2019). The relative importance of crops and livestock differs across communities (Giles and Valdivia, 2009).

The climate is cool and semi-arid to arid, and the region is characterized by a wide range of daily temperature cycle, with maximum temperatures ranging from 12 to 24 degrees Celsius and minimum temperatures of -20 to 10 degrees Celsius (Jensen 2010). The livelihood activities of households in this region are vulnerable to climate variability and shocks. For instance, the high altitude and low temperatures at night make frost a constant concern in the region, alongside periodic droughts, and floods (Giles and Valdivia, 2009).

Specifically, this study comprises of three communities in Umala municipality (Kellhuiri, Vinto Coopani, and San Jose Llanga) and four communities in Ancoraimes municipality (Chinchaya, Chojñapata, Calahuancani and Cohani)—all located in Bolivia. Communities in this region vary in livelihood activities, wealth, access to infrastructure and formal institutions (Jensen 2010). Ancoraimes is subhumid and has access to a lake, and communities in this municipality cultivate various crops including potatoes and onions, as well as raise cattle. Whereas households in Umala municipality, which has a relatively flatter landscape, raise sheep on the hillsides but also grow alfalfa, as well as potatoes.

3.3. Analytical Approach and Measurement

Although Béné et al. (2019) proposed the conceptual framework adopted in this paper, their study did not empirically operationalize the full model due to data limitations. Rather, using two different datasets from Frankenberger and Smith (2015) and Béné et al. (2016), the authors tested different hypotheses derived from the overall framework. For instance, they examined whether subjective resilience influenced households' propensity to engage in different types of responses (e.g., negative coping strategies such as asset or consumption smoothing). Also, using self-reported recovery scores as a proxy for resilience—i.e., self-assessments of the degree of recovery from adverse events (Béné et al. 2016)— they assessed the relationship between psychosocial factors and households' level of recovery to various shocks.

On the contrary, the operationalization of resilience carried out in this study more closely mirrors the framework described above i.e., as comprising of a combination of households' perceptions, as well as of more concrete elements of resilience. There is value in having a resilience evaluation toolkit that integrates elements of both objective and subjective measurement methods, as this can help capitalize on advantages inherent in both approaches (Jones and d'Errico 2019). Furthermore, this study links both subjective and objective resilience elements to a wellbeing outcome—for which objective measures for household resilience outcomes were employed, as opposed to self-assessments as in Béné et al. (2019).

In general, the existing literature points to three dimensions of resilience capacity: *absorptive, adaptive,* and *transformative capacities* (Béné et al., 2012; Smith and Frankenberger, 2018). Béné et al. (2012) suggest that these three capacities lead to different respective outcomes—persistence, incremental adjustment (or adaptation), and transformational response. Persistence speaks to resistance (i.e., being able to stop the shock from causing dysfunctions); while adaptation speaks to the various adjustments that are made in order to continue operating without major qualitative changes in the identity or function of the system. Transformation, on the other hand, involves changes in the primary structure or function of the system. Further explanations of these pillars are provided below.

Absorptive capacity: This refers to "the ability to minimize exposure to shocks and stresses (*ex-ante*) where possible and recover quickly when exposed (*ex-post*)" (Smith and Frankenberger 2018, p. 366). It encompasses the various coping strategies by which

households mitigate the impacts of shocks on their livelihoods and basic needs (Béné et al. 2012).

Adaptive capacity: Within the context of climate change and environmental phenomena, adaptive capacity refers to the ability of a system to "moderate potential damages, to take advantage of opportunities, or to cope with the consequences" of a changing climate (Béné et al. 2012, p. 21). These incremental adjustments prevent major qualitative changes in the function or structural identity of the system. With respect to the household, it involves making proactive and informed decisions about alternative livelihood strategies as a result of the changing conditions around them (Smith and Frankenberger, 2018).

Transformative Capacity: Transformative capacity refers to the ability to create "a fundamentally new system when ecological, economic or social structures make the existing system untenable" (Béné et al. 2012, p. 21). It encompasses the enabling conditions that foster longer term resilience and relates to "governance mechanisms, access to markets, services and infrastructures, community networks and formal safety nets that are a part of the wider system in which households and communities are embedded" (Smith and Frankenberger, 2018, p. 366). According to Béné et al. (2012), transformation goes beyond incremental changes and involves an alteration in the structure and function of the system (such as the introduction of new state variables within the system/loss of old ones). e.g., a household venturing into a new livelihood activity or a region switching from an agrarian economy to one dominated by resource

extraction. Transformational changes could include a combination of technological innovations, institutional reforms, behavioral shifts, or cultural changes.

To account for the subjective dimension of resilience, this study utilizes two main perceptions: perceptions of dread and perceptions of control. They are further described below:

*Perception of dread***:** According to Béné et al. (2019), risk perceptions within a resilience context could be viewed along two dimensions: the perceived risks associated with experiencing certain shocks (i.e., actors' estimation of the probability of an event occurring and the likely severity if it happens); and the perceived risks surrounding an actor's responses to shocks after the occurrence of an adverse event (i.e., actors' estimation of the riskiness or uncertainty associated with possible responses to a shock). The perception of dread variable employed in this study speaks more to the former. The question used was: "*How do you feel when thinking about the possibility of these dangers/threats*[7] *happening and affecting your family.*" Reponses were on a scale of 1-3 where 1 = A common risk that doesn't worry you; 2 = not sure how it will make you feel; and 3 = it scares/terrifies you.

Perception of Control: As used in this paper, perception of control can be likened to the term coping appraisal used by Grothmann and Reuswigg (2006). It refers to "[an

[7] There were 14 threats provided in the questionnaire, but only 5 of them were utilized because of this study's focus on environmental shocks. The following are the relevant adverse events utilized in this study: hail, frosts, drought, floods, and climate change. The other threats presented in the questionnaire related to pests infestation; animals falling sick; low fertility of soils; road blockings and strikes; low market prices for crops and livestock; children and adults in the households getting sick; and loss of job for migrant family member.

evaluation of one's] ability to cope with and avert being harmed by the threat, along with the cost of coping" (p. 104). Conceptually, it incorporates the belief that a person's actions will in fact be effective in keeping them from being harmed by the threat; the perceived ability to carry out the response; and the cost of acting (Grothmann and Patt, 2005). A similar concept appears in the Béné et al. (2019) framework as self-efficacy which they describe as the belief actors hold in their ability to manage situations. The survey asked respondents: "*How much control do you think you have over these events[8]?"* The Likert scale responses were: 1 = You have no control; 2 = more or less not under your control; 3 = not sure being able to control; 4 = it can be controlled a little; 5 = completely under your control.

It is worth pointing out that the analytical model utilized in this study does not directly mirror the explication of the resilience pillars provided in theory (i.e., absorptive, adaptive, and transformational capacities). The resilience pillars in this study are somewhat unique [9]. They are however still reflective of the dimensions of resilience capacity expounded in theory. Such an approach is not uncommon in the field of resilience analysis within a human dimensions context.

For example, the Resilience Index Measurement and Analysis (RIMA) model developed by the Food and Agriculture Organization (FAO) also uses some unique factors.

[8] The same 5 of 14 events utilized in the question on perception of dread were used here.

[9] The initial model proposed for the analysis in this study was strictly driven by the theory (i.e., the pillars of resilience were comprised of absorptive, adaptive, and transformative capacities, as well as a pillar for subjective resilience) and the indicators for each of these pillars were informed by the literature. However, the specified model did not converge (possibly due to the limited sample size and the data transformation that was required to create some of the variables e.g., the diversity indices). As a result, model calibration was carried to achieve acceptable goodness of fit levels, thus providing the final pillars utilized.

The RIMA model utilizes pillars of resilience that are best suited for the FAO's outcome of concern (i.e., food security). In addition to serving FAO's organizational mandate, the RIMA-II model—an updated version of FAO's resilience measurement tool—was developed to satisfy practical application needs (FAO 2016). The RIMA-II framework adopts five pillars of resilience: access to basic services; assets; social safety nets; sensitivity[10]; and adaptive capacity. However, several studies employing the RIMA-II framework use different numbers of these pillars e.g., Brück et al. (2019), Jones and d'Errico (2019), and d'Errico et al. (2018) use varying combinations of four of these pillars, while Murendo et al. (2020) utilize only three of them. On the other hand, d'Errico and Giuseppe (2018) employ a unique resilience pillar in their model which they referred to as "Income and Food Access." In short, evidence from the literature suggests that resilience pillars generally employed are those deemed appropriate within the context of the study, and novel ones may sometimes be constructed if need be.

In this study, each pillar is operationalized as a latent variable made up of relevant indicators, just like RIMA-II and similar frameworks (e.g., Smith and Frankenberger 2018). The resulting pillars and their constituent indicators[11] are presented in Figure 3.3 and are further described below:

The first resilience pillar (RP1) in the analytical model utilized in the current study incorporates the productive capacity of households. This pillar captures the multiple

[10] Sensitivity is considered to be an exogenous pillar and as a result is not often used in constructing the resilience capacity index, but rather employed in regression analyses to evaluate the real impact of shocks (FAO 2016).

[11] As in Smith and Frankenberger (2018), some indicators are utilized in the construction of more than one resilience pillar.

sources of income-generating activities, as well as their ability to develop new sources of livelihoods relatively quickly. It may also be taken to capture the capacity of households to adapt to their changing environment through the human capital component represented in this pillar. This resilience pillar will be referred to as *Prod-AC* (productive and adaptive capacity).

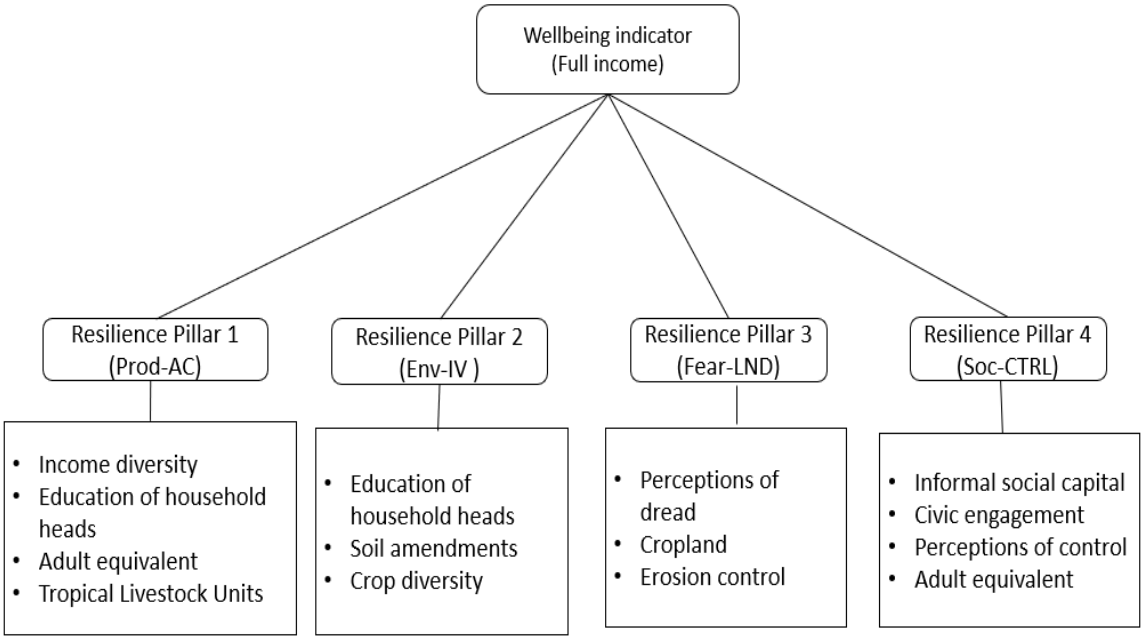


Figure 3.3. Analytical model utilized in this study revealing the resilience pillars and their constituent indicators.

The second pillar (RP2) is suggestive of households' ability to minimize the impact of shocks to their farming operations. It plays a major role in determining the degree of risk exposure, especially with respect to crop production with spillover effects of pastoralism. This pillar will be referred to as *Env-IV* (environmental investment).

The third pillar (RP3) relates to households' perception of dread, as well as their investments in land for crop and pasture production and restoration. As noted earlier, it is

expected that subjective measures of resilience will incorporate elements of the tangible component of resilience since these are expected to influence perceptions (Béné et al. 2019). A lot of the anxiety generated with respect to environmental shocks can be associated with the potential impact of those hazards on their assets which are sustained by or connected to the land. For instance, the adverse effects that erosion could potentially have on households' cultivation or water sources would be a major source of fear for them. This pillar will be referred to as *Fear-LND*.

The fourth resilience pillar (RP4) is both indicative of households' social networks and their self-efficacy, which are both crucial in spurring longer term resilience. For instance, stronger formal network ties could lead to increased exposure to new knowledge, as well as contribute to households' ability to explore new livelihood activities or territories—which may further be reinforced by greater belief in their ability to manage adverse situations (perception of control). This pillar will be referred to as *Soc-CTRL*.

The following are the indicators for the various pillars utilized for this study's analysis with their respective measurements:

- *Tropical Livestock Units*: A standardization of different types of livestock into a single unit of measurement (*Appendix I*)
- *Cropland:* The number of hectares used for crop production in the previous planting season

- *Crop diversity*: Inverse Simpson index[12] of diversity of species planted
- *Informal social capital*: A count of activities that indicate access to resources through informal social capital
- *Education of household heads*: Average number of years of formal education received by household heads
- *Adult Equivalent (AE):* The amount of labor within the household (constructed using the following metric: AE=1 for age>17.5 years; AE=0.5 for 17.5>age>12.5; AE=0.3 for 12.5<age<5.5; AE=0 for age<5.5 years)
- *Income diversity*: Inverse Simpson's index of livelihood strategies households participate in. It includes income sources from crops, livestock, and labor markets
- *Civic engagement*: Total number of formal local organizations that household members participate in
- *Erosion control*: Area of land in hectares dedicated to fallow, native pastures, and alfalfa for more than one year. The use of land for this purpose allows for the growth of deep-rooting plants that help with the control of erosion.
- *Soil amendments:* Total cost of soil inputs (chemical or organic fertilizers) that help replace the nutrients extracted through crop production
- *Civic engagement*: Total number of formal local organizations that household members participate in, such as community and school committees

[12] Inverse Simpson's Index =1/ $\sum_{i=1}^{N}(n_i/N)^2$ where n_i is the hectares planted with species *i* and *N* is the total number of hectares planted. The value of the index drops as either the number of species drops or as specialization in specific species increases (Jensen 2010).

- *Perception of dread:* Average value of household heads to questions to questions about they feel when thinking about the possibility of being affected by environmental threats
- *Perception of control:* Average value of household heads to questions about their ability to exercise control over the impact of environmental shocks

Since resilience is an unobservable and multidimensional construct, this paper employs a structural equation modelling (SEM) technique in the assessment of resilience capacity. SEM makes it possible to model and jointly test complex patterns of relationships. SEM utilizes the combination of a factor analysis-type model and regression-type model. The unobserved variables are measured via the observed variables in the factor analysis, while the relationships among the variables are simultaneously identified using the regression-type model (d'Errico and Pietrelli, 2017).

In the analysis for this paper, the latent variables (i.e., the resilience pillars) are thought to explain the variation and covariation in the observed variables and are taken to be linear combinations of the underlying factors. The employed technique allows for the evaluation of the relevance and role of each pillar, as well as their constituent indicators. Specifically, the equations are:

$$RP_{hc} = f(X_{1hc} + \ldots + X_{nhc}) + e_{hc} \quad (1)$$

$$Y_{hc} = \beta_0 + \beta_1 RP_{1hc} + \cdots + \beta_n RP_{nhc} + \varepsilon_{hc} \quad (2)$$

where resilience pillars (*RP*) are a function of their constituent indicators (*X*) and *Y* is the outcome variable for household *h* in community *c*, which for this study is *full income* (explicated below).

Full income: Any resilience measure has to be indexed to a specific wellbeing indicator which could range from food security to poverty or any other development outcome (FAO 2016). As opposed to income in its usual sense, the outcome variable utilized in this study is the value in exchange of the various productive activities households participate in. This is an augmented form of the farm household model (Ellis 1993). The *full income* concept in the original farm household model is:

$$F' = wT_z + pC + mM, \qquad (3)$$

where F' is full income, *wT* is the opportunity cost of time spent in *Z*-goods production, *pC* is market value of home consumption of output and *mM* is value of market purchases (Ellis 1993, p. 132). However, given the context of the study, other sources of earnings and household operations not present in the original farm household model were incorporated into the variable. Thus, for this study full income is comprised of the total market value of the commodities, livestock and livestock products produced; the income earned from off-farm work; and the remittances received.

3.4. Results and Discussion

The data used in this analysis had 103 households from Ancoraimes municipality in the Northern Altiplano, near Lake Titicaca in Bolivia, and 117 households from Umala

municipality located in the Central Altiplano of Bolivia. The summary statistics is presented in Table 1. On average, heads of households in the sample had just above five years of formal education. In terms of social networks, households participate more in informal social activities than they do in formal local organizations. With regard to animal husbandry, a wide range of ownership of animals was observed within the sample, such as sheep (both criollo and improved cattle), and South American camelids. Dairy cattle, sheep and camelids can be found more in Umala region. In Ancoraimes, cattle can be found in the lower and middle elevation, while camelids are more often found in the higher elevations. There was a wide dispersion in terms of the investments households make in managing erosion.

Table 3.1. Summary statistics of households in communities in Umala (Kellhuiri, Vinto Coopani and San Jose Llanga) and Ancoraimes (Chinchaya, Chojñapata, Calahuancani, and Cohani) in 2009.

Variable	Mean	Std. Dev.	Min.	Max.
Tropical Livestock Units	8.10	7.26	0.00	58.90
Income diversity	1.65	0.48	1.00	2.95
Education HH	5.38	3.69	0.00	16.00
Adult Equivalent	3.65	1.96	1.00	9.80
Soil amendments	2.52	1.04	0.00	5.39
Crop diversity	3.27	1.37	1.00	8.39
Cropland	1.98	2.21	0.00	11.00
Erosion control	3.52	4.35	0.00	27.00
Civic engagement	1.00	0.96	0.00	4.00
Informal social capital	1.34	1.68	0.00	12.00
Risk perception	2.78	0.34	1.00	3.00
Perception of control	1.73	0.91	1.00	5.00

Despite the differences in landscapes and the resulting production activities in Ancoraimes and Umala, the overall means for the perceptions of dread and of control for

households in both municipalities were comparable (Table 2). Similarly, the self-appraisals of households to individual environmental shocks were not different across municipalities (Table 3.3).

Table 3.2. Subjective resilience indices* for households in communities in Umala and Ancoraimes municipality in 2009

Municipality	Community	Perception of dread		Perception of control	
		Mean	*SD*	*Mean*	*SD*
Umala		**2.78**	**0.37**	**1.69**	**0.94**
	Kellhuiri	2.40	0.71	1.75	1.09
	Vinto Coopani	2.75	0.26	1.96	1.07
	San Jose Llanga	2.90	0.16	1.58	0.83
Ancoraimes		**2.77**	**0.30**	**1.78**	**0.89**
	Chinchaya	2.83	0.20	1.96	1.04
	Chojñapata	2.68	0.45	1.58	0.62
	Calahuancani	2.59	0.41	1.84	0.67
	Cohani	2.85	0.11	1.48	0.75

* The perception of dread variable is on a Likert scale of 1-3 (where higher values indicate greater feelings of dread), while the perception of control variable is on a scale of 1-5 (where higher values indicates greater control)

Table 3.3. Perceptions of households to environmental shocks in Umala and Ancoraimes municipalities in 2009

	Umala		Ancoraimes	
	Mean	**SD**	**Mean**	**SD**
Perceptions of dread to:				
Hail	2.86	0.44	2.85	0.42
Frost	2.88	0.41	2.91	0.31
Drought	2.87	0.38	2.90	0.31
Flood	2.62	0.57	2.53	0.59
Climate change	2.70	0.51	2.69	0.51
Perception of control to:				
Hail	2.00	1.33	2.28	1.38
Frost	1.54	1.15	2.07	1.36
Drought	1.37	0.97	1.46	0.97
Flood	1.84	1.08	1.58	0.90
Climate change	1.71	1.05	1.50	0.94

Table 3.4. SEM results

Parameters	Standardized coefficients	P(>|z|)
Loadings		
Prod-AC -> Adult equivalent	0.324**	0.030
Prod-AC -> Income diversity	0.354***	0.001
Prod-AC -> Education	0.129	0.227
Env-IV -> Crop diversity	0.634***	0.007
Env-IV -> Education	0.216**	0.049
Fear-LND -> Cropland	0.771***	0.000
Fear-LND -> Risk perception	0.205**	0.010
Fear-LND -> Perception of control	0.196***	0.017
Soc-CTRL -> Informal social capital	0.305***	0.000
Soc-CTRL -> Civic engagement	0.462***	0.000
Regressions		
Prod-AC	0.188***	0.043
Env-IV	0.132	0.222
Fear-LND	0.552***	0.000
Soc-CTRL	-0.663***	0.000

***p<0.01, **p<0.05, *p<0.1

Table 3.5. Fit indices for the SEM model

TLI	CFI	RMSEA	SRMSR
0.97	0.98	0.02	0.04

Overall, the model utilized for the analysis has good fit as revealed by the goodness of fit measures (Table 4). The Standardized Root Mean Square Residual (SRMSR) was 0.04 while Root Mean Square Error of Approximation (RMSEA) of 0.02. Furthermore, the model had a Tucker Lewis Index (TLI) of 0.97 and Comparative Fit Index (CFI) of 0.98 which are both higher than the suggested cut-offs of 0.95 (West et al. 2012).

The SEM results reveal the multidimensional nature of capacities that enable households to achieve resilience. The regression estimates of Prod-AC, Fear-LND and Soc-

CTRL were statistically significant (Table 3). The results show that Prod-AC and Fear-LND had a positive relationship with full income, whereas Soc-CTRL was found to be inversely related to the wellbeing indicator. The first set of results point to the role that human capital (knowledge and skills, along with labor availability) and diversified livelihoods play in improving the resilience outcomes of households. The human capital component of this factor allows households to engage in a diversified portfolio of economic activities, thus reducing their vulnerabilities. Furthermore, livestock act as a savings mechanism as they can quickly be sold in the presence of shocks, thereby serving as a consumption smoothing strategy for households. Overall, families with greater productive assets in the form of land and animals, and households that engage in livelihood activities that are not likely to be directly affected by similar shocks, will tend to experience higher wellbeing levels.

On the other hand, the observed negative association between Soc-CTRL and full income was unexpected. However, a number of possible interactions could have resulted in this finding. It could be that the culture of reciprocity and communal action practiced among the Aymara people may in essence be negatively influencing the full income of households as operationalized in this study. Since these practices involve giving and receiving assistance among neighbors, a neighbor experiencing an idiosyncratic shock may necessitate less time being devoted to one's own portfolio of activities. However, in the case of covariant risks, such trade-offs may become insignificant since a household will also benefit from the aid rendered by other community members. A similar advantageous

effect of these cultural practices is expected if a household is hit by an adverse effect idiosyncratic to them.

Additionally, the correlation between perceptions of control and informal social capital was found to be relatively high (Appendix I) and may suggest that some of the confidence households have in their ability to control hazardous events spring from the faith they have in their support network. Furthermore, the observed negative relationship between Fear-LND and full income could as well be attributed to the life cycle effects of households (as represented by the adult equivalent variable). The presence of older household members would result in lower engagement in productive activities. Likewise, the presence of young children that need to be cared for would also lead to competition for the time of working adults.

3.5. Conclusion

Due to an increase in adverse environmental conditions such as climate variability and weather extremes, it is important to understand the factors that enable households to achieve resilience in the face of these shocks. This essay sought to examine the resilience capacity of agro-pastoralist households in the Bolivian Altiplano, adopting an approach that integrated both objective and subjective measurement indices. The utilization of household perceptions in resilience analysis moves beyond the top-down approach that relies only on objective measures.

Employing a structural equation modelling technique, this study assessed the combined effects of households' attributes, perceptions, and livelihood strategies on their

wellbeing. The results from the analysis suggest that investments in the productive assets of households improved their wellbeing—which was proxied by full income. Having a diversified portfolio of income-generating activities, as well as the skills and human resources to quickly respond to adverse changing conditions was shown to be resilience enhancing. On the other hand, the positive roles of the combined effect of social capital and households' perceptions of their ability to control unexpected circumstances were not supported by this analysis.

However, several limitations in the analysis limit the claims of the findings from this essay and the results should therefore be treated with some caution. As pointed out earlier, modification indices were utilized during re-specification of the original hypothesized model. That is, a data-driven modification was employed to ensure better fitting of the analytical model. The risk with such a process is that it may lead to models that are not representative of the true population model (MacCallum, Roznowski and Necowitz 1992). However, such concerns are somewhat assuaged in this study as the resulting model (i.e., the categorization of the ensuing pillars of resilience) was not completely devoid of theory.

Furthermore, the parameter estimation in SEM is done by maximum likelihood estimator which often assumes a large sample size. The small sample and relatively weak empirical relationships between the constructed variables utilized in this study (Appendix II) reduce the reliability of the results. Future studies can seek to improve the analysis conducted in this study by utilizing a larger sample size, coupled with repeated sampling of the study households.

References

Béné, C., Al-Hassan, R.M., Amarasinghe, O., Fong, P., Ocran, J., Onumah, E., Ratuniata, R., Van Tuyen, T., McGregor, J.A. and Mills, D.J., 2016. Is resilience socially constructed? Empirical evidence from Fiji, Ghana, Sri Lanka, and vietnam. *Global Environmental Change*, *38*, pp.153-170.

Béné, C., Frankenberger, T., Griffin, T., Langworthy, M., Mueller, M. and Martin, S., 2019. 'Perception matters': New insights into the subjective dimension of resilience in the context of humanitarian and food security crises. Progress in Development Studies, 19(3), pp.186-210.

Béné, C., Frankenberger, T. and Nelson, S., 2015. Design, monitoring and evaluation of resilience interventions: conceptual and empirical considerations. *IDS Working Paper, Vol. 15, No. 459,* pp.1-26.

Béné, C., Wood, R.G., Newsham, A. and Davies, M., 2012. Resilience: new utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. *IDS Working Papers*, *2012*(405), pp.1-61.

Brück, T., d'Errico, M. and Pietrelli, R., 2019. The effects of violent conflict on household resilience and food security: Evidence from the 2014 Gaza conflict. *World Development*, *119*, pp.203-223.

Davidson, D.J., 2010. The applicability of the concept of resilience to social systems: some sources of optimism and nagging doubts. *Society and Natural Resources*, *23*(12), pp.1135-1149.

d'Errico, M. and Di Giuseppe, S., 2018. Resilience mobility in Uganda: A dynamic analysis. *World Development*, *104*, pp.78-96.

d'Errico, M., Garbero, A., Letta, M. and Winters, P., 2020. Evaluating Program Impact on Resilience: Evidence from Lesotho's Child Grants Programme. *The Journal of Development Studies*, pp.1-23.

d'Errico, M. and Pietrelli, R., 2017. Resilience and child malnutrition in Mali. *Food security*, *9*(2), pp.355-370.

d'Errico, M., Romano, D. and Pietrelli, R., 2018. Household resilience to food insecurity: Evidence from Tanzania and Uganda. *Food Security*, *10*(4), pp.1033-1054.

Ellis, F., 1993. *Peasant economics: Farm households in agrarian development*. Second edition. Cambridge University Press.

Elrick-Barr, C.E., Thomsen, D.C., Preston, B.L. and Smith, T.F., 2017. Perceptions matter: household adaptive capacity and capability in two Australian coastal communities. *Regional Environmental Change*, *17*(4), pp.1141-1151.

Frankenberger, T. and Smith, L.C., 2015. Ethiopia Pastoralist Areas Resilience Improvement and Market Expansion (PRIME) Project Impact Evaluation Report of the Interim Monitoring. *USAID: Washington DC, USA*.

FAO. 2016. RIMA-II: Resilience Index Measurement and Analysis – II. Retrieved from https://www.fao.org/3/i5665e/i5665e.pdf on April 28, 2023.

Gilles, J.L. and Valdivia, C., 2009. Local forecast communication in the Altiplano. *Bulletin of the American Meteorological Society*, *90*(1), pp.85-92.

Grothmann, T. and Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Global environmental change*, *15*(3), pp.199-213.

Grothmann, T. and Reusswig, F., 2006. People at risk of flooding: Why some residents take precautionary action while others do not. *Natural hazards*, *38*(1), pp.101-120.

Jensen, N., 2010. *Exploring the relationships between livelihood dimensions and socio-ecological resilience in the Bolivian altiplano* (Publication No. 13850739) Master's thesis, University of Missouri-Columbia. ProQuest Dissertations Publishing

Jones, L., 2019. Resilience isn't the same for all: Comparing subjective and objective approaches to resilience measurement. *Wiley Interdisciplinary Reviews: Climate Change*, *10*(1), p.e552.

Jones, L. and d'Errico, M., 2019. Whose resilience matters? Like-for-like comparison of objective and subjective evaluations of resilience. *World Development*, *124*, p.104632.

Jones, L. and Tanner, T., 2017. 'Subjective resilience': using perceptions to quantify household resilience to climate extremes and disasters. *Regional Environmental Change*, *17*(1), pp.229-243.

Kosec, K. and Mo, C.H., 2017. Aspirations and the role of social protection: Evidence from a natural disaster in rural Pakistan. *World Development*, *97*, pp.49-66.

Lebel, L., Anderies, J.M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes, T.P. and Wilson, J., 2006. Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and society*, *11*(1).

MacCallum, R.C., Roznowski, M. and Necowitz, L.B., 1992. Model modifications in covariance structure analysis: the problem of capitalization on chance. *Psychological bulletin*, *111*(3), p.490.

Murendo, C., Kairezi, G. and Mazvimavi, K., 2020. Resilience capacities and household nutrition in the presence of shocks. Evidence from Malawi. *World Development Perspectives*, *20*, p.100241.

Nguyen, K.V. and James, H., 2013. Measuring household resilience to floods: a case study in the Vietnamese Mekong River Delta. *Ecology and Society*, *18*(3).

Rees, L.M., 2009. *What is the impact of livelihood strategies on farmers' climate risk perceptions in the Bolivian Highlands?* (Publication No. 1481480) Doctoral dissertation, University of Missouri-Columbia. ProQuest Dissertations Publishing.

Rogers, R.W., 1983. Cognitive and psychological processes in fear appeals and attitude change: A revised theory of protection motivation. *Social Psychophysiology: A Sourcebook*, pp.153-176.

Schipper, E.L.F. and Langston, L., 2015. A comparative overview of resilience measurement frameworks. *Analyzing Indicators and Approaches; Overseas Development Institute: London, UK*, *422*.

Shah, S.H., Angeles, L.C. and Harris, L.M., 2017. Worlding the intangibility of resilience: The case of rice farmers and water-related risk in the Philippines. *World Development*, *98*, pp.400-412.

Smith, L.C. and Frankenberger, T.R., 2018. Does resilience capacity reduce the negative impact of shocks on household food security? Evidence from the 2014 floods in Northern Bangladesh. *World Development*, *102*, pp.358-376.

Frankenberger, T. and Smith, L.C., 2015. Ethiopia Pastoralist Areas Resilience Improvement and Market Expansion (PRIME) Project Impact Evaluation Report of the Interim Monitoring. *USAID: Washington DC, USA*.

Tanner, T., Lewis, D., Wrathall, D., Bronen, R., Cradock-Henry, N., Huq, S., Lawless, C., Nawrotzki, R., Prasad, V., Rahman, M.A. and Alaniz, R., 2015. Livelihood resilience in the face of climate change. *Nature Climate Change*, *5*(1), p.23-26.

Valdivia, C., 2004. Andean livelihood strategies and the livestock portfolio. *Culture & Agriculture*, *26*(1-2), pp.69-79.

Valdivia, C., Seth, A., Gilles, J.L., García, M., Jiménez, E., Cusicanqui, J., Navia, F. and Yucra, E., 2010. Adapting to climate change in Andean ecosystems: Landscapes, capitals, and perceptions shaping rural livelihood strategies and linking knowledge systems. *Annals of the Association of American Geographers*, 100(4), pp.818-834

Valdivia, C., Rojas, S., Yager, K. and Bekee, B. 2019. *Landscapes, livelihoods, and resilience in the context of climate change in the Bolivian Altiplano*. Conference presentation, AAEA Annual Meetings, Atlanta, GA, United States

West, S.G., Taylor, A.B. and Wu, W., 2012. Model fit and model selection in structural equation modeling. *Handbook of Structural Equation Modeling*, *1*, pp.209-231.

APPENDICES

APPENDIX I – TROPICAL LIVESTOCK UNITS [a]

Animal	Weight (kg)	Metabolic Weight [b]	TLU
Cattle (mejoradad)	240	63	0.89
Cattle (Criollas)	160	44	0.7
Alpaca/Llama	65/75	22.9/25.5	0.38
Donkey/Horse	100/ 225	(.5/.9)	0.7
Pigs	30	13	0.2
Sheep (mejoridad)	35	14.4	0.23
Sheep (Criollas)	20	9.5	0.15
Birds	1	1	0.01
Rabbit/Guinea Pig	(2.5/.5)	2/1	0.02

[a] (Source: Jensen 2010)

[b] Metabolic weight is used to calculate TLUs because energy use is more closely tied to tissue mass, not body weight which is a product of tissues and fats.

APPENDIX II – CORRELATION TABLES

a) Resilience Pillar 1

	TLU	Income diversity	Education HH	Adult Equivalent
TLU	1.000			
Income diversity	0.244	1.000		
Education HH	0.095	0.181	1.000	
Adult Equivalent	0.319	0.100	0.054	1.000

b) Resilience Pillar 2

	Education HH	Soil amendments	Crop diversity
Education HH	1.000		
Soil amendments	0.121	1.000	
Crop diversity	0.141	0.350	1.000

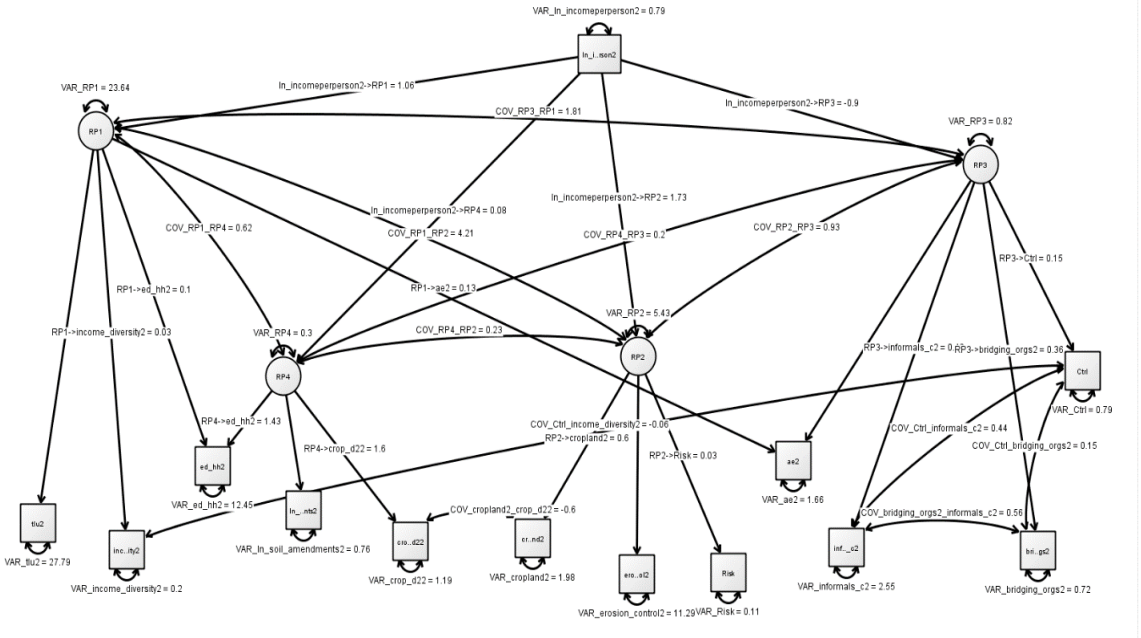
c) Resilience Pillar 3

	Cropland	Erosion control	Risk perception
Cropland	1.000		
Erosion control	0.502	1.000	
Risk perception	0.147	0.132	1.000

d) Resilience Pillar 4

	Adult equivalent	Informal social capital	Civic engagement	Perception of control
Adult equivalent	1.000			
Informal social capital	0.217	1.000		
Civic engagement	0.306	0.489	1.000	
Perception of control	0.166	0.356	0.276	1.000

APPENDIX III – PATH DIAGRAM



CHAPTER 4. ADOPTION OF SMART FARM NETWORKS: A TRANSLATIONAL PROCESS TO INFORM DIGITAL AGRICULTURAL TECHNOLOGIES

4.1. Introduction

The increased rate and severity of changes in weather patterns have led to alterations in the growing conditions of crops, as well as the degradation of soil and water resources (United States Environmental Protection Agency, 2022).[13] Since the adverse effects of these climatic changes usually extend beyond the perimeters of individual farms (e.g., pest migration), the proper responses from farmers may often require coordinated efforts among them. Consequently, information and communication technologies are being developed to assist farmers with timely and collective mitigation and adaptation strategies for their current and future agricultural challenges. However, among other impediments, social and behavioral factors like data privacy and trust pose a threat to realizing the goals of these technological solutions.

In this study, we use a translational research process to examine the drivers of adoption of smart and connected farm networks. We probe farmers' views about participating in these types of networks and provide insights into the technological and socioeconomic constraints associated with the uptake of smart farm networks. Such an investigation is crucial in identifying and eliminating the barriers that keep farmers from embracing tools and practices that could enhance their productivity and profitability. In addition, the participatory approach we adopt in this study sheds light on how to engage

[13] https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply

farming communities in the development process of digital innovations in an agricultural context. Involving the end-users in the creation and refinement of agricultural technologies is important because it ensures that these technologies meet the practical needs of farmers, thereby increasing the likelihood of adoption in the long run.

4.1.1. Agriculture in the context of climate change

The changes in temperature, precipitation patterns and extreme weather events being observed across the globe are bound to adversely affect agricultural productivity, food security, and overall human wellbeing (Nelson et al., 2009). The impact of climate change on agricultural systems is both substantial and complex. For instance, the effects of a changing climate, as mediated by the development of plant diseases, is itself complex (Garrett et al., 2011). At the minimum, climate change is expected to affect the geographical distribution of hosts and pathogens, as well as transform the physiology of host-pathogen interactions by altering the stages and rates of pathogen development and modifying host resistance (Coakley et al., 1999).

Although an increase in agricultural production and trade have contributed to the rapid spread of crop pests and pathogens, changing environmental conditions have also been responsible for the observed patterns of pest and pathogen emergence and migration globally (Bebber, 2015). Moreover, the risk of crop diseases and damages by insect pests is increased by the concentrated nature of many agricultural landscapes (i.e., monoculture farming), especially in a country such as the United States where four crop species account for over two-thirds of croplands (Margosian et al., 2009).

Other menaces such as the dispersal of weed seeds and the diffusion of pesticides by wind also demonstrate that agricultural production is increasingly faced with threats that transcend farm boundaries. Besides, climate change is expected to encourage the proliferation of weeds and pests (Nelson et al., 2009). Consequently, there is a need to respond appropriately to the current agricultural production context with proper management approaches—those that emphasize mitigation efforts and decision-making at the landscape or community level, aided by rapid computing and communications technology. These management approaches will unavoidably require the willingness of farmers to act collectively.

4.1.2 Digital agricultural technologies, smart farming, and data sharing

The agricultural sector has been experiencing an "information revolution" (Dyer, 2016), also known as a "digital agricultural revolution" that is rapidly changing the agricultural management landscape (Weersink et al., 2018). This revolution is characterized by the use of digital agricultural technologies and platforms and is driven by both the low cost of data collection and improved computational capacity in analyzing data (Coble et al., 2018; Weersink et al., 2018).

Digital agricultural technologies are those that "digitally collect, store, analyze and share electronic data/information along the agricultural value chain," while digital platforms are "a group of technologies that are used as a base upon which other applications, processes and technologies are developed" (Runck et al., 2021, pp1-2). Examples of digital technologies used in agriculture are unmanned aerial vehicles (UAVs),

sensors (soil, water, light), and location and navigation systems such as the GPS. Among examples of digital platforms are digital tool suites that link data to tools, or a website that aggregates information about digital tools (Runck et al., 2021).

On the other hand, smart farming is a phenomenon that emphasizes the use of information and communication technology in the cyber-physical farm management cycle, thereby enabling farmers to make context- and situation appropriate responses to real-time events (Wolfert et al., 2017). That is, smart farming entails the use of digital technologies to manage farms with the goals of increasing the quantity and quality of products, reducing production risks, and minimizing costs in the long run, while optimizing human labor. Examples include the use of sensors and drones for smart crop management (e.g., pest detection and spraying), and utilizing artificial intelligence and location tracking software in autonomous ground vehicles (e.g., self-driving tractors) to increase field work accuracy.

It is believed that smart farming will enhance efficiency and productivity, support sustainability, and positively affect rural communities (Regan, 2019). Although there have been advances in the adoption of smart equipment (e.g., smart tractors, aerial surveillance), efficient computing and communications technology that connect farmers within a community and enable them to share data are scarce. As earlier pointed out, the transboundary nature of current production threats necessitates data collection and decision-making at a community or beyond-farm level. However, farmers often express concerns with respect to using technologies that utilize large volumes of farm-level data (Carolan, 2018, p. 748).

There are several reasons for the concerns around data sharing among farmers, many of which revolve around issues of data privacy, data ownership, trust, and control (autonomy). Many farmers believe that they have the right to know what data is being collected, who is accessing it, and how it is going to be disseminated and used (Regan, 2019; Ryan, 2019). Farmers also often express skepticism about the ability of current regulations and practices to adequately protect their farm data. Even where privacy and security measures do exist, some farmers are still worried about the risk of potential breaches (Jakku et al., 2019). Furthermore, farmers perceive data as a valuable commodity and are concerned about who will capture the value of accessing and using the data, especially if it will be at the expense of farmers themselves (Jakku et al., 2019; Zhang et al., 2021). For example, farmers fear that by accessing their data, data aggregators could gain an unfair advantage and engage in price speculation in commodity and real-estate markets (Sykuta, 2016).

Another concern that farmers have with regards to data governance is the lack of transparency/clarity around contracts with technology providers, and a limited awareness of the terms and conditions regarding data ownership and use (Ryan, 2022; van der Burg et al., 2020; Wiseman et al., 2019). Farmers may not be aware of or may not fully understand how much control the contract relinquishes to the service provider, or the extent to which the data will be shared, raising ethical issues around the informed consent that they may provide (Ryan, 2019). It is also concerning that many of such license agreements are generally non-negotiable and are presented in a “take it or leave it” format (Wiseman et al., 2019).

However, the level of farmers' skepticism varies with respect to whom they are dealing with. The type of organization managing the data-sharing platform and farmers' idiosyncratic attitudes towards them have been shown to influence the degree of farmers' willingness to engage in arrangements that require sharing of farm data. For instance, Turland and Slade (2020) found that Canadian farmers were more willing to share their data with university researchers and grower associations than with government officials or equipment manufacturers. Potential explanations for this relate to farmers' fear that the government could generate new regulations or reveal violations of existing regulations based on the shared data, as well as skepticism about the benefit that the government can provide relative to private organizations (Coble et al., 2016).

Another obstacle that could potentially hinder the realization of such community-wide data sharing among farmers is the fear of being stigmatized or penalized if worrisome data is traced to a particular farmer's operation (Regan, 2019). That is, farmers may be concerned about the practicability of assuring privacy of individual farm-level data and the potential consequences of such negligence. Moreover, even in cases where individual anonymity is guaranteed, concerns about undesirable action being taken against the group or community to which the farmer belongs may be another source of concern (Taylor, 2017).

4.1.3. Behavioral determinants of agricultural adoption and the practice of farming

In general, innovations are taken to be the new methods, customs, or devices used to perform new tasks (Sunding and Zilberman, 2001). Innovations are usually adopted

because of their perceived benefits (Chavas and Nauges, 2020). That is, the adoption of a new technology is often the result of calculations that weigh the incremental benefits of adoption against the cost of change, often within a context of uncertainty (Chavas and Nauges, 2020; Hall and Khan, 2003).

In addition to the external determinants of adoption such as the characteristics of the technology, economic factors, institutional factors, social networks, and decision-makers' characteristics (Mwangi and Kariuki 2015), intrinsic behavioral factors have also been shown to influence the adoption of agricultural technologies (Streletskaya et al., 2020). For instance, risk preferences seem to influence farmers' decision-making when it comes to adopting new technologies. Loss aversion, ambiguity aversion, and the overweighting of small probabilities of loss may lead farmers to tread extra cautiously when presented with new technologies (Carter, 2016; Streletskaya et al., 2020).[14]

In settings that require collective action, trust in the cooperation level of others plays a vital role in farmers' decision to adopt an innovation. If the innovation in question is of a public good nature and requires the voluntary contribution of individuals within the community, trust is one of the elements of social capital that facilitates the required cooperative behavior (Leonard et al., 2010). For example, Halimatussadiah et al. (2017) find that trust—used as a proxy for social capital—impacts the contributions made by

[14] Loss aversion refers to the proclivity to choose to avoid losses over comparable gains or the greater intensity of the response to losses than to gains (Kahneman and Tversky, 1979), while ambiguity aversion refers to "aversion to being unsure about the probabilities of outcomes" (Barham et al., 2014), i.e., the tendency to prefer known risks to unknown risks.

individuals towards an environmental collective action involving the management of waste collection.

Additionally, other regarding preferences, such as altruism and social norms about fairness or one's obligation to others, may influence adoption decisions. Chouinard et al. (2008) provide evidence that some farmers are willing to sacrifice profitability to achieve conservation goals—and such stewardly inclinations may be prompted by a consideration of others (e.g., future generations). That is, the observed conservation behavior among farmers may not always be consistent with the profit-maximizing motives they are usually assumed to operate with. Similarly, Greiner and Gregg (2011) show that farmers are driven by a "care-based ethic" and are strongly motivated by stewardship aspirations than by external economic goals. In short, farming practices are often influenced by psychological factors such as altruistic behavior and intrinsic motivations.

Furthermore, farmers' trust in new technologies and their views on whether certain innovations are useful to their agricultural practice are often determined by the values and relationships that farmers have (Raedeke et al., 2003). To explore this notion further, we look to the discipline of Sociology and draw insights from Bourdieu's concepts of "field" and "habitus" that highlight how actors' objective conditions, internal interpretations and social actions can help understand the practices and operating logic of a given social group (Bourdieu, 1977, 1984, 1988, 1990; Bourdieu and Wacquant, 1992; Raedeke et al., 2003). This framework has been previously used to inform how farmers and entrepreneurs negotiate change and to explore the inherent characteristics that

shape their responses (Barbieri and Valdivia, 2010; Glover, 2010; Schucksmith, 1993; Valdivia et al., 2021).

Under this framework, the *field* of farming entails the social relations that make farming possible (Raedeke et al., 2003). It emphasizes the networks or set of relationships farmers have, as opposed to the individuals and social structures that make up the system. These relationships exert considerable influence on the practice of farming. For example, family members may sway farmers' views of what constitutes "good farming," while the perceived preferences of landlords may play an important role in the farming methods their tenants use (Raedeke et al., 2003). Similarly, farmers' relationship networks often influence their adoption of innovation (Caffaro et al., 2020), and more generally, these networks situate much of their learning since learning is argued to be a social process (Oreszczyn et al., 2010).

On the other hand, the concept of *habitus* has to do with the habitual schemas and dispositions of individuals that operate in their subconscious. Specifically, the habitus of farming refers to the "taken-for-granted, shared meanings and behaviors" utilized by farmers and it works as a "matrix of perceptions, appreciations, and actions [that] makes possible the achievement of infinitely diversified tasks" (Raedeke et al., 2003, p. 69). The habitus of farming could also be described as the "active residue of past action that functions within the present" and allows for a farmer's "efficient negotiation through mundane day-to-day activities on the farm" (Carolan 2005, pp. 389-390). That is, habitus is the internalization of the dominant modes of thoughts and experiences (through social interactions and one's own experiences) that are derived from the subconscious and

cumulative assimilation of an established ethos of being a farmer (Shucksmith and Herrmann, 2002).

The interrelation of habitus and the constraints, demands and opportunities of a field produces practices (Shucksmith and Herrmann, 2002). The practice of farming therefore encapsulates the dialectical relationship between field and habitus, and the interaction of field and habitus is what gives rise to specific attitudes, feelings, and dispositions (Raedeke et al., 2003).

4.1.4. Aims of the study

The objective of this study is to investigate farmers' impressions and concerns about participating in a smart and connected farm network. By adopting a participatory approach, we attempt to answer the following questions: *What are farmers' opinions with regards to participating in a smart and connected farm network? What are the perceived benefits and perceived risks of participating in such a network?*

Whereas previous studies investigating farmers' perceptions and experiences with data-sharing agricultural networks have utilized a few approaches such as face-to-face interviews (e.g., Regan, 2019), computer-assisted telephone interviews (e.g., Zhang et al., 2021), and surveys (e.g., Wiseman et al., 2019), this study combines data from focus groups and questionnaires, allowing us to capture the views and behavioral profiles of the farmers in a more holistic manner. In addition, while previous related studies have been conducted in other parts of the world such as Australia, Canada, and a few European countries, this study was carried out in the Midwestern region of the United States. There

is a need to capture the views of farmers across different regions since farming and policy contexts may differ significantly across geographical locations.

4.2. Methodology

4.2.1. *Translational research process*

This study is embedded in a translational research process (Woolf, 2008) that involves potential end-users of a technology in the discovery process by effectively communicating their needs, wants and perspectives on related issues (Valdivia et al., 2014). Within the context of agricultural development, this is a participatory process involving a two-way communication (feedback loop) between actors in the technology development sphere and those in the practice of farming (Valdivia et al., 2014; Valdivia et al., 2018) (see Figure 4.1). Such feedback loop is intended to bridge any differences in knowledge systems and facilitate learning among the different groups of actors, with the end goal of creating an innovation that is salient, trusted, and actionable within the context of the end-users. For instance, feedback from potential end users can help developers improve the technology, while information from various sources—including the developers and their own social networks—can help the end users in mastering the technology.

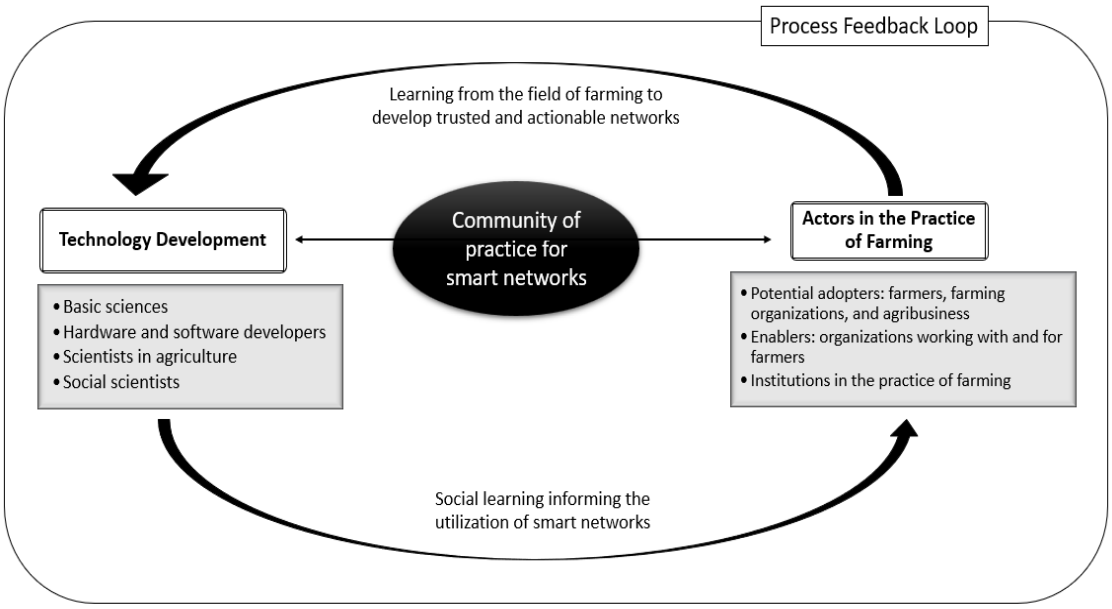


Figure 4.1[15]**.** Translational research process in the development of smart farm networks

4.2.2. *Study context and procedures*

This study is part of a project that aims to develop novel socio-technical solutions that will create smart, connected farm networks for rural farmer communities by facilitating data sharing, knowledge exchange and coordinated responses to production threats. The project intends to promote real-time monitoring of threats and contribute to community-led decisions, with the end goal of improving the management practices and crop yield of farmers in an efficient and cost-effective manner. The technology in question is expected to have a network component where farmers can share their knowledge and data, and coordinate responses.

[15] The community of practice and the process feedback loop are further discussed in the next section.

The study was implemented in collaboration with an association that serves farmers in the U.S. state of Iowa. A community of practice (CoP) was formed to engage potential users of the innovation from its inception and throughout the development process. Engaging the farmers themselves to learn about their views of the innovation represents the first step in the feedback loop process of the innovation pathway (Valdivia et al., 2018). This stage consists of the scientists sharing the concept of the smart network, what it takes to be produced and deployed, and which issues it could address (Valdivia et al., 2014). The network in question requires on-the-ground data from farmers' fields—in this case from farms distributed in a region—to provide information beyond a particular farm. A group of eight farms with soybean production in common constituted the CoP. They agreed to participate in the technology testing and to be part of participatory workshops that inform the innovation and provide feedback to developers.

Two participatory workshops were conducted in August 2021 in the state of Iowa. Participants consisted of farmers representing the eight farms in the CoP and a team of scientists from four institutions involved in the creation of the technology. The protocols for the participatory workshops were developed with respect to the specific technology and were designed based on a related literature review and feedback from the scientists involved in the development of the technology—including agronomists, computer scientists, computer engineers, and social scientists. The protocols were then pilot tested among team members involved in the creation and deployment of the network.

The participatory workshops lasted approximately 90 minutes and began with a presentation about the goals of the project and a short description of the network by the

scientists. Participants were informed that the network would help improve data collection, transfer, and processing, as well as improve connectivity within and between fields. They were told that the communication infrastructure for the network was to be realized with the help of emerging technologies such as dynamic spectrum access, unlicensed radio frequency, unmanned aerial vehicles (or drones), Internet of Things sensors, and mobile crowdsourcing; and that sensors would be the source of information, providing data and images on crops, soil, environment, diseases, etc.

The participants were also notified that the collected data would be processed using state-of-the-art algorithms and machine learning approaches; that cloud services would be used to store both raw and processed data; and that drones and novel wireless technologies would be utilized to transfer data to the cloud. Furthermore, they were informed that farmers participating in the network would have real-time access to the processed data to visualize the resulting information from fields and possible recommendations through a dedicated website portal on a tablet, desktop, or smartphone; and that farmers could also send information and data to the system in a privacy-preserving manner through a crowdsensing paradigm.

After describing the network, participants then engaged in a focus group discussion where they shared their experiences with related innovations, as well as their views on participating in the network. Subsequently, participants performed a discrete choice experiment intended to elicit their valuations of various attributes of the innovation. Afterwards, participants completed a questionnaire eliciting information on their farm operations, socio-demographics, and attitudinal characteristics. The workshop

ended with several interactive behavioral games which elicited risk preferences, trust, and cooperation levels. Approval from the university's Institutional Review Board was obtained prior to conducting the workshops. Responses to the discrete choice experiment and the behavioral games are not included in this article as they were implemented with the sole purpose of pilot testing protocols for future experiments with similar sample populations. Participants' responses to these tasks are not expected to influence their participation in the focus group as they were implemented at the end of the session.

4.2.2.1 Focus Group Discussions

The members of the CoP participated in a guided focus group discussion to share their impressions, experiences, and vision about how the proposed network could become an actual trusted tool in their hands. The focus groups were designed following Morgan (1997) and they allowed us to observe group interactions around the nature of the innovation, bringing into discussion many more ideas than an individual interview. The interactions and dynamics in the focus groups also presented an opportunity for participants to elaborate on the perspectives and experiences shared by others in the group.

Two focus group discussions were conducted, one with three subjects and one with six subjects.[16] Each focus group started with a presentation about the proposed technology given by the scientists developing the technology and a grower specialist

[16] Although eight farms made up the community of practice, there were a total of nine participants for the workshop sessions. This was because one farm had two representatives (i.e., a married couple), whereas the other farms had only one representative each.

involved in the deployment process. Information about the technology was given through a 10-minute video about characteristics of the innovation followed by an 8-minute in-person presentation about the potential benefits of the innovation to the practice of farming. The presenters were the same in both focus groups. Subjects then had the opportunity to ask general questions about the innovation and introduce themselves to the group. Both focus groups were facilitated by the same researcher who followed a script to ensure consistency with the content, prompts, and framing of questions. The focus groups were recorded using Zoom and cellphones. Participants used their names during the discussion; however, anonymous identifying numbers (e.g., 101) were used when transcribing the recordings to maintain anonymity of responses. That is, there is no personal identification linked to the responses.

A literature review on the practice of farming concept (field and habitus) informed the design of the questions used in the focus groups. The discussions were structured based on the following four sets of questions (in this order):[17] 1) *What are your impressions of what was just presented to you about the technology? Have you had or interacted with similar technologies before?* 2) *What do you like most about the technology, and what are some problems you are currently facing that this technology may be able to address?* 3) *What concerns do you have about the technology? Why wouldn't you adopt this technology on your farm?* and 4) *What are your thoughts about how the technology could become a reality for farmers in your community?*

[17] The complete script used in the focus groups is available from the authors upon request.

4.2.2.2. Questionnaire

The purpose of the questionnaire[18] was to obtain information on the characteristics of the farmers and their farming operations, as well as behavioral attitudes that may influence adoption of the smart and connected farm network. Participants were asked questions about their farm specializations, types of digital technologies currently being used, and their current practices for managing pests, diseases, and weeds. Regarding farm networks, participants provided information about the formal and informal networks, organizations, and people they interacted with, as well as the frequency of such interactions. They also responded to various statements regarding the level of trust they had in their neighbors, other farmers, agricultural technology and network providers, and several other stakeholders in their field of farming. The questionnaire also enquired about the farmers' knowledge and use of different services provided by digital agricultural technologies. Furthermore, the farmers were asked about the perceived value and risks they associate with digital agricultural technologies and networking, and the conditions for increased trust in these service providers.

4.2.2.3. Qualitative data analysis

The recordings of the focus groups were transcribed using *Otter.ai* software and the transcripts were then revised by two researchers separately. The three members of the research team engaged in active reading and re-reading of the edited transcripts and independently carried out a thematic analysis (Braun and Clarke, 2006). The data was

[18] The complete questionnaire is available from the authors upon request.

coded manually and the themes for the coding protocol were based on the *field* and *habitus* framework described above.

Since the intent of the focus groups was to capture farmers' impressions about the proposed technology, the coding strategy took into consideration both the group and individual level phenomena; that is, insights from both the individuals that make up the CoP and the dynamics of the group as a whole were acknowledged (Morgan, 1997). An analysis that recognizes the interplay between these two levels of analysis is often recommended because neither the individual nor the group represent a "separable unit of analysis" (Morgan, 1997). Furthermore, this approach helps to reduce the potential impacts of omissions by an analysis at only the group level such as the effects of censoring and conformity—situations that tend to occur in group settings (Carey and Smith, 1994).

Our thematic analysis followed a more "theoretical or top-down" approach, as opposed to the "inductive or bottom-up" alternative (Braun and Clarke, 2006). That is, rather than simply focusing on providing a rich description of the data itself, the theoretical approach was driven by the analytic interest of the researchers and centers more on the specific questions of interest, thereby providing more detailed analysis of relevant aspects of the data. Specifically, the researchers sought to determine the networks of farmers (while identifying those that they trust), the shared values in the practice of farming, and their adaptive capabilities (Glover, 2010; Valdivia et al., 2021). Subsequently, the researchers met multiple times to review their independent analyses of the data and to discuss the emerging themes and sub-themes.

4.3. Results

4.3.1. Description of the Community of Practice

The community of practice (CoP) consists of nine farmers (8 farms) who are members of the same grower association. Almost all farmers are male (90%), with an average age of 51 years and average household income of $135,000, whereas the average net farm income (cash) in 2021 for the state of Iowa was about $153, 000 (Ag Decision Maker, 2022). All participating farmers have completed high school and half have at least a college degree. They are all involved in crop production (mainly corn and soybean) and had each planted between 1,000 acres to almost 4,000 acres of cropland in the study year. On average, participants plant 700 acres of soybean and 850 acres of corn. About 75% of participants are involved in other farming operations such as beef cattle and/or hog production.

In addition to being members of grower associations, the members of the CoP are also part of cooperatives. They mostly use these groups as well as other private company networks for sharing information about farming, with the nature of these interactions varying depending on the field of farming. For instance, farmers interact daily with other farmers; whereas, on average, the respondents indicate that they meet with university extension agents and representatives of environmental agencies (e.g., Natural Resources Conservation Service) on a quarterly or annual basis. While most participants do not have any contact with scientists, two report interacting with them annually and one respondent indicates monthly interactions. Participants' interactions with independent crop consultants present the greatest variation, ranging from weekly or monthly interactions

to annual or no interactions whatsoever. Engagement with policy makers is also seldom or non-existent.

In terms of technology exposure, members of the CoP can be considered as relatively technologically savvy as they have previous experience with various types of digital agricultural technologies on their fields such as variable rate technologies (i.e., the use of data and automation to apply varying rates of inputs like fertilizers and seeds in appropriate areas around the field); GPS-based field mapping; and drone/aerial imagery for scouting weed, disease, pest, and nutrient stress plant stand count. However, other technologies such as crop canopy sensors and machine optimization solutions are scarcely being used within the group. The farmers also report that they rely mainly on private companies for information and technical expertise on the management of pests.

4.3.1.1. Practice of farming

The information participants shared during the focus group sessions revealed high diversity regarding their farm operations, ranging from part-time to full-time operations; growing of soybean and corn commodities to rearing of animals such as pigs and cattle; and renting of land alongside owning enterprises as a family business. There were varying years of engagement and partnerships with family members, such as parents still owning land and multiple generations being involved in farming: "*I am now at the stage of life, when I'm probably starting to downsize and transfer the operation over to my grandson… So that's kind of a challenge for me. I'm kind of a "I can do it all" kind of guy. And it's hard to even let him take over*."

Some participating farmers have gone into debt to begin their enterprise. While some participants have farmed for several years and even generations, there are others who are younger and beginning farmers. In addition, some participants have off-farm work experience but still within the practice of farming such as working for an agribusiness firm. All the participants are currently members of the same grower association and have been exposed to different technologies and projects involving data collection: "*I've been involved with this association, of course through the on-farm network and different projects that they've had for years. I'm kind of enjoying new technologies and working with drone imagery on my own farm.*"

The conversations held during the focus groups were rich and touched on a wide range of issues. However, our analysis focuses on areas related to the adoption of the smart and connected farm network and is split into two main sections: 1) first impressions about the proposed network; and 2) concerns related to the adoption of the network.

4.3.2. Initial impressions about the smart and connected network

Overall, participants show optimism and excitement about the proposed smart and connected network. They sense the opportunities that such a network would provide for collecting, analyzing, and utilizing data. They recognize the need for a technology that can give farmers access to information that they hitherto would not have been privy of: "*If there's certain insects that are moving through an area and this can communicate to others, it's helpful to be aware of this problem potentially reaching your farm, and kind of tracking some of the disease, crop disease or insect problems that can develop along.*"

This positivity was further reinforced by the results from the questionnaire where all the respondents agreed or strongly agreed that digital agricultural technologies and networking can help them deal with production-related issues and make more informed decisions.

The timeliness of the information to be provided among the network users is also attractive to farmers; as another participant indicated: "*I've met other growers and so we kind of have this informal network of sharing information on practices and/or management practices, you can say. So, something like this would definitely help us share information, and make it easier and timelier in a quantifiable way.*" Additionally, the necessity for production-related information in farmers' own locality was noted: "*And I would say, this fact, is this localized data collection seems like, versus like a climate field view, which is, who knows where that comes from? And how big an area?*"

However, since farmers already have existing avenues that they utilize (and trust) for receiving information and for interacting with other farmers, an innovation would have to demonstrate its superiority for it to be adopted: "*I think the benefit that the technology has to prove is that it's going to be better than what's already out there. If the forums that I'm already looking at or using isn't as good as the new technology, then I'm going with the new one, but if the proposed technology doesn't replace what I'm already using as a better trusted advisor, then I probably wouldn't. You know, it won't catch on*."

4.3.3. Technological factors and behavioral drivers of adoption

4.3.3.1. Requisite technological infrastructure and network size

Participants feel that there is a need for reliable highspeed internet access for farmers to be able to utilize the technology. One participant remarked: "*That's why the investment needs to be in infrastructure.*" The importance of telecommunication infrastructure to agricultural operations has also been echoed elsewhere (Zhang et al., 2017). Among the respondents, individual experiences with quality of internet differed. Unlike some participants who noted that they have only recently gotten access to good internet, others indicated that they have enjoyed quality service for several years. One participant stated: "*I kind of have the impression that most of rural Iowa has pretty good internet, I know I have good internet,*" but not all participants affirmed that opinion. "*Yeah, you're extremely spoiled. Live in my place for about a week, for about a day and a half and you go crazy,*" another participant reacted.

Moreover, farmers perceive that the benefits of being in a network such as the one to be provided by the proposed technology will only be harnessed if there are enough people participating in that network: "*So it's good to have a wider base, bigger pool. I think your data is only as good as the environment it's coming out of.*" It is the belief that a larger network will provide more data points for any potential analysis, thus ensuring that the report produced about any phenomenon taking place in a landscape is more accurate.

4.3.3.2. Data validation and accuracy

Due to the prospect of data coming from various sources, data quality has been highlighted as a potential challenge for digital agriculture technologies (Tantalaki et al., 2019). Regarding data accuracy, a participant states a preference for information that can be validated. "*The one thing I can see is where if there is bug pressure, or if there is disease pressure, that's something that could be validated. And you can look it up. And you know, if it shows it's more in this area, or they've seen a lot, well, that's something that could be validated, or fact checked.*" A potential reason for this stems from the lack of trust in the information source. Another participant clearly states his concern regarding unknown sources of information: "*The hesitancy to be reading other information on the network and not knowing where it's coming from, and if it's a trusted source. You know, all the time you hear about on Facebook or Twitter, whether this is fake information, false information, and so you want some validation behind it… Before I go invest my money in a new practice, or changing my operation based on what this guy did on his farm, I want to make sure that it is good for me.*"

However, to combat this concern and to improve the credibility of the network, a participant envisages that having information verified—probably by a third party—may be useful: "*I do like the growers' association because they cater to what I want, and for what I use them for. They can be my third-party independent auditor that makes sure all the data is accurate. So now they can take that information and you have somebody like that, that can make sure that information is accurate before it gets on to [the network].*" The participant is however quick to note that this may be a challenge to implement in

reality: "*But then there's a lot of puzzles and pieces to make that work. You know who's going to be that fact-checker?*"

4.3.3.3. Trust

With respect to lack of trust in information sources, the role of previous experience—both with working with a stakeholder, as well as one's personal experience trying out an innovation–was highlighted. "*My impression was I think there's a lot of good information out there. But for me, it's a matter of where the information comes from. How do I trust the information? So, if I'm looking for information, I go to the people that I know that have the right information or that I trust...We have a lot of trials. And so, I can disprove a lot of information or prove it. So, I trust my information cause I've actually put it to the test.*" This observed correlation between familiarity and trust is consistent with findings by Mase et al. (2015). The authors report that for information about soil and water quality, agricultural respondents in midwestern United States indicated higher levels of trust for organizations that they were more familiar with, including agencies that had a longer historical presence in their region such as the Farm Bureau and the state natural resources agencies.

Regarding data sharing, several participants express higher trust levels toward public universities and grower associations compared to private companies: "*I think the fact that it's being run or being overseen by a grower association or a university or whatever, makes it more legitimate. If somebody from a for-profit company came and said, "Hey, we want to get farmers to start doing this," I'm always skeptical that they're*

going to steal my information or want something from it, and either use it against me or use it for their own profit. I trust you guys aren't going to be doing that. So, I have a little more trust in a university." The more positive attitude of farmers towards universities and grower associations relative to other stakeholders align with findings among Canadian farmers reported by Turland and Slade (2020). These findings are also supported by subjects' responses to questions regarding their trust level toward different institutions and organizations; the results are reported in Table 4.1. Overall, participants seem to trust agricultural organizations and other farmers the most, followed by land grant universities and financial institutions. The lowest levels of trust are expressed towards the government and public institutions.

Table 4.2. Farmers' responses to questions on trust in institutions and organizations

Statement: *How much do you trust the following?*	**Mean**	**SD.**
Neighbors	3.6	0.88
Other farmers	3.8	0.44
Landowners	3.3	0.71
Cooperatives	3.1	0.78
Agricultural organizations	3.9	0.92
Commercial agricultural service providers	3.4	0.72
Banks and other financial institutions	3.7	0.50
Land grant universities	3.7	0.87
Government	2.3	0.50
Public institutions-based start-up company	2.7	0.50

Note: Respondents were asked to indicate their level of trust on a scale of 1-5, with 5 being Total trust and 1 being No trust at all.

When there are conflicting opinions and farmers are torn between choices that seem contradictory, they tend to rely more on recommendations from non-commercial entities: "*And so it's really a struggle, because you have one side telling you, yeah, you better put it on, because you know, it's just a good thing to do for ensuring your yields. And the other one saying, well, there's no evidence that it is going to ensure your yield, because there's nothing affecting, it's not affecting this product…. So, an independent crop consultant, somebody that is not actually selling a product, or Extension or a grower association, things like that, somebody unbiased, will be the ones that could really use this.*"

Commercial companies are perceived to mainly care about their margins while trying to take advantage of farmers via the information they provide. A participant repeated those sentiments by stating: "*But I sometimes think it's, of course the industries that we buy from are senior petrochemicals or fertilizers, they also provide that type of information almost competitive with our universities sometimes. And personally, I trust information from them very little, because they're always biased*. *They have their own opinion. And that's why this type of a project, can be so beneficial, because hopefully, we weed out all that noise from people that try to make a buck off the information they're sharing.*" Another participant added: "…*I feel I'm really interested in this because I would like to see data that isn't biased by anything. Hard to find*…" Low level of trust toward commercial digital and networking providers is also suggested in the responses to the questionnaire, where only 20% of farmers agree that these stakeholders are either trusted by them or by other farmers. However, all the respondents indicate that their trust in

digital agriculture technology and network providers will be increased if they complied with agreements on data access, privacy, and ownership. [19]

Nevertheless, it appears that trust towards these different types of institutions may not be absolute—i.e., farmers may not show (dis)trusting behaviors to certain stakeholders in all situations—but may be dependent on the service in question. For instance, one participant admits that he does not trust public universities with providing up-to-date information: "*I hope they don't take offence, but the university information seems dated at most times, whether it's our state or Missouri… they'll be teaching me things that we started doing 10 years ago.*" On the other hand, another participant indicates that he trusts private companies when it came to scouting his fields: "*And so I'm always having my seed company do it…you know, they give me good information, because they've been out scouting other people's fields*."

It is worth noting that in general, there tends to be a relationship between trust attitudes, risk perceptions, and technology adoption. Within the context of adoption of digital agricultural technologies, it is argued that trust lies at the heart of concerns around data ownership, transparency, privacy, and security (Jakku et al., 2019; Shepherd et al., 2018), and as a result, significantly influences the risks farmers associate with a given technology. Therefore, farmers who have lower trust levels towards a technology and/or the entities involved in its management or operation may be expected to have lower adoption rates. For example, Jayashankar et al. (2018) investigate the mediating role of

[19] Only one respondent indicates that they neither agree nor disagree that complying with an agreement that provides clarity on data access would increase their trust in these providers. All others agree with the statement.

perceived risk and value in the relationship between trust and adoption of Internet of Things (IoT) technologies. The authors find that the perceived risks of farmers have a negative impact on their willingness to adopt IoT, and that trust helps to mitigate such perceived risks.

In our study, participants express concerns about how commercial companies would handle their data, whether it is by deliberately sharing such data or by inadvertently losing it (see Table 4.2). Farmers' perceptions of the risks associated with working with private organizations may also help to explain some of the distrusting attitudes they have towards these stakeholders.

Table 4.3. Farmers' responses to questions on risk perceptions

Statement: *There is a high risk that digital agriculture technology and networking providers will:*	**Mean**	**SD.**
share raw data from my farm with neighboring farmers without my knowledge	2.8	1.30
share raw data from my farm with land speculators without my knowledge	3	1.32
share raw data from my farm for commodity trading without my knowledge	2.8	1.30
be hacked and lose my personal and sensitive business information	3	1.22
make decisions for me with raw data from my farm	2.9	0.93

Note: Respondents were asked to indicate their level of agreement on a scale of 1-5, with 5 being Strongly agree and 1 being Strongly disagree.

4.3.3.4. Data quantity and data utilization

A concern that was constantly brought up during the focus group is the large volume of data that smart devices tend to collect, and the time demands of using such tools. Farmers are concerned that they could spend a lot of time reviewing and/or analyzing information in a way that is no longer effective/efficient. "*I might call it the overwhelming factor of information overload. There's just so much information we process and analyze already...I think that could be the challenge. Like well, do I need to be collecting this? Do I even need to spend time trying to read or look at this, or should I, you know, either focus my time on other places?*"

A related concern is farmers' inability to utilize the data that will be generated. The participants indicate that they currently have lots of success collecting various types of data but express dissatisfaction with their capacity to use that data to make informed decisions on their farms. "*For five years at least we've been doing aerial imagery stuff studies. So, we've done a lot of data collection there, we've done soil conductivity tests and things like that on that. But as far as putting everything together to help make agronomic decisions or financial decisions, no.*" This sentiment was echoed by another participant: "*We have so many variables and to have information is nice, but it's only nice and valuable if you can make an improvement, or a cost-saving measure with that data. So being able to utilize the data to make me more efficient is the goal.*" Furthermore, this participant anticipates a need in the future to expand their field of farming in order to be able to engage other stakeholders (experts) who can analyze the data. In essence, participants are interested in learning what types of data would be collected in the

proposed network, how it would be analyzed, and how it would ultimately assist with decision-making in their practice.

The large volume and complexity of data produced, as well as the models required for computational efficiency, have indeed been identified in the literature as some of the potential challenges of agricultural technologies requiring the use of big data.[20] For instance, Tantalaki et al. (2019) describe the extraordinary techniques required to efficiently process voluminous datasets and suggest that these demands cannot be adequately met by traditional learning models. In addition, they note that advanced visualization techniques and strong multidisciplinary engagement may be needed for appropriate data interpretation; thereby corroborating the views among farmers in our CoP.

4.3.3.5. Data privacy

Although the issue of data privacy and security are one of the main challenges discussed in the literature on adoption of digital agricultural technologies (Coble et al., 2016; Ryan, 2019; Shepherd et al., 2018; van der Berg et al., 2020), our focus group participants seem more interested in evaluating the pros and cons of utterly protecting the identities of the members of the network. During the sessions, they raised concerns about how privacy-preserving features of the network could limit data integrity. Some participants are worried that if complete privacy is guaranteed, it will be difficult to track

[20] Big data refers to the "massive volumes of data with wide variety that can be captured, analyzed and used for decision-making" (Wolfert et al., 2017, p.69).

the source of information provided on the network, which may inadvertently increase one's risk of being exposed to misinformation: "*To keep it anonymous, then you don't know where the information is coming from, but if they don't keep it anonymous, then people can point fingers.*"

Furthermore, participants fear that total privacy may be a disincentive to engaging on the platform, or may prevent those who want to build a reputation of being knowledgeable (or respected contributors) from doing so i.e., it may be at odds with building one's online credibility: "…*all those forums have names on them, you know, and you gain respect for that person from South Dakota that's always posting on the forum because he has 1000 herd feed lot and he consistently has good advice and people respect him. If it was anonymous, you know, someone could also be posting from the sofa and you don't know whether to trust them or not.*"

4.3.3.6. Market competition among farmers

A reason to favor privacy in farmers' practice is the competitive nature of farming. On one hand, participants acknowledge the appeal of privacy to them as farmers; on the other hand, they recognize the need for collaboration to make the network function as it is supposed to: "*I guess it's a fine line between privacy and giving information that can help you… Say you got something good; can you share that information? Maybe you're taking your competitive edge away, you know, so while you want to talk to your neighbors and friends, on the other hand you're still trying to run a successful business.*"

Farmers worry that sharing certain information may impact them negatively. One participant stated: "*I think I'm a little concerned about sharing data with my competitive neighbors… We farmers, whether we like to admit it or not, are competitors with our neighbors. And the data sharing will help me grow and hopefully help our agriculture industry grow. But in some respects, I don't want it to put me into a disadvantage with my neighbor.*" Another participant corroborated: "*It's unfortunate that we have to compete against one another, and we cannot compete against another industry. We need to work together, as opposed to against.*" Responses to the questionnaire suggest that participants are indeed least willing to share information from their farms with their neighbors and other farmers living in the same county (see Table 4.3).

Table 4.3: Responses to questions on willingness to share information

Statement: *I will be more willing to share information generated on my farm with:*	**Mean**	**SD.**
Farmers who are my neighbors	3	0.71
Farmers who live in my county	3.3	0.50
Farmers that have similar farming operations like mine	4	0.71
Farmers who I know personally	3.7	0.50

Note: Respondents were asked to indicate their level of agreement on a scale of 1-5, with 5 being Strongly agree and 1 being Strongly disagree.

There is an obvious tension between sharing data to improve the resolution of the collected information and the inherent competition of the market, such as the competition for renting land: "*I think a lot of the sharing just goes back to even just the land you farm, you know, I mean it's a dog-eat-dog world out there for cash rent. And so I*

mean, any information you share, I feel can be misdirected and be, you know, either used against you…" This point was expounded by another participant: "*The guy that farms within 50 miles of you is really almost your competitor, cause people will travel to farm land if it's a lot of viable, larger chunk of land. If they know something about your farm, that they think oh, I can find out who owns that land and give them more money because I know what they're getting as a return or whatever. There are concerns about that.*"

4.3.3.7. Costs of adoption

Since farmers are interested in their enterprises being profitable, it is no surprise that they would undertake a cost-benefit analysis before adopting a new technology into their practice, and only those technologies perceived as yielding a net-benefit would eventually be adopted. As one participant expressed: "*I got to get at least as much out of it as I'm putting into it.*" Also, considering that the farmers in the CoP are relatively small, farmers worry about the average cost of taking up a new technology and the ability of their operations to justify such an investment: "…*an operation of his size, he's 1200 acres, I'm 1100 acres, so basically the same size, and so the number of acres that we cover per year is not so great to spread the cost over, you know. It's a higher cost per acre investment.*"

Furthermore, farmers in the CoP would like to be able to sync new tools with existing infrastructure or would prefer a machine that can perform multiple tasks: "*I have a planter that plants beans, one does the corn, the tracker, everything's older equipment. But I can't afford to buy five or six different devices to collect GPS location and analyze*

data as we go through the field. I'm going to have to be able to quick switch it from one to the other, or how's that going to work? That's a big concern to me."

Respondents acknowledge the additional costs associated with adopting a new technology such as the time it would take them to familiarize themselves with the technology and the possibility of not receiving the expected returns, particularly in the short run. For instance, the ability of big farms and big agribusinesses to cover some of the upfront costs associated with running data-driven operations—as well as their ability to access the required skills and advice to efficiently utilize such technologies—have led some farmers to posit that big data is for "big farming" and not for everyone (Fleming et al., 2018). Even those with a contrary opinion felt that the potential benefits to farmers may take some time before they are actualized (Fleming et al., 2018).

4.4. Discussion and implications[21]

While digital agricultural innovations have the potential to enable farmers mitigate and respond to current and future production threats in a collective and efficient manner, our findings point out issues that need to be resolved to actualize this possibility. This study sheds light on farmers' engagement in the field of farming and brings to the fore considerations that should go into the design of digital agricultural innovations that are trusted and actionable. Broadly speaking, the concerns that the farmers express mainly stem from the potential features of the innovation, their anticipated interaction with the

[21] As part of the translational process adopted for this research, findings from the analysis of the focus groups and questionnaire were presented to the scientists involved in the development of the technology.

innovation, and their attitudes towards various stakeholders involved in the management and utilization of the technology. Although the framework of field and habitus provides a useful lens for examining the dispositions and relationships shaping the practice of farming, it does not underscore the characteristics of the technologies themselves.

The interest of the CoP in the attributes of the proposed smart and connected network was accentuated, encompassing matters related to the feasibility of enlisting the required number of participants onto the network, as well as its capacity for quality assurance (i.e., the ability of the network to operate in a way that minimizes errors). A good starting point in confronting the former challenge could be to streamline farmer recruitment efforts by drawing insights from existing models of successful farmer networks (Chapman et al., 2016). On the other hand, effective strategies for ensuring data accuracy and consistency within the practice of farming will need to be developed, as claims of precision in digital agriculture often appear to be speculative (Visser et al., 2021). It will also be crucial for these strategies that guarantee data reliability not to be at odds with the data privacy goals of farmers—to the degree possible—since farmers are also interested in protecting the confidentiality of their data.

Similarly, the participating farmers also raised issues of data quantity and data utilization, and these challenges correlate with the widely acknowledged characteristics of big data, referred to as the "4 V's of Big Data"—volume, velocity, variety, and veracity (Lokers et al., 2016). Smart farming is bound to generate very large amounts of data that will require data analytic techniques (Bacco et al., 2019). The frustration of farmers in the CoP about their inability to utilize both currently available and future datasets suggests

that they do not possess the skills needed to analyze them. This implies the need for technicians to transform these raw data into meaningful information; thus, giving rise to the demand for an additional service or technology.

Moreover, it was evident from the discussions that the potential costs farmers would have to incur could severely restrict their adoption of digital innovations. Economic constraints are among the factors often identified in the literature as limiting the adoption of agricultural innovations (Shiferaw et al., 2015; Ruzzante et al., 2021). Consequently, the possibility for developers to manufacture devices that are compatible with existing farming technologies would need to be explored. Success in this regard would help maximize the net-benefits of farmers' investments by lowering the setup and operation costs associated with such new technologies.

Likewise, there is a need for increased investment in rural broadband deployment to provide the requisite telecommunications infrastructure that digital agriculture and networking technologies can ride on. Evidence suggests there is a positive impact of rural broadband initiatives on high-speed internet use among farmers, as well as on farm sales and expenditures (Kandilov et al., 2017). However, these gains presently appear to have a spatial gradient and are mainly confined to counties adjacent to densely populated urban areas. There is therefore an opportunity to further harness the overall gains of the digital agricultural revolution by expanding quality internet access to currently underserved rural communities.

In addition to the specific attributes of the proposed network, participants were also particularly interested in the stakeholders that will be involved in the operations of

the decision support system. Many of the participants echoed skepticism towards the roles of for-profit entities in different aspects of the innovation apparatus, ranging from the management of the information being collected from farmers to the recommendations that will ultimately emerge from the analyzed data. Some of these pessimistic attitudes mirror those acknowledged by previous research (Jakku et al., 2019; Wiseman et al., 2019; Zhang et al., 2021). As a result, it may be pertinent to explore the practicability of non-commercial organizations and institutions managing such networks, and the ramifications of such arrangements.

On the other hand, it will also be worth the effort from a regulatory and policy standpoint to address the specific concerns that farmers have with private companies, such as the opaqueness in how data is collected, stored, processed, utilized, and shared. It will be crucial to promote greater transparency in agreements involving farmers and agribusinesses, as well as to address the existing asymmetry in power relations between various actors in the industry (Bronson, 2019; Avelino and Wittmayer, 2016). However, it is also important to state that farmers' attitudes towards different actors in their field of farming could also be shaped in part by the inherent behavioral characteristics of farmers themselves, such as their general trust levels and risk preferences—which are themselves determined by other idiosyncratic characteristics (Nielsen et al., 2013).

Some other concerns raised by participants in the focus groups have received relatively limited attention in the literature on digital agricultural technologies. For instance, during the sessions, attention was directed to the way the competitive nature of farming could act as a hinderance to the willingness of farmers to share their data. From

our results, it appears that farmers may have to be assured that the data they share will not hurt their competitive advantage. The dilemma and mechanisms of knowledge sharing in relationships that are simultaneously cooperative and competitive (or "coopetition") have been more formally developed and addressed in the fields of management and organizational science (Bengtsson and Kock, 2000; Hackney et al., 2005; Tsai, 2002; Walley, 2007). This kind of business arrangement allows for the use of shared knowledge to pursue common goals, as well as to outperform competitors.

Within the context of digital agriculture, the challenges that are bound to arise from operating such "coopetitive" knowledge-sharing platforms will necessitate a need to better understand how to effectively instigate and sustain network participation. It will be important to know if, and to what degree, factors such as the size, nature, and exact location (or relative proximity) of farmers' operations will influence their desires to participate in these types of network arrangement.

4.5. Conclusion

In this paper, we provide a discussion of the various factors influencing farmers' perceptions and acceptance of digital agricultural innovations, highlighting the role that trust and cooperation play in the likelihood to participate in a smart and connected network. Findings from our study highlight the gains to be harnessed when farmers are involved in the discovery process of an innovation. The multiple interactions between scientists and potential end users in this participatory process allows for the creation of a

feedback loop that shapes the stakeholders' values, constraints, needs and likely responses.

In situations where the effectiveness of the innovation depends on the willingness of users to collaborate (e.g., sharing quality data to produce high resolution information for an early warning system to threats), scientists involved in the creation and deployment of the new technology have a higher likelihood of developing an innovation that is trusted and actionable by engaging farmers in networks early in the innovation pathway. This engaged and continuous dialogue will help uncover the concerns farmers anticipate having within the network or with the stakeholders that will be involved in some part of the technology's functioning. Addressing these concerns in a timely and cost-effective manner will ultimately lead to the provision of the appropriate tools farmers need to effectively respond to both current and emerging agricultural challenges in a coordinated way.

A limitation of this study is that the data utilized came from a relatively small sample size. Also, the participants in the focus groups were conveniently selected through a growers' association. As a result, we may not have achieved data saturation for the goals of the study as it is possible that some unique perspectives from those not in this network of farmers may have been missed. Furthermore, as pointed out earlier, the farmers in the CoP could be considered as early adopters and more technologically savvy than the average farmer. Although several potential factors that could constrain participation in a novel smart and connected farm network were highlighted during the focus group discussions, the views expressed may still be more optimistic than those that would have

come from farmers who are late adopters. Future studies could seek to use a more representative sample of farmers to capture a wider range of views and experiences relating to the use of digital agricultural technologies in collaborative contexts.

References

Ag Decision Maker, 2022. 2021 Iowa Farm Costs and Returns. Iowa State University Extension and Outreach. https://www.extension.iastate.edu/agdm/wholefarm/pdf/c1-10.pdf (Retrieved July 5, 2023)

Avelino, F. and Wittmayer, J.M., 2016. Shifting power relations in sustainability transitions: a multi-actor perspective. *Journal of Environmental Policy & Planning*, *18*(5), pp.628-649.

Bacco, M., Barsocchi, P., Ferro, E., Gotta, A. and Ruggeri, M., 2019. The digitisation of agriculture: a survey of research activities on smart farming. *Array*, *3*, p.100009.

Barbieri, C. and Valdivia, C., 2010. Recreation and agroforestry: examining new dimensions of multifunctionality in family farms. *Journal of Rural Studies*, *26*(4), pp.465-473.

Barham, B.L., Chavas, J.P., Fitz, D., Salas, V.R. and Schechter, L., 2014. The roles of risk and ambiguity in technology adoption. *Journal of Economic Behavior & Organization*, *97*, pp.204-218.

Bebber, D.P., 2015. Range-expanding pests and pathogens in a warming world. *Annu. Rev. Phytopathol*, *53*(1), pp.335-56.

Bengtsson, M. and Kock, S., 2000. ” Coopetition” in business Networks—to cooperate and compete simultaneously. *Industrial marketing management*, *29*(5), pp.411-426.

Bronson, K., 2019. Looking through a responsible innovation lens at uneven engagements with digital farming. *NJAS-Wageningen Journal of Life Sciences*, *90*, p.100294.

Braun, V. and Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), pp.77-101.

Bourdieu, P., 1990. *The logic of practice*. Stanford University Press.

———. 1988. *Homo academicus*. Stanford University Press.

———. 1984. *Distinction: A social critique of the judgement of taste*. Harvard University Press.

———. 1977. *Outline of a theory of practice*. Cambridge University Press.

Bourdieu, P., and Wacquant, L.J., 1992. *An invitation to reflexive sociology*. University of Chicago Press.

Braun, V. and Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), pp.77-101.

Caffaro, F., Cremasco, M.M., Roccato, M. and Cavallo, E., 2020. Drivers of farmers' intention to adopt technological innovations in Italy: The role of information sources, perceived usefulness, and perceived ease of use. *Journal of Rural Studies*, *76*, pp.264-271.

Carey, M.A. and Smith, M.W., 1994. Capturing the group effect in focus groups: A special concern in analysis. *Qualitative health research*, *4*(1), pp.123-127.

Carolan, M.S., 2005. Barriers to the adoption of sustainable agriculture on rented land: An examination of contesting social fields. *Rural Sociology*, *70*(3), pp.387-413.

Carolan, M., 2018. 'Smart farming techniques as political ontology: access, sovereignty and the performance of neoliberal and not-so-neoliberal worlds. *Sociologia ruralis*, *58*(4), pp.745-764.

Carter, M.R., 2016. What farmers want: the "gustibus multiplier" and other behavioral insights on agricultural development. *Agricultural Economics*, *47*(S1), pp.85-96.

Chapman, K., Kyveryga, P., Morris, T. and Menke, T., 2016. Farmer network design manual: A guide for practitioners, advisors, and research partners. Environmental Defense Fund.

Chavas, J.P. and Nauges, C., 2020. Uncertainty, learning, and technology adoption in agriculture. *Applied Economic Perspectives and Policy*, *42*(1), pp.42-53.

Chouinard, H.H., Paterson, T., Wandschneider, P.R. and Ohler, A.M., 2008. Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. *Land Economics*, *84*(1), pp.66-82.

Coakley, S.M., Scherm, H. and Chakraborty, S., 1999. Climate change and plant disease management. *Annual review of phytopathology*, *37*(1), pp.399-426.

Coble, K., Griffin, T., Ahearn, A., Ferrell, S., McFadden, J., Sonka, S., & Fulton, J. 2016. Advancing U.S. agricultural competitiveness with big data and agricultural economic market information, analysis, and research. The Council on Food, Agricultural, and Resource Economics, Washington D.C. Retrieved from https://fabe.osu.edu/sites/fabe/files/imce/images/10-7-2016BigData_v1.pdf

Coble, K.H., Mishra, A.K., Ferrell, S. and Griffin, T., 2018. Big data in agriculture: A challenge for the future. *Applied Economic Perspectives and Policy*, *40*(1), pp.79-96.

Dyer, J., 2016. The data farm: an investigation of the implications of collecting data on the farm. *Nuffield Australia Project, Taunton, Somerset*.

Fleming, A., Jakku, E., Lim-Camacho, L., Taylor, B. and Thorburn, P., 2018. Is big data for big farming or for everyone? Perceptions in the Australian grains industry. *Agronomy for sustainable development*, *38*(3), pp.1-10.

Garrett, K.A., Forbes, G.A., Savary, S., Skelsey, P., Sparks, A.H., Valdivia, C., Van Bruggen, A.H.C., Willocquet, L., Djurle, A., Duveiller, E. and Eckersten, H., 2011. Complexity in climate-change impacts: an analytical framework for effects mediated by plant disease. *Plant Pathology*, *60*(1), pp.15-30.

Glover, J.L., 2010. Capital usage in adverse situations: Applying Bourdieu's theory of capital to family farm businesses. *Journal of Family and Economic Issues*, *31*(4), pp.485-497.

Greiner, R. and Gregg, D., 2011. Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments: Empirical evidence from northern Australia. *Land use policy*, *28*(1), pp.257-265.

Hackney, R., Desouza, K. and Loebbecke, C., 2005. Cooperation or competition: knowledge sharing processes in inter-organizational networks. In *Knowledge Management: Nurturing Culture, Innovation, and Technology* (pp. 79-91).

Halimatussadiah, A., Resosudarmo, B.P. and Widyawati, D., 2017. Social capital to induce a contribution to environmental collective action: results from a laboratory experiment in Indonesia. *International Journal of Environment and Sustainable Development*, *16*(4), pp.397-414.

Hall, B.H. and Khan, B., 2003. Adoption of new technology. *NBER Working Paper No. 9730*, National Bureau of Economic Research, Cambridge, MA.

Jakku, E., Taylor, B., Fleming, A., Mason, C., Fielke, S., Sounness, C. and Thorburn, P., 2019. "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharing in Smart Farming. *NJAS-Wageningen Journal of Life Sciences*, *90*, p.100285.

Jayashankar, P., Nilakanta, S., Johnston, W.J., Gill, P. and Burres, R., 2018. IoT adoption in agriculture: the role of trust, perceived value and risk. *Journal of Business & Industrial Marketing*.

Kandilov, A.M., Kandilov, I.T., Liu, X. and Renkow, M., 2017. The impact of broadband on US Agriculture: An evaluation of the USDA broadband loan program. *Applied Economic Perspectives and Policy*, *39*(4), pp.635-661.

Kahneman, D. and Tversky, A., 1979. Prospect Theory: An analysis of decision under risk. *Econometrica, 47(*2), pp.363-391.

Leonard, T., Croson, R.T. and de Oliveira, A.C., 2010. Social capital and public goods. *The Journal of Socio-Economics*, *39*(4), pp.474-481.

Lokers, R., Knapen, R., Janssen, S., van Randen, Y. and Jansen, J., 2016. Analysis of Big Data technologies for use in agro-environmental science. *Environmental Modelling & Software*, *84*, pp.494-504.

Margosian, M.L., Garrett, K.A., Hutchinson, J.S. and With, K.A., 2009. Connectivity of the American agricultural landscape: assessing the national risk of crop pest and disease spread. *BioScience*, *59*(2), pp.141-151.

Mase, A.S., Babin, N.L., Prokopy, L.S. and Genskow, K.D., 2015. Trust in sources of soil and water quality information: Implications for environmental outreach and education. *JAWRA Journal of the American Water Resources Association*, *51*(6), pp.1656-1666.

Morgan, D. L. 1997. Focus groups as qualitative research. 2nd Edition. Qualitative Research Methods Series 16. A SAGE University Paper. CA.

Mwangi, M. and Kariuki, S., 2015. Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development*, *6*(5), pp.208-216.

Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M. and Magalhaes, M., 2009. *Climate change: Impact on agriculture and costs of adaptation* (Vol. 21). Intl Food Policy Res Inst.

Nielsen, T., Keil, A. and Zeller, M., 2013. Assessing farmers' risk preferences and their determinants in a marginal upland area of Vietnam: a comparison of multiple elicitation techniques. *Agricultural Economics*, *44*(3), pp.255-273.

Oreszczyn, S., Lane, A. and Carr, S., 2010. The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. *Journal of Rural Studies*, *26*(4), pp.404-417.

Raedeke, A.H., Green, J.J., Hodge, S.S. and Valdivia, C., 2003. Farmers, the practice of farming and the future of agroforestry: an application of Bourdieu's concepts of field and habitus. *Rural Sociology*, *68*(1), pp.64-86.

Regan, Á., 2019. 'Smart farming' in Ireland: A risk perception study with key governance actors. *NJAS-Wageningen Journal of Life Sciences*, *90*, p.100292.

Runck, B.C., Joglekar, A., Silverstein, K.A., Chan-Kang, C., Pardey, P.G. and Wilgenbusch, J.C., 2021. Digital agriculture platforms: Driving data-enabled agricultural innovation in a world fraught with privacy and security concerns. *Agronomy Journal*, pp.1-9.

Ruzzante, S., Labarta, R. and Bilton, A., 2021. Adoption of agricultural technology in the developing world: a meta-analysis of the empirical literature. *World Development*, *146*, p.105599.

Ryan, M., 2019. Ethics of using AI and big data in agriculture: The case of a large agriculture multinational. *The ORBIT Journal*, *2*(2), pp.1-27.

Ryan, M., 2022. The social and ethical impacts of artificial intelligence in agriculture: mapping the agricultural AI literature. *AI & SOCIETY*, pp.1-13.

Shepherd, M., Turner, J.A., Small, B. and Wheeler, D., 2018. Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture'

revolution. *Journal of the Science of Food and Agriculture*, *100*(14), pp.5083-5092.

Shiferaw, B., Kebede, T., Kassie, M. and Fisher, M., 2015. Market imperfections, access to information and technology adoption in Uganda: Challenges of overcoming multiple constraints. *Agricultural economics*, *46*(4), pp.475-488.

Shucksmith, M., 1993. Farm household behaviour and the transition to post-productivism. *Journal of Agricultural Economics*, *44*(3), pp.466-478.

Shucksmith, M. and Herrmann, V., 2002. Future changes in British agriculture: projecting divergent farm household behaviour. *Journal of Agricultural Economics*, *53*(1), pp.37-50.

Streletskaya, N.A., Bell, S.D., Kecinski, M., Li, T., Banerjee, S., Palm-Forster, L.H. and Pannell, D., 2020. Agricultural adoption and behavioral economics: Bridging the gap. *Applied Economic Perspectives and Policy*, *42*(1), pp.54-66.

Sunding, D. and Zilberman, D., 2001. The agricultural innovation process: research and technology adoption in a changing agricultural sector. *Handbook of Agricultural Economics*, *1*, pp.207-261.

Sykuta, M.E., 2016. Big data in agriculture: property rights, privacy and competition in ag data services. *International Food and Agribusiness Management Review*, *19*(1030-2016-83141), pp.57-74.

Tantalaki, N., Souravlas, S. and Roumeliotis, M., 2019. Data-driven decision making in precision agriculture: the rise of big data in agricultural systems. *Journal of Agricultural & Food Information*, *20*(4), pp.344-380.

Taylor, L., 2017. Safety in numbers? Group privacy and big data analytics in the developing world. In *Group privacy: The Challenges of New Data Technologies*. Taylor, L., van der Sloot, B. and Floridi, L. (eds.) pp. 13-36. Springer, Cham.

Tsai, W., 2002. Social structure of "coopetition" within a multiunit organization: Coordination, competition, and intraorganizational knowledge sharing. *Organization science*, *13*(2), pp.179-190.

Turland, M. and Slade, P., 2020. Farmers' willingness to participate in a big data platform. *Agribusiness*, *36*(1), pp.20-36.

Valdivia, C., Danda, M.K., Sheikh, D., James, H.S., Gathaara, V., Mbure, G., Murithi, F. and Folk, W., 2014. Using translational research to enhance farmers' voice: a case study of the potential introduction of GM cassava in Kenya's coast. *Agriculture and Human Values*, *31*(4), pp.673-681.

Valdivia, C.B., Gold, M.A., Barbieri, C., Gao, J. and Flora, C.B., 2021. Human and institutional dimensions of agroforestry. *North American Agroforestry*, pp.489-519. in H.E. Garrett, Jose, S. and Gold, M. A. (eds.) North American Agroforestry. 3rd Edition. American Society of Agronomy-Crop Science Society of America-Soil Science Society of America (ASA-CSSA-SSSA). Madison, WI, USA

Valdivia, C., James Jr, H.S. and Quiroz, R., 2018. New Technology, Ethical Tensions and the Mediating Role of Translational Research. *Ethical Tensions from New Technology: The Case of Agricultural Biotechnology*, *6*, p.162.

van der Burg, S., Wiseman, L. and Krkeljas, J., 2020. Trust in farm data sharing: reflections on the EU code of conduct for agricultural data sharing. *Ethics and Information Technology*, *23*(3), pp.185-198.

Visser, O., Sippel, S.R. and Thiemann, L., 2021. Imprecision farming? Examining the (in) accuracy and risks of digital agriculture. *Journal of Rural Studies*, *86*, pp.623-632.

Walley, K., 2007. Coopetition: an introduction to the subject and an agenda for research. *International Studies of Management & Organization*, *37*(2), pp.11-31.

Weersink, A., Fraser, E., Pannell, D., Duncan, E. and Rotz, S., 2018. Opportunities and challenges for big data in agricultural and environmental analysis. *Annual Review of Resource Economics*, *10*(1), pp.19-37.

Wiseman, L., Sanderson, J., Zhang, A. and Jakku, E., 2019. Farmers and their data: An examination of farmers' reluctance to share their data through the lens of the laws impacting smart farming. *NJAS-Wageningen Journal of Life Sciences*, *90*, p.100301.

Wolfert, S., Ge, L., Verdouw, C. and Bogaardt, M.J., 2017. Big data in smart farming–a review. *Agricultural systems*, *153*, pp.69-80.

Woolf, S.H., 2008. The meaning of translational research and why it matters. *Jama*, *299*(2), pp.211-213

Zhang, A., Baker, I., Jakku, E. and Llewellyn, R., 2017. Accelerating precision agriculture to decision agriculture: The needs and drivers for the present and future of digital agriculture in Australia. Across-industry producer survey for the rural R&D

for Profit ‘Precision to Decision (P2D) project. EP175936, Commonwealth Scientific and Research Organization (CSIRO), Australia

Zhang, A., Heath, R., McRobert, K., Llewellyn, R., Sanderson, J., Wiseman, L. and Rainbow, R., 2021. Who will benefit from big data? Farmers’ perspective on willingness to share farm data. *Journal of Rural Studies*, *88*, pp.346-353.

CHAPTER 5. CONCLUSION

The world we live in is characterized by various kinds of change, ranging from environmental, to social and technical. Some of these changes are becoming more rapid and complex, for instance climate change and variability. This dissertation sought to contribute to the understanding of actions and processes that are associated with individual and communal responses to such changes and scenarios of uncertainty. The first essay in this dissertation provided an overview of studies on the resilience of rural households and offered a systematic classification of concepts and issues to further guide multidisciplinary research efforts on the subject matter. The second essay assessed the factors that help to limit the vulnerabilities of agro-pastoralist households to environmental hazards in the Bolivian Altiplano. Whereas the final essay investigated farmers' perceptions about participating in a smart and connected farm network, highlighting factors that influence the adoption of digital agricultural innovations within a collaborative context.

Together, the essays in this dissertation shed light on the strategies that can contribute to the achievement of sustainability goals. From highlighting the importance of reflecting the perceptions of decisionmakers in resilience analyses, to emphasizing the need of facilitating communication between end-users and developers in a bid to uncover potential concerns that may hinder adoption of new technologies, the studies carried out in this dissertation reveal ways in which adaptation efforts can be strengthened. The findings and recommendations from these essays are relevant for various stakeholders including policy makers, development practitioners and researchers as they provide useful

insights into decisions of agents in different contexts. These discoveries can guide the design of policies and interventions that aim at improving households' livelihoods and other resilience outcomes, as well as inform research on the kinds of mitigation and adaption strategies that will be appropriate in various settings.

VITA

Barituka Bekee earned his Bachelor of Science in economics from the University of Port Harcourt, Nigeria, and a Master of Arts in economics from the University of Missouri, St. Louis. He completed his PhD in the Department of Agricultural and Applied Economics at the University of Missouri – Columbia (Mizzou), with an emphasis in environmental and development economics. He also obtained a graduate certificate in Society and Sustainable Development from Mizzou. He has taught a class on International Agriculture and served as a teaching assistant for an International Agricultural Development course. Prior to graduate studies, he worked at the International Institute of Tropical Agriculture. Broadly speaking, Barituka is interested in issues related to international development and agricultural development. His current research focuses on the resilience of rural households and the adoption of digital agricultural innovations.