DISASTER RESILIENCE TO FOOD INSECURITY METRICS: A CASE STUDY IN RURAL COSTA RICA.

by

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DEDICATION

Les dedico mi disertación a mi familia y a las grandes mujeres, que hacen de mi vida, un mundo de continuo aprendizaje. A mi esposo, quien me apoyo inmensamente para lograr mi meta. Gracias por estar conmigo a cada paso y a cada hora en este camino que hemos recorrido y que nos ha llevado a conseguir mi doctorado. Sin tu dedicación a nuestra familia, mi logro no hubiera sido posible. A mis tesoros, Jessica Estefanía y Cassandra Leilani, quienes son mi más grande motivación e iluminan cada día de mi existencia–gracias por ser mis más fervientes fans y porristas en los últimos tres años. Cassandra, te agradezco tus continuos cuidados al recordarme lo importante que era tomarme el tiempo para cuidar de mi salud. Jessica, gracias por ayudarme a prepararme para mis presentaciones. Tus consejos y honestidad fueron siempre de gran ayuda. Mis niñas, con su cariño y apoyo no hay meta que no pueda cumplir.

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Abbreviations

ACCRA	Africa Climate Change Resilience Alliance
CNE	*Comisión Nacional de Prevención de Riesgos y Atención de Emergencias* (National Commission for Risk Prevention and Emergency Attention)
CRED	Center for Research on the Epidemiology of Disaster
DFID	Department for International Development of the UK
DRM	Disaster Risk Management
EII	Earthquake Impact Index
FA	Factor Analysis
FANTA	Food and Nutrition Technical Assistance III Project
FAO	Food and Drug Administration of the United Nations
GIS	Geographic Information Systems
HFIAS	Household Food Insecurity (Access) Scale
HDRFII	Household Disaster Resilience to Food Insecurities Index (resilience index)
NLPCA	Non-Linear Principal Component Analysis
UNISDR	United Nations International Strategy for Disaster Reduction
MAUP	Modifiable Areal Unit Problem
MDG	Millennium Developmental Goals
NGO	Non-Governmental Organization
PAR	The Pressure and Release Model

PCA	Principal Component Analysis
UN	United Nations
WFP	World Food Programme

ABSTRACT

The impact of disasters on food security can be devastating, especially in rural settings where livelihoods are closely tied to their productive assets. A new research agenda in food security explores the characteristics of resilient households and the effectiveness of disaster response programming in assisting households and communities recover after a natural disaster. To increase our understanding of the disaster recovery process, there is a need for the development of metrics to measure resilience to food insecurity based on empirical data. With this end in mind, this study was concerned with the development of an integrative conceptual framework and the identification of indicators that would increase our understanding on the influential factors in creating disaster resiliency to food insecurity. The conceptual framework comprises commonalities among the food security and hazards disciplines' perspectives on disaster resilience. By identifying and integrating commonalities among disciplines in its conceptual and analytical frameworks, this study addresses the need for collaborative work across disciplines on community resiliency research. This is an empirical study conducted in six communities in Costa Rica affected by the 2009 earthquake. Households categorized as total loss in the communities selected were surveyed to collect primary data. The data obtained through the 126 households surveyed was run to a series of multivariate analyses to create a resilience index. The results show the important influence of adaptive capacity, when the absorptive capacity threshold of households is

surpassed. In addition, religion and community cohesiveness were identified as influential factors impacting resiliency to food insecurity needing further exploration.

I. INTRODUCTION

1.1 Overview

Reducing food insecurity vulnerabilities continues to be at the core of the global agenda (Millennium Summit 2000; World Summit 2005 and 2010; Hyogo Framework for Action 2005; Rio+20 Conference 2000 and 2012). Food security is achieved, **"**When all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO 2003 p.29). This complex, dynamic, multidisciplinary, and multidimensional problem continues to be one of the key challenges of the 21st century. Many are the causes of food insecurity–lack of sufficient nutritious food at all times–poverty, war, exploitation of the environment, political instability and nature. As the frequency and intensity of natural disasters continue to increase, food insecurities are exacerbated among the most vulnerable populations least able to cope and recover from these events.

Spatial variation on disaster resilience usually shows a pattern of urban/rural divide where rural communities are less resilient than urban centers (Cutter et al. 2010). A variety of reasons can contribute to this resilience bias. For example, the destructive nature of earthquakes in rural areas affects not only the built environment (as it is traditionally seen in urban areas), but ecosystems as well. The direct dependence of rural communities on ecosystems is seen as an influence on their social resilience and ability to cope with shocks, particularly in the context of food security and coping with hazards (Adger 2000). Rural communities' isolation and sometimes difficult access, together with the destruction of vital roads to market or other economic activities, can quickly erode rural livelihoods. Nonetheless, community actions stimulated by social networks and local capacities can significantly influence recovery trajectories. There is a need to enhance our understanding of how all of these components interact and influence rural community disaster resilience to food insecurity.

The concept of resilience generally refers to the ability of a system to recover from a stress or shock and has become an important framework for assessing advances in natural hazard's risk-reduction and food insecurity. In order for this concept to become a useful policy objective, advances need to be made on its definition, indicators and operation (Klein, Nicholls, and Thomalla 2003; Cutter et al. 2010; Constas and Barrett 2013). Numerous definitions, frameworks and conceptual models have been proposed to advance the theoretical basis for resilience based on different perspectives such as socio-ecological, hazards and food security.

The socio-ecological perspective conceptualizes resilience in a coupled system framework of humans-in-nature in which the social system's capacity to respond to a shock is dependent on the ecosystem's ability to sustain the change (Smit and Wandel 2006; Folke 2006). In hazards, resilience is conceptualized as a process and as an outcome. As a process, the focus is the role of society in disaster response and recovery, and as an outcome it mainly addresses the engineering perspective of the built environment in which society's role is not considered. Cutter et al. (2008) define resilience as "the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a threat" (p. 599). In the food security discourse, definitions of resilience include “the likelihood over time of a person, household or other unit being non-poor and food secure in the face of various stressors and in the wake of myriad shocks” (Constas and Barrett 2013 p. 6). The myriad of resilience definitions and conceptual frameworks creates a challenge for interdisciplinary work needed to address the multi-facet nature of resilience. Commonalities among the different perspectives conducive to integrated approaches that can lead to more interdisciplinary collaboration are obscured in a web of incongruous lexicon.

Measuring resilience has been increasingly recognized as important in disaster risk and food insecurity reduction. Proposed measures for estimating general community resilience through a group of components and indicators (Cutter et al. 2010), and more specifically resilience to food insecurity (Alinovi et al. 2009, 2010), have attempted to move the resilience concept from conceptual frameworks towards an operational tool. However, there is a need to continue developing indicators to test in real-world applications (Alivoni et al. 2009; Cutter et al. 2008) and empirical evidence that illustrates what factors consistently contribute to resilience, to what types of shocks and in what context (Frankenberger and Nelson 2013).

Increasing understanding of resilience determinants, measure, and how it is maintained is vital for this concept to be useful (Klein et al. 2003; Cutter et al. 2008). This can provide the international community with viable measurements for assessing at-risk communities’ resilience to food insecurities and programming effectiveness. To advance this research agenda, it necessitates further research on resilience metrics and methodologies based on integrated approaches that can facilitate interdisciplinary work.

1.2 Purpose and Research Questions

The purpose of this research is to provide an integrative framework for understanding disaster resilience to food insecurity that incorporates hazards and food security resilience conceptual commonalities, variables and measurements at a sub-national level of geography. The intended result of this dissertation is to advance interdisciplinary work on disaster resilience to food insecurity. To accomplish this objective this work proposes a framework for further research and a set of indicators on disaster resilience to food insecurity. The results of this study can inform non-governmental and governmental organizations, other stakeholders and communities assess programming effectiveness and options for policy driven action.

Research Questions

The following research questions are addressed:

1. What set of indicators are most influential in a household's disaster resilience to food insecurity in a rural context?

2. To what extent can these indicators predict a food security outcome?

II. LITERATURE REVIEW

2.1 Overview

Natural hazards such as earthquakes, flooding, landslides, tsunamis, etc., have the potential to become disasters in the absence of proper mitigation plans (Chadha et al. 2007). Disasters present impact spatial variation where in many cases the most affected are the poorest and most vulnerable populations. The impact of disasters on food security can be devastating, especially in rural settings where livelihoods are closely tied to their productive assets (Carter et al. 2006; Tirivarombo and Hughes 2011; OCHA 2005), creating poverty traps that can increase the prevalence of food insecurity (FAO 2013). Natural hazards can erode rural livelihoods by destroying agricultural production, livestock, infrastructure, and tourism and by interrupting access to markets, trade and food supply.

As an increasing number of people are being affected by natural hazards, there is growing recognition by governments and organizations that building resilient communities and reducing disaster risk are core initiatives (UNISDR 2014). The United Nations International Strategy for Disaster Reduction (UNISDR) was established in 2000 to support and coordinate this movement through international conventions such as the Hyogo Framework for Action 2005 – 2015. The shift from the study of vulnerable populations to disaster risk, to the framework of resilience study, has resulted from the realization that future natural disasters cannot be prevented. This is because of the likelihood that these events will involve unexpected forms, magnitudes, or locations (Zhou et al. 2010). Such was the case of the 2009 Cinchona earthquake in Costa Rica. The unexpected event took by surprise residents and seismologists alike. It significantly impacted the local agricultural production and livestock, devastated the tourism industry and had a major impact on road infrastructure preventing many people from returning to their economic activities.

Resilience is a complex and multidisciplinary research agenda that includes, but is not restricted to, disciplines such as ecology, development, economics, hazards, global climate change, and food security (Holling 1973; Adger 2000; Carpenter et al. 2001; Rose 2004; Adger et al. 2005; Lobell et al. 2008; Vugrin et al. 2010; Alinovi et al. 2010). The main body of this literature review consists of three sections. First, in section 2.2, in order to provide contextualization information for the scope of this research study that focuses on a human-environmental approach, I explore the concept of resilience through the perspective of three relevant disciplines in this interdisciplinary work: social-ecological, hazards and food security. The different conceptualizations of resilience in the above mentioned disciplines provide the basis for the integrated working definition of resilience of this study. Second, in section 2.3, I proceed to introduce the conceptual links between resilience and vulnerability through the perspectives of hazards and food security studies. Finally, in section 2.4, I discuss the current frameworks and models that suggest possible indicators and methodology for the measurement of resilience. Sections 2.3 and 2.4 describe the conceptual framework of this dissertation research that proposes an integrative approach to measuring resilience to food insecurity.

2.2 Defining the Resilience Concept

Holling (1973) defined resilience as the ability of a system to absorb changes which could be measured by the magnitude of disturbance the system could tolerate and still persist. Today, the many definitions of resilience in the literature have resulted in an incongruous lexicon that has hindered or limited the integration of multidisciplinary approaches in this research agenda. Refer to Table 2.1 for a list of selected definitions relevant to this study.

Table 2.1: Resilience Multidisciplinary Definitions

SOCIAL-ECOLOGICAL	
Adger (2000)	Resilience is the ability to anticipate risk, limit impact, and bounce back rapidly in the face of turbulent change.
Carpenter et al. (2001)	Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future.
Walker et al. (2004)	Resilience refers to the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.
Folke (2006)	The resilience approach is concerned with how to persist through continuous development in the face of change and how to innovate and transform into new more desirable configurations.
HAZARDS	
Miletti (1999)	Resilience is the ability of a community to recover by means of its own resources.
Tobin (1999)	Sustainable and resilient communities are defined as societies which are structurally organized to minimize the effects of disasters, and, at the same time, have the ability to recover quickly by restoring the socio-economic vitality of the community.
Klein, Nicholls, and Thomalla (2003)	Since the 1970s the concept [resilience] has also been used in a more metaphorical sense to describe systems that undergo stress and have the ability to recover and return to their original state.
Manyena (2006)	Viewing disaster resilience as a deliberate process (leading to desired outcomes) that comprises a series of events, actions, or changes to augment the capacity of the affected community when confronted with singular, multiple or unique shocks and stresses, places emphasis on the human role in disasters.
Norris et al. (2008)	Community resilience is a process linking a network of adaptive capacities (resources with dynamic attributes) to adaptation after a disturbance or adversity.

Twigg (2009)	System or community resilience can be understood as the capacity to: anticipate, minimize and absorb potential stresses or destructive forces through adaptation or resistance; manage or maintain certain basic functions and structures during disastrous events; recover or "bounce back" after an event.
Cutter, Burton, and Emrich (2010)	Resilience is as a set of capacities that can be fostered through interventions and policies, which in turn help build and enhance a community's ability to respond and recover from disasters.
Peacock et al. (2011)	[Resilience is] the ability of social systems along with the bio-physical systems upon which they depend, to resist or absorb the impacts of natural hazards, to rapidly recover from those impacts and to reduce future vulnerabilities through adaptive strategies
UNISDR (2002)	The capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level in functioning and structure. This is determined by the degree to which the social system is capable of organizing itself and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster.
FOOD SECURITY	
Alinovi et al. (2009)	Resilience aims to measure household's capability to absorb the negative effects of unpredictable shocks, as a legitimate component of vulnerability analysis.
FAO (2012)	Resilience is defined as the ability of a system to anticipate, resist and/or recover from stresses or shocks in ways that preserve integrity and do not deepen vulnerability. This includes both the ability to withstand threats and the ability to adapt to new options if necessary.
Frankenberger et al. (2012)	[Resilience is] "…the ability of countries, communities, and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses – such as earthquakes, drought or violent conflict – without compromising their long-term prospects." (Adopted from DIFD)
Constas and Barrett (2013)	Resilience represents the likelihood over time of a person, household or other unit being non-poor and food secure in the face of various stressors and in the wake of myriad shocks. If and only if that likelihood is and remains high over time, then the unit is resilient.
Maxwell et al. (2013)	The ability of an individual, a household, a community, or an institution to "bounce back" in such a manner—to cope with adversity by adapting, learning, and innovating—has lately come to be termed "resilience."

2.2.1 Social-Ecological Perspective

Social-ecological systems (SES) are integrated systems of ecosystems and human society with reciprocal feedback and interdependence (Folke et al. 2010). The concept emphasizes the humans-in-nature perspective. Broadly, in the context of social-ecological systems, resilience is about the integration of ecosystems and people recognizing them as an interdependent coupled system (Berkes and Ross 2013). The SES to resilience approach focuses on how the capacity of societies to respond to change may be at the expense of changes of the ecosystems to sustain social adaptation and transformation (Smit and Wandel 2006; Folke 2006). Resilience in this context refers to the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al. 2004).

Three important features of SES are identified in the literature: 1) the ability of a SES to stay in the domain of attraction is related to the slowly changing disturbance regimes (Holling 1973; Carpenter et al. 2001; Walker et al. 2004); 2) the degree to which the system is capable of self-organization (versus lack of organization, or organization forced by external factors) and innovation (Folke 2006; Carpenter et al. 2001; Walker et al. 2004); and 3) the degree to which the system can build and increase the capacity for learning and adaptation (Adger et al. 2005; Lebel et al. 2006). Folke, Colding and Berkes (2002) further identify four critical factors deemed important for building resilience in SES: 1) learning to live with change and uncertainty; 2) nurturing diversity for reorganization and renewal; 3) combining different types of knowledge for learning; and 4) creating opportunity for self-organization toward social-ecological sustainability.

Indicators that reflect the degree of a system's capacity for learning and adaptation in the social-ecological perspective may be used to deduce whether the system is resilient or not (Bahadur et al. 2010). However, the quantification and measurement still present a challenge.

2.2.2 Hazards Perspective

Overviews of the resilience conceptual development in hazards and disaster studies show that this is a complex concept driven by many perspectives and with multiple definitions. These perspectives and definitions are based on theoretical backgrounds, conceptual frameworks, and areas of interest such as community development, climate change, or methodological approaches (Klein, Nicholls and Thomalla 2003; Manyena 2006; Zhou et al. 2010). One prevalent theme in hazards studies is community resilience. In this perspective, divergent views can be found conceptualizing resilience as an outcome and as a process.

The conceptualization of resilience as an outcome comes primarily from engineering scientists emphasizing building and infrastructure resilience. Bruneau et al. (2003), in their study of critical infrastructure resilience to earthquakes, identify four dimensions of resilience: 1) robustness – strength to withstand a given level of stress without loss of function; 2) redundancy – the extent to which elements of a systems are substitutable; 3) resourcefulness – the capacity to identify problems, establish priorities, and mobilize resources; and 4) rapidity – the capacity to meet priorities and achieve goals in a timely manner. In another example, Kahan et al. (2009) focus on critical infrastructure resilience assuming that resilience is an outcome measured by the level of damage to infrastructure. In this framework, the social aspect of community resilience is not addressed – which ignores the “scientific consensus that disasters can only be understood as a phenomenon emerging from the complex interactions among the network of physical and social systems and the built environment” (Peacock, Tripoli and Wood 2011 p.6).

Typically, studies conceptualizing resilience as a process focus on the role of society in hazard mitigation and risk-reduction, and disaster response and recovery. Norris et al. (2008) argue that resilience is a process that “leads to adaptation, not an outcome, not stability” (p. 144). Here, the authors make a distinction usually made in hazards studies that stability in this context is not the ultimate goal, it is rather how to persist through continuous development in the face of change and how to innovate and transform into new more desirable configurations (Folke 2006). Looking at disaster resilience as a process places emphasis on the human role in disasters moving from a deterministic view of hazards to one where Disaster Risk Reduction (DRR) is the collection of actions, or processes, undertaken towards achieving resilience (O’Keefe et al. 1976; Twigg 2009).

The conceptualization of resilience, as a process or an outcome, has operational and policy action implications. Viewing disaster resilience as a dynamic process (leading to desired outcomes) of changes and actions when confronted with singular, multiple or unique shocks and stresses, places emphasis on the human role in disasters (McEntire et al., 2002; Manyena 2006).

In vulnerability and resilience studies, indexes to produce an aggregated measure of resilience provide a viable operational method of their conceptualizations (Shahid and Behrawan 2008; Zhou et al. 2010; Cutter, Burton, and Emrich 2010; Renschler et al.

2010). The analysis of selected indicators for the components of the resilience index can reveal the relative position of the phenomenon being measured and when evaluated over time, can illustrate the magnitude of change (a little or a lot) as well as direction of change (up or down; increasing or decreasing) (Cutter, Burton, and Emrich 2010). This information in turn can inform programming priorities and translate into policy action as part of DRRs goal of building more resilient communities. Renschler et al. (2010) present a community resilience framework of seven dimensions: (1) population and demographics; (2) environmental/ecosystem; (3) organized governmental services; (4) physical infrastructure; (5) lifestyle and community competence; (6) economic development; and (7) social-cultural capital (PEOPLES) that builds on previous works. The authors suggest the use of GIS and remote sensing to map community resilience. Although a theoretical model, it speaks to the benefits of incorporating geospatial analysis in this research agenda. This is not something new but a trend that continues as social application of geographic information technologies (GIS, remote sensing, GPS, etc.) evolves.

While most scholars agree on the basic premise that resilience connotes the capacity to recover, still little consensus exists on the specific structure or components of resilience in hazards studies (Shimizu 2013). There is a need to continue working on indicators (Cutter et al. 2008). Klein, Nicholls and Thomalla (2003) state that “the challenge remains to transform the concept into an operational tool for policy and management purposes – a challenge that thirty years of academic debate does not seem to have resolved” (p. 41).

Resilience study in geography crosses sub-disciplinary boundaries. Natural hazards, climate change, and sustainability geographers are increasingly collaborating with GIS and remote sensing scientists to work on predicting models and resilience maps. The system approach to resilience study is perhaps the best bridge between the hazards, climate change, social-ecological systems, and sustainability studies in geography.

A system approach focuses on the complexity of the reciprocal nature of the relationship between humans and their environment (Hessl 2010). According to Klein, Nicholls and Thomalla (2003), the most important development over the past thirty years is the increasing recognition across the disciplines that human and natural systems are interlinked. They further contend that the human system resilience and the natural system resilience relates to the functioning and interaction of the systems rather than to the stability of their components or the ability to maintain or return to some equilibrium state. This approach is useful in the rural context because it is possible to do cross-scale analysis if data is available, applicable to many social and environmental settings, and capable of addressing some of the complex thresholds, feedbacks, and unpredictable events inherent in human-environment interactions (Hessl 2010). Furthermore, this approach focuses on the elements existing on interrelationship and also in interdependency (Handmer & Dovers, 1996; Shimizu 2013) to manage both natural environments and human societies. The system approach ranges from the identification of system elements, that is, two or more things which act together to achieve a common purpose, to identification of system boundaries and the synthesis of the system (Shimizu 2013). The system approach is also less a theory (capable of prediction) than a framework for examining and describing coupled human and natural/environmental systems. Although the system approach has advanced resilience study, it adds to the complexity of operationalizing this concept.

The use of the term “systems” is found in hazards and disaster studies definitions of resilience. Below are some examples of the resilience definition that include a reference to the system approach.

> The ability of social systems along with the biophysical systems upon which they depend, to resist or absorb the impacts of natural hazards, to rapidly recover from those impacts and to reduce future vulnerabilities through adaptive strategies. (Peacock et al. 2011).
>
> [S]ystem or community resilience can be understood as the capacity to: 1) anticipate, minimize and absorb potential stresses or destructive forces through adaptation or resistance; 2) manage or maintain certain basic functions and structures during disastrous events; 3) recover or ‘bounce back’ after an event (Twigg 2009).
>
> Resilience is the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a threat. (Cutter et al. 2008). Cutter et al. (2010) include resilience *within natural systems* as part of the discussion of disaster resilience.
>
> Resilience can be defined as the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a major shock in a timely and efficient manner (G-Science Academies 2012)

As it is evident by the discussions above, moving from theory and conceptualization of resilience in hazard and disaster studies, to an operational tool that allows the measurement of resilience accounting for all its complexity has eluded scholars.

2.2.3 Food Security Perspective

The diverse literature on food security in the past decade can be positioned in three strands. The first strand focuses on social vulnerability emphasizing lessons learned and the identification of food (in)security dynamics (UN WFP 2004; Doocy et al. 2006; Carter et al. 2007). The second strand looks at the impact of natural hazards on food security. This research agenda explores the economic and social impact of rapid on-set and protracted natural hazards such as droughts, tsunamis, flooding and earthquakes (Doocy et al., 2006; Tirivarombo 2011). The third strand, the literature on complex crisis, explores humanitarian food aid and its logistics effectiveness and efficiency as well as future research trends (Clay, Molla, and Habtewold 1999; Zerbe 2004; Barbarosoğlu and Arda 2004; Beamon and Balcik 2007; Maxwell 2007; Sharp 2007; Kovács and Spens 2007, 2011; Rawls and Turnquist 2010; Maxwell et al. 2011; Overstreet et al. 2011; Seaman and Rivers 2012).

An emerging research agenda attempts to build conceptual frameworks and methodologies for measuring resilience within a humanitarian aid framework as to assess programming interventions. It is in this body of literature where most of the examples of studies of resilience to food insecurity are found (Alinovi et al. 2009, 2010; Oxfam GB 2011; Ciani 2011; DRLA 2012). Although the resilience concept has long been of interest in other fields such as ecology, psychology and hazards, its inclusion in the food security literature in the framework of community development has been recently introduced (Constant and Barrett 2013). The resilience concept has emerged as a plausible framework because it implies a capacity to withstand future shocks and stresses (Béné et al. 2012; Constas and Barrett 2013; Frankenberger and Nelson 2013) that regularly undermine efforts to sustainable solutions to chronic poverty (Constas and Barrett 2013).

The definitions of resilience in this discipline have the unique characteristic of placing greater emphasis on the unit of analysis whether it is community, household or individual (Alinovi et al. 2009, Frankenberger et al. 2012). Commonalities, however, can be found with the previous disciplines explored. The system approach found in the social-ecological and hazards studies appears explicitly in the resilience definition (FAO 2002) or implicitly in the methodology used to measure resilience (Alinovi et al. 2009).

2.2.4 Summary

Although many definitions and methodological approaches are found in social-ecological, hazards, and food security studies, there are very important compatibilities. Some approaches in these disciplines look at resilience as the interaction between humans and nature systems. This interaction leads to the conceptualization of resilience as a dynamic process where constant change is expected and stability is not considered the ultimate goal of the system – property that is referred to among the three disciplines. Perhaps the most contested relation in the conceptualization of resilience is the link between vulnerability and resilience. Section 2.3 explores the relationship through the hazards and food security main perspectives selected for this study.

2.3 Vulnerability and Resilience Links

2.3.1 Vulnerability Definitions

Social vulnerability assessments in the past two decades have evolved and developed. They reflect the many theoretical frameworks (critical realism, post-structuralism, logical positivism, etc.) and ontological perspectives in geography. Social vulnerability is a complex, multidimensional, and multidisciplinary research agenda. Sociologists have been interested in people's responses to disaster, and environmental advocacy groups (Ellis 2003) and NGOs have added perspectives to issues of human and environmental justice (Ellis 2003; Lovendal et al. 2004). However, geographers have been very prolific in the study of social vulnerability because of its intrinsic environmental-human relation. Geographers in hazard studies, as well as climate change and globalization, have been particularly active in this research area.

In the last two decades, studies of social vulnerability in the hazards research tradition in geography has shifted from the physical hazard agent to a focus on disaster as an outcome of the hazardous event (Fordham 2004). Currently, there are two basic epistemological approaches of social vulnerabilities to hazards. The realist epistemological approach to hazards sees risk as an objective hazard that exists and can be measured independently of social and cultural processes (Wisner et al. 2004). New geospatial technologies such as GIS data and remote sensing are being applied to disaster risk management studies to assess social vulnerability through image analysis and physical proxies (Rashed and Weeks 2003; Ebert et al. 2009) . Other studies focus on the creation of vulnerability indexes through numerical and GIS modeling and simulation of the physical phenomena (Koshimura et al. 2006; Uno and Kashiyama 2008). On the other hand, the constructionist epistemological position sees risk as mediated through social and cultural processes and a product of historically, socially, and politically "created ways of seeing" (Wisner et al. 2004). In this geographical paradigm the researcher is particularly interested in the social structures that create inequality and vulnerability (Fordham 2004).

Increasingly, there has been a need to combine both approaches for a more holistic study of social vulnerability. This new approach has been referred to as “system-oriented research” (Adger 2006) or coupled system. With this approach, nature and society are seen as a coupled system resulting in integrated theoretical approaches. The conceptualization of this new paradigm shows the interaction between the properties of human-environmental systems moving from quantifying vulnerable places towards measures that can be applied at any scale (Adger 2006). Although, attempts are being made to incorporate more holistic approaches to the study of social vulnerability, these integrated approaches continue facing the challenges of a complex and dynamic phenomenon.

According to Cutter et al. (2008), the most often cited conceptual models for hazard vulnerability include: 1) pressure and release model (Wisner et al. 2004); 2) Turner et al.’s (2003) vulnerability framework; and 3) Cutter’s hazards-of-place model of vulnerability (Cutter et al. 2003). However, all these approaches have their limitations. The pressure and release model (PAR) tracks the progression of vulnerability from root causes to dynamic pressures to unsafe conditions, yet it fails to adequately address the coupled human-environment system associated with the proximity to a hazard (Adger 2006; Cutter et al. 2008). Turner et al.’s (2003) vulnerability framework provides a template with a place-based approach that links broad classes of components to the larger systemic problem. The model, however, fails to include a temporal dimension – where vulnerability begins and ends is not clear (Cutter et al. 2008). Cutter’s hazards-of-place model integrates systems exposure and social vulnerability, but fails to account for the root causes of the antecedent social vulnerability, larger contexts, and post-disaster impact and recovery (Cutter et al. 2008).

In summary, the current trend in social vulnerability assessment in hazards views the human and natural systems as coupled, “and differentially exposed, sensitive, and adaptable to threats” (Polsky et al. 2007 p.472). Although advances have been made in conceptualizing social vulnerability in hazard studies, there is the need to continue improving its measurement, and understanding of its dynamic, multiscalar, and multidimensional nature.

Important developments have also occurred in the food security literature. Adger (2006) states that food security vulnerability research has moved from a description of vulnerability as “a failure of entitlements and shortage of capabilities” (antecedent) to explanations of “why populations become or stay poor based on analysis of economic factors and social relations” (successor) (p.275). Adger’s study does, in fact, reveal an important trend in food security research - the need to understand underlying causes of food insecurities. Atieno Oluoko-Odingo’s (2010) quantitative study of underlying factors of food insecurity in Kenya is a clear example of the current research trend on the study of social vulnerability. She uses many different statistical analyses such as component, factor, and cluster analysis to determine the main contributor to food insecurity looking at factors such as climate change, natural hazards, and poverty, among others. She concludes that poverty is the main contributor to food insecurity. The literature on social vulnerability is a multidisciplinary research agenda. Thomalla et al. (2006) state that there are four independent research communities that address incongruently and disconnected the issue of social vulnerability to natural hazards -

disaster risk reduction, climate change adaptation, environmental management, and poverty reduction. At least three of these areas directly address food security concerns. In their study, the authors look at the research agendas of the groups mentioned above and concluded that there is a need for a collaborative research agenda. A collaborative agenda is needed in the research community between practitioners, NGOs, and government entities. Such is the case of food security plans in Disaster Risk Management (DRM).

As progress is made in understanding social vulnerabilities to food security, governments and organizations seek to incorporate that knowledge into DRMs. In January 2005 at the World Conference on Disaster Reduction in Kobe Hyogo, Japan, 168 States adopted the *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters* (ISDR 2007). The goal was to reduce global disaster risk through action-oriented policy guidance. Indicators towards this goal were cited as vital in achieving this objective. The incorporation of food security plans and initiatives in DRM appears to be a fairly new trend that resulted from efforts such as the Millennium Developmental Goals (MDG) and the Hyogo Framework. This is probably why not much research has been done yet to assess these initiatives' effectiveness in mitigating food insecurities in at-risk or vulnerable populations. This lack of literature points to the need for collaboration among the research community, NGOs and government entities in the mitigation of food insecurities as part of national DRMs.

Increasingly countries and organizations are attempting to move from vulnerability assessments to identify populations at risk to the creation of programs aiming at creating more resilient communities. The debate concerning the link between vulnerability and resilience has yet to be settled. Some scholars see resilience as the flip side of vulnerability, when others argue it is an important component of vulnerability.

Recently the linkages between vulnerability and resilience have surfaced in hazard studies. Cutter et al. (2008) look at the conceptual linkages between vulnerability and resilience through different perspectives such as climate change and political ecology. They conclude that the incorporation of the concept of resilience in other sub-disciplines in geography, as the aforementioned, is more prevalent that in hazard studies.

2.3.2 Theoretical Propositions

The previous section shows how the hazards literature is divided based on the proposed causal structure of vulnerability. The different theoretical propositions on vulnerability's causal structure are important because they influence the two dominant views on the relationship of resilience and vulnerability in hazards studies.

When vulnerability is defined as the capability of a system to anticipate, cope with, resist and recover from a hazard (Blaikie et al. 1994), there is no fundamental difference with the definition of resilience. This suggests that the two concepts are the "flip side" of each other. In this case, something very vulnerable is not very resilient and the other way around. This view sees resilience as a factor of vulnerability, and vulnerability as a factor of resilience which Klein, Nicholls, and Thomalla (2003) term circular reasoning.

Conversely, if the definition of vulnerability in hazards studies as the pre-event, inherent characteristics or qualities of social systems that create the potential for harm (Cutter et al. 2008) is accepted, the relationship with resilience is different or less strong. Within this context, the two concepts are seen as discrete entities (Manyena 2006). In other cases, vulnerability and resilience are seen as separate, but their links and complementarities suggested (Cutter et al. 2008; Kafle 2012).

In the food security literature, vulnerability to food insecurity–the propensity to fall below the consumption threshold–has been seen as a function of the nature of risks and the individual's or household's responses to such risks. Resilience to household food security, on the other hand, aims at measuring households' capability to absorb the negative effects of unpredictable shocks, rather than predicting the occurrence of a crisis–as in the case of most vulnerability to food insecurity assessments (Alinovi et al. 2009). These two definitions indicate two separate concepts without a clear or even suggested link. The inclusion of the resilience concept is fairly recent in food security studies, nonetheless, practitioners are starting to look at the links between vulnerability and resilience. Alinovi et al. (2009) define vulnerability as a function of a household's risk exposure and its resilience to such risks. In this context, resilience becomes a component of vulnerability.

Many scholars that have explored the links between resilience and vulnerability from different disciplines (Dilley 2001; Cutter et al. 2008; Alinovi, Mane, and Romano 2009; Miller et al. 2010; Peacock et al. 2011) argue the need for more integrated definitions of the resilience and vulnerability concepts to facilitate interdisciplinary work that addresses the complexity of these concepts. As impacts of natural hazards to poverty and food insecurity are escalating, it appears that food security scholars are attempting to address the commonalities between the hazards and food security perspectives to advance research agendas. Dilley (2001) attempts to demonstrate how the concepts of vulnerability and risk as developed for DRM also apply in the food security context, where Alinovi, Mane, and Romano (2009) adopt in its vulnerability definition concepts of exposure and resilience. Figure 2.1 places the resilience research agendas of the hazards and the food security disciplines. The literature review reveals an absence of works on resilience to food insecurity through a hazards perspective. This dissertation will address this gap and it is represented by the dotted lines.

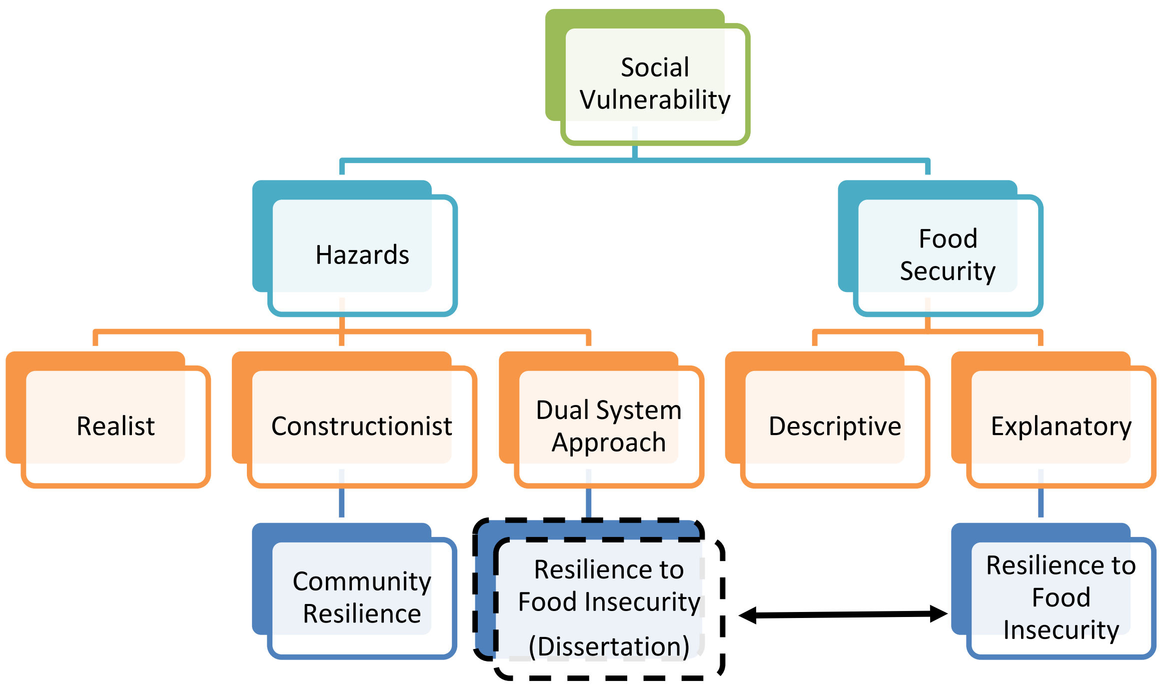


Figure 2.1: Literature Review Study Placement

2.4 Resilience Frameworks and Models

For the purpose of this study several frameworks for measuring community and household resilience are explored from the hazards and food security literature. The objective is to focus the approach to measuring household resilience to food insecurity from an integrated framework.

2.4.1 Hazards

Several disaster management and risk reduction frameworks have been advanced in developed countries, mostly utilizing secondary data. Susan Cutter's work on vulnerability mapping (2003) influenced later work on disaster resilience frameworks such as her Disaster Resilience of Place (DROP) model (Figure 2.2). Six dimensions are proposed in this model: ecological, social, economic, institutional, infrastructure, and community competence. Additionally, there are 29 total possible variables to those dimensions. A continuation of Cutter's work resulted in the Baseline Resilience Indicators for Communities (BRIC) model (Cutter, Burton and Emrich 2010), which follows the conceptual basis of the DROP Model, and extended the variables proposed. Here, again, secondary data are used to build a composite indicator defined as a manipulation of individual variables to produce an aggregate measure of disaster resilience. Refer to Table 2.2.

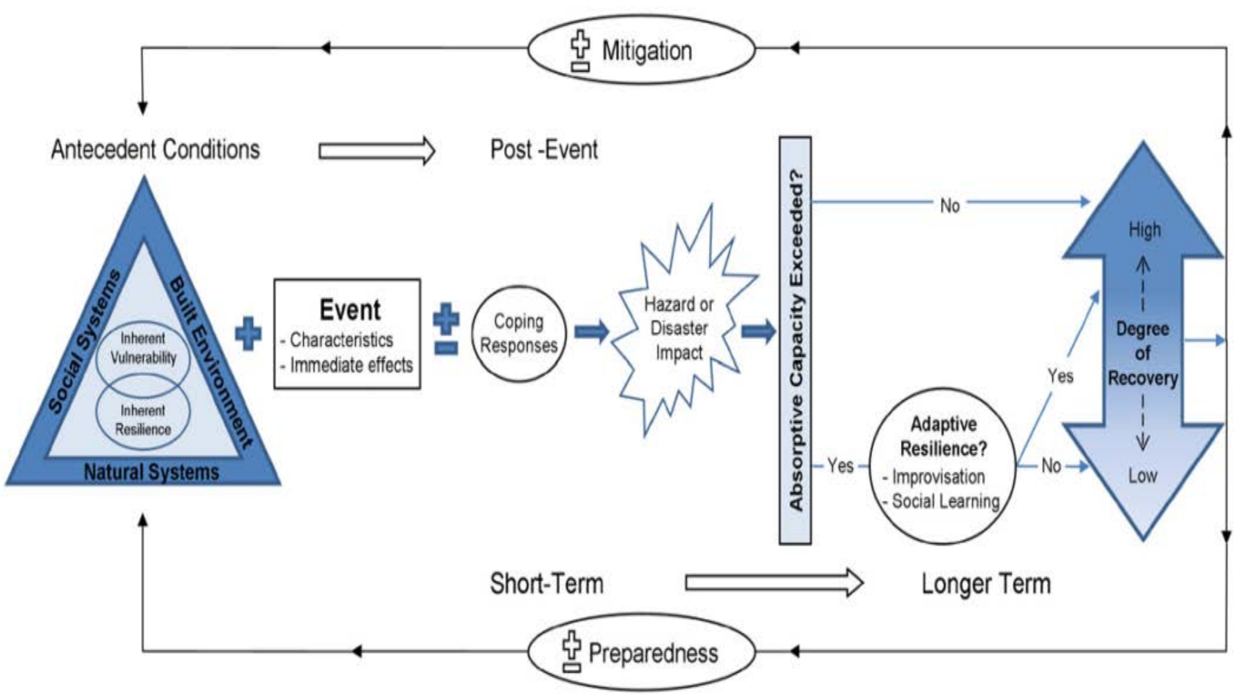


Figure 2.2: DROP Model (Cutter et al. 2008)

Table 2.2: BRIC Model Components and Variables (Cutter, Burton, and Emrich 2010)

Category	Variable	Data Source
Social Resilience		
Educational equity	Ratio of the pct. population with college education to the pct. population with no high school diploma	U.S. Census 2000
Age	Percent non-elderly population	U.S. Census 2000
Transportation access	Percent population with a vehicle	U.S. Census 2000
Communication capacity	Percent population with a telephone	U.S. Census 2000
Language competency	Percent population not speaking English as a second language	U.S. Census 2000
Special needs	Percent population without a sensory, physical, or mental disability	U.S. Census 2000
Health coverage	Percent population with health insurance coverage	U.S. Census 2000
Economic Resilience		
Housing capital	Percent homeownership	U.S. Census 2000
Employment	Percent employed	U.S. Census 2000
Income and equality	GINI coefficient	Computer from U.S. Census 2000
Single sector employment dependence	Percent population not employed in farming, fishing, forestry, and extractive industries	U.S. Census 2000
Employment	Percent female labor force participation	U.S. Census 2000
Business size	Ratio of large to small businesses	County Business Patterns (NAICS) 2006
Health Access	Number of physicians per 10,000 population	U.S. Census 2000
Institutional Resilience		
Mitigation	Percent population covered by a recent hazard mitigation plan	FEMA.gov
Flood coverage	Percent housing units covered by NFIP policies	bsa.nfipstat.com
Municipal services	Percent municipal expenditures for fire, police, and EMS	USA Counties 2000
Mitigation	Percent population participating in Community Rating System for Flood (CRS)	FEMA.gov
Political fragmentation	Number of governments and special districts	U.S. Census 2002
Previous disaster experience	Number of paid disaster declarations	FEMA.gov
Mitigation and social connectivity	Percent population covered by Citizen Corps programs	citizen.corps.gov
Mitigation	Percent population in Storm Ready communities	stormready.noaa.gov
Infrastructure Resilience		
Housing type	Percent housing units that are not mobile homes	U.S. Census 2000
Shelter capacity	Percent vacant rental units	U.S. Census 2000
Medical capacity	Number of hospital beds per 10,000 population	American Hospital Directory

Table 2.2: Continue

Access/evacuation potential	Principle arterial miles per square mile	GIS derived from National Atlas.gov
Housing age	Percent housing units not built before 1970 and after 1994	City and County Databook 2007
Sheltering needs	Number of hotels/motels per square mile	County Business Patterns (NAICS) 2006
Recovery	Number of public schools per square mile	Gnis.usgs.gov
Community Capital		
Place attachment	Net international migration	census.gov
Place attachment	Percent population born in a state that still resides in that state	U.S. Census 2000
Political engagement	Percent voter participation in the 2004 election	City and County Databook 2007
Social capital religion	Number of religious adherents per 10,000 population	Assn. of Religion Data Archives
Social capital – civic involvement	Number of civic organizations per 10,000 population	County Business Patterns (NAICS) 2006
Social capital – advocacy	Number of social advocacy organizations per 10,000 population	County Business Patterns (NAICS) 2006
Innovation	Percent population employed in creative class occupations	USDA Economic Research Service ers.usda.gov

2.4.2 Food Security

The livelihood framework, advanced by Chambers and Conway (1992), focuses on people and their livelihood capabilities rather than institutions, organizations or the built environment for rural development. Livelihood capabilities include the ability to recover from a stress or shock in reactive, proactive and adaptive ways (Chambers and Conway 1992). As a new approach for sustainable rural development, this approach became quite popular among organizations such as Department for International Development of the UK (DFID) (2011), Oxfam (2013), and Food and Agricultural Organization (FAO) (Alinovi et al. 2010). These organizations implemented and further developed the sustainable livelihoods approach over the years.

Figure 2.3 depicts graphically the sustainable livelihood framework, its main components and how these components fit together. The arrows within the framework denote different relationship patterns and influences without establishing causal relationships (Chambers and Conway 1992; DFID 1999). The vulnerability context denotes the broader social, political, and physical environment in which households and communities operate and through which livelihoods can be affected by trends and shocks. In the sustainable livelihood framework, the concept of resilience is expressed as part of sustainability as one of its dimensions. In this context, livelihoods are sustainable when they are resilient in the face of external shocks and stresses (DFID1999). The approach is dynamic in that it seeks to understand and learn from change that can support positive patterns of change and help mitigate negative patterns (DFID 1999). A primary feature of this framework is a focus on improving capital assets as the key mechanism for reducing vulnerability and enhancing resiliency (DFID 199; Peacock et al. 2010). The asset pentagon in Figure 2.3 represents five principle types of capital: 1) social, 2) human, 3) financial, 4) physical, and 5) natural.

> **Social capital** is a theoretical concept from the social sciences that emphasizes aspects of trust, informal and formal social networks, types of social interaction, and norms (Coleman 1988; Putnam 1999; Peacock et al. 2010). Social capital can influence the recovery path of communities after a disaster by providing the social interactions necessary and trust to re-organize towards a common goal. Social capital can be critical for household ability to mobilize resources and information necessary to respond to natural hazard threats and recover from natural disasters (Morrow 1997; Peacock et al. 2010) as well as address normal household livelihood and consumption needs (DFID 1999; Peacock et al. 2010).
>
> **Human capital** is a concept that refers to the attainment of education, training or skills as well as the health of communities. Informal hazard knowledge through previous experience or formal training can increase the resiliency of a community by being able to respond, adapt and recover from disasters. Human capital thus can be measured through education

> attainment, demographic characteristics (e.g. ethnicity), household characteristics, housing quality, and population density (Mayunga 2007).
>
> **Financial capital,** also sometimes referred as economic capital, refers to the financial resources available to people and households to support their livelihoods. It includes income, wealth, as well as savings or credit (Peacock et al. 2010). Financial capital allows households the ability to absorb the impact of disasters through their ability to gain access to resources for their recovery. Among other factors it can be measured through employment, household income, property value, and investments (Mayunga 2007).
>
> **Physical capital** is a measure of the built environment including housing, schools, businesses, infrastructure and lifelines (i.e. electric power, water, telecommunications, and transportation) and critical facilities such as hospitals and police and fire stations. Studies have shown that there is a clear relationship between disaster resilience and physical capital (Peacock et al. 2010). Lack of access to main road or markets can hinder the ability of rural households to continue their economic activities, and therefore, cope with disasters.
>
> **Natural capital** includes natural resources that are vital for life including water, land, minerals and oil. Studies have shown that there is a relationship between natural capital and disaster resilience. For example, alteration of wetlands is one of the significant contributing factors for increasing flood hazards in the United States (Peacock et al. 2010), and wetland and vegetation cover play and important role in protecting coastal areas from floods (Mayunga 2007). Natural capital can thus be measured through water quality, air quality, soil quality, wetland, forests, and national and local parks (Mayunga 2007).

The importance of the livelihood framework for this research is its structure of analysis through a focus on capacities. This focus of analysis represents a parallel structure to the resilience frameworks found in the food security literature. The following section is an overview of said frameworks.

Scholars and practitioners of food security and poverty dynamics interested in the resilience concept place particular importance in the development of indicators and methodologies to measure resilience to food insecurities. To date, several models and frameworks have been proposed trying to address the challenges of these measurements.

Below is a brief discussion of the most cited frameworks for resilience to food insecurity measures.

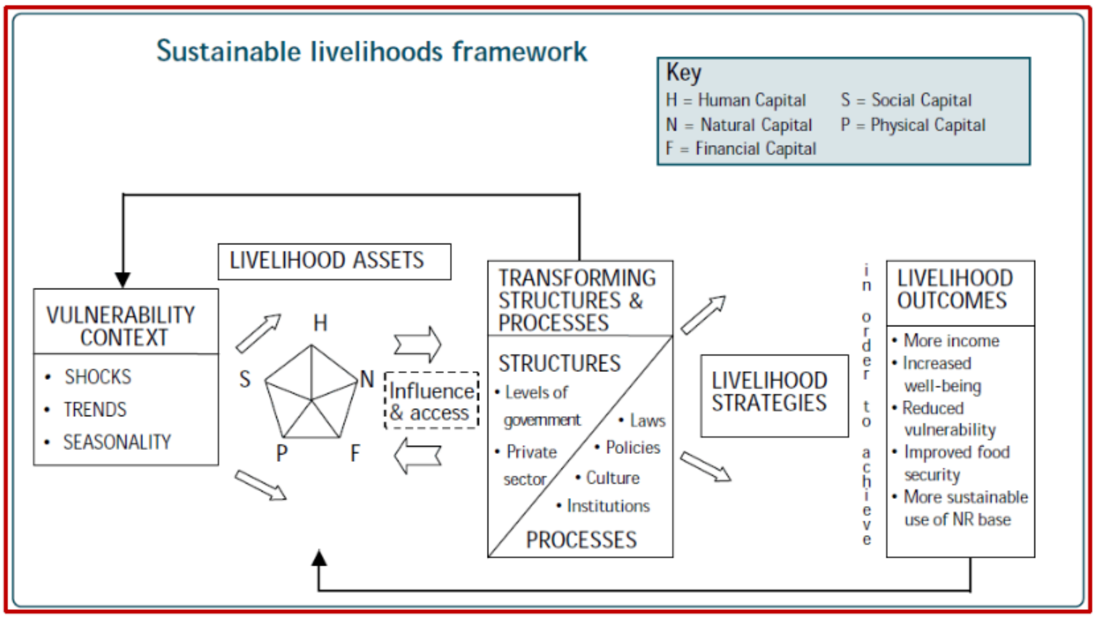


Figure 2.3: Sustainable Livelihoods Framework Adapted from DFID (1999).

Similar to the above explored disciplines, in the food security research agenda, the resilience definition is directly related to the methodology used to measure it. Alinovi, Mane, and Romano (2009) conducted one of the first attempts to develop a methodology to measure resilience to food insecurity in Palestine. Resilience was defined as the approach to measure households' capability to absorb the negative effects of unpredictable shocks, as a legitimate component of vulnerability analysis. Their work considers resilience to be a latent variable defined according to four building blocks: 1) income and food access; 2) assets; 3) access to public services; and 4) social safety nets (Figure 2.4). A resilience index was used to measure resilience and assess the resilience role in measuring vulnerability. Their findings showed that resilience was the most important regressor in measuring vulnerability to food security.

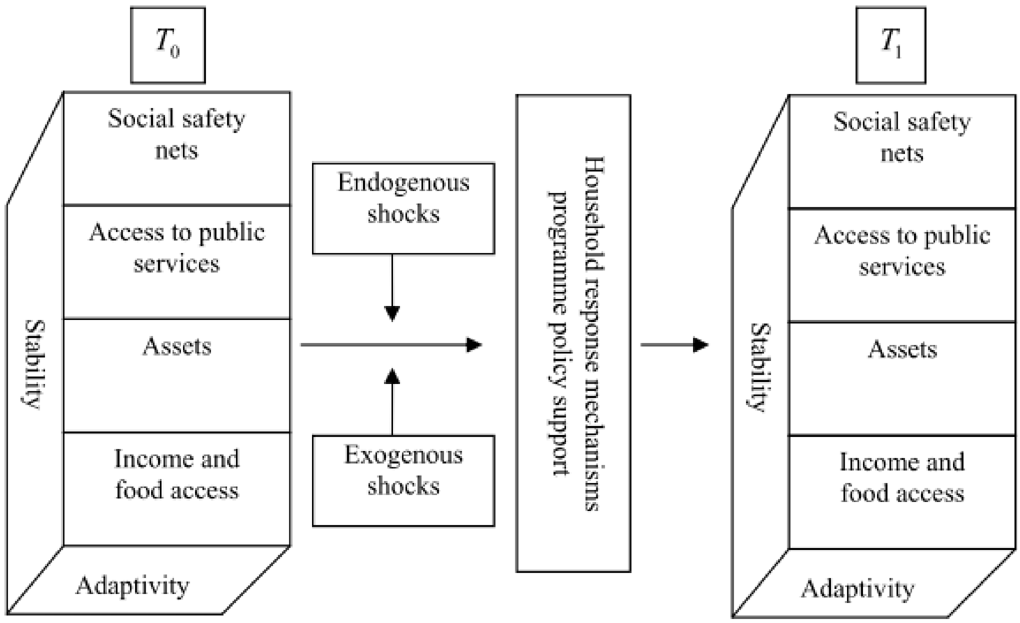


Figure 2.4: Resilience to Food Insecurities Conceptual Framework (Alinovi, Mane, and Romano 2009).

Constas and Barrett (2013) address the need for theory-grounded measures by proposing a framework to model dynamics of resilience related to food security regardless of context specific variation. Their framework is built from their working definition of resilience as "the likelihood over time of a person, household or other unit being non-poor and food secure in the face of various stressors and in the wake of myriad shocks. If and only if that likelihood is and remains high over time, then the unit is resilient" (Constas and Barrett 2013 p. 3). The authors address the temporal challenge and the dynamic process of resilience by offering four standard measures: 1) initial states measures; 2) disturbance measures; 3) risk-response measures; and 4) subsequent states measures.

At the "Expert Consultation on Resilience Measurement Related to Food Security" (hereafter referred to as the Expert Consultation) conference sponsored by the FAO and the World Food Program in Rome February 2013, the Constas and Barrett (2013) framework was adopted, resulting on a proposed measure for estimating resilience to food insecurity. Refer to Figure 2.5 for the analytical framework. This framework adopts the analysis structure of the livelihood framework focusing on households' capacities (absorptive, adaptive and transformative). It models dynamics of resilience in relation to food security general enough to allow their use across various contexts and provides a set of proposed indicators to measure this dynamic process (Frankenberger and Nelson 2013).

The above efforts to develop methodologies to measure resilience to food insecurity have informed a new research agenda. This research agenda seeks to increase our understanding of the dynamics of resilience in different contexts and to different stressors and shocks. To move forward there is a need to: 1) build theory-grounded measures to identify empirical properties of *ex ante* and *ex post* properties of resilience (Constas and Barrett 2013); 2) empirical evidence that illustrates what factors consistently contribute to resilience, to what types of shocks, and in what contexts (Frankenberger et al. 2012; Frankenberger and Nelson 2013); and 3) identification of indicators to best assess or measure household reactions to shocks (Frankenberger and Nelson 2013).

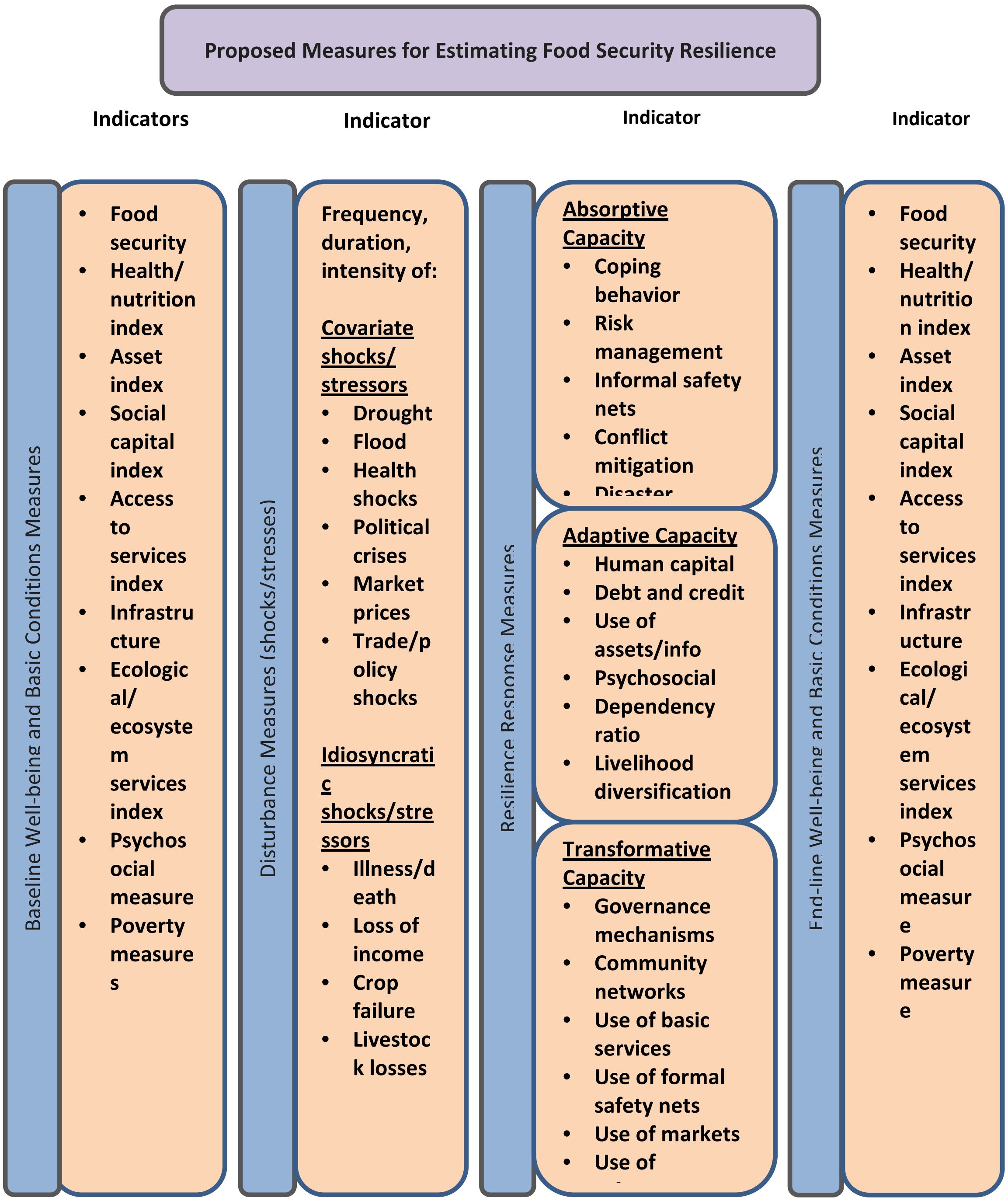


Figure 2.5: Proposed Measures for Resilience to Food Insecurity (Frankenberger and Nelson 2013).

The explored frameworks present commonalities for inclusion into an integrative approach for the measurement of resilience to food insecurity. Antecedent conditions in the DROP, BRIC, Alinovi, Mane, and Romano (2009) and Frankenberger and Nelson (2013) frameworks, recognize explicitly resilience as a dynamic process and its temporal nature. The DROP and the analytical framework advanced at the Expert Consultation integrate transformative and adaptive capacities as important in measuring resilience. Furthermore, all these frameworks represent resilience as a multi-facet concept difficult to operationalize and in need of empirical evidence.

2.4.3 Summary and Conclusions

Vulnerability studies and assessments have been important in disaster risk reduction and recovery for a long time, and have contributed to our understanding of the multidimensional nature of the underlying causal relationships of it. As a result, the concept has been incorporated into practice in the development, food security, and disaster risk research communities. Notwithstanding the advance of the resilience concept in the different disciplines, there are few examples that document how resilience is explicitly incorporated into practice and policy (Miller et al. 2010). As natural hazards continue to turn into disasters, the international community has shifted from a vulnerability framework to the idea of creating resilience communities as a key concept in disaster risk reduction. However, several challenges have prevented the incorporation of the resilience concept into practice and policy-driven action.

While this literature review has yielded insights into the different approaches, components and characteristics of a resilient system (and possible indicators and measurement), gaps in the literature necessitate further exploration. There are three main challenges for the incorporation of disaster resilience into practice. First, the many definitions and conceptualizations of resilience hinder interdisciplinary collaboration. Integrated definitions that can cut across disciplinary boundaries should continue to be explored. Second, the conceptualization of resilience and its components and indicators lack empirical evidence. Third, there is a lack of conceptual agreement on the link between vulnerability and resilience. These points to an interest and need in this research agenda to establish 1) the conceptual differences between resilience and vulnerability (Klein, Nicholls, and Thomalla 2003; Gaillard 2007; Twigg 2009) and 2) the development of an operational tool (Klein, Nicholls, and Thomalla 2003; Renschler et al. 2010; Shimizu 2013).

III. INDICATOR SELECTION AND REFINEMENT METHODS

3.1 Study Site

Latin America's geography makes it one of the most hazard-prone regions of the world (Biles and Cobos 2004). In Central America alone, five out of the eight countries that comprise this region are in the top 30 countries world-wide at high risk of multiple hazards (World Bank 2010). In the last two decades the economic cost of natural disasters has surpassed the economic growth in the region (IDB 2007). Furthermore, from 1990 to 2010 the occurrences of natural disasters and the number of people affected doubled in the region according to the Center for Research on the Epidemiology of Disaster (CRED) (www.EMDAT.be) (Figure 3.1). This necessitates the immediate action of Central American countries towards a comprehensive analysis of DRR that incorporates community resilience measures.

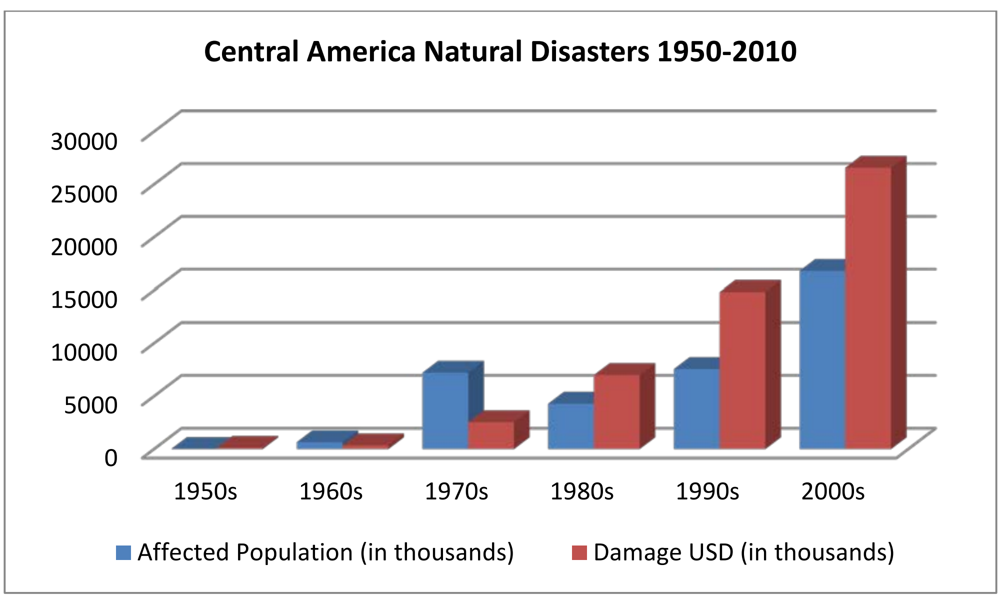


Figure 3.1: Central America Natural Disasters 1950-2010 (CRED)

To select a proper study area for this dissertation, three requirements had to be met: 1) the presence of an earthquake within the past five years; 2) the high impact area needed to cover several rural communities for comparison purposes; and 3) available data on formal assistance provided during and after the event as part of the recovery process. The selected site for the study is the area close to the epicenter of what came to be known as the Cinchona earthquake in Costa Rica in the surrounding areas of the Poás volcano. The earthquake took place in 2009 in the Varablanca fault–also referred to as El Angel by some authors (Barquero 2009).

The Republic of Costa Rica is located in Central America. It is bordered by Nicaragua to the north, Panama to the southeast, the Caribbean to the east and the Pacific Ocean to the west. It has a total area of 51,100 sq. km with a coast line of 1,290 km. Costa Rica, with 36.8 percent of the total area exposed to three or more adverse natural events, is considered to be the second most exposed country to natural hazards based on land area (Dilley et al. 2005). Dilley's study also estimates that 77.9 percent of Costa Rica´s population resides in areas at risk of multiple hazards. Since 1900, according to CRED (EM-DAT 2012), Costa Rica has experienced 13 earthquakes, 3 droughts, 26 floodings, 8 tropical cyclones and 6 volcanic eruptions. Costa Rica has been identified as one of the most earthquake-prone and volcanically active countries in the world**.**

In January 2009, an earthquake reaching 6.2 on the Richter scale, thereafter referred to as the Cinchona earthquake, killed approximately 22 people and caused more than USD $492 million in losses from damage to infrastructure and the agro-industry (Barquero 2009). The earthquake impacted an extended area around the Poás volcano. For the purposes of this study, the highest impacted rural area was selected with quadrant coordinates of the upper right corner 10°19’59.85” N 84°07’58.79” W and the lower left corner 10°06’59”.85N 84°14’58.79” W (Figure 3.2). This area comprises several of the most affected communities including Cinchona, which was declared uninhabitable and was resettled into a new community called Nueva Cinchona. The highest number of fatalities came from this zone as well as the largest number of landslides, the most houses collapsed, and the highest impact on hydroelectric infrastructure (Duarte et al. 2009). According to reports from the International Federation of Red Cross and Red Crescent Societies (2009) and the United Nations Office for the Coordination of Humanitarian Affairs (2009), humanitarian and relief efforts were conducted in the selected area. These factors are considered critical for this study.

To achieve the aim of this study of exploring which capacities (absorptive, adaptive, etc.) of resilience to food insecurity in case of an earthquake are most influential in the recovery process, it was deemed necessary to select communities and households that had been directly and highly impacted by the earthquake. A two-step process was developed to this end: 1) a review of the literature to create a list of impacted communities in the study area with a direct and high event impact; and 2) selection of final communities through an impact index. The literature review included government reports and journal articles (Duarte et al. 2009; Barquero et al. 2009; Quirós 2009).

Given the nature of the study, which follows the coupled system approach in hazard studies, the earthquake impact index (EII) created for the selection of the communities for this study incorporates three impact components: (1) environmental impact, (2) structural impact, and (3) human impact (Table 3.1). These components were

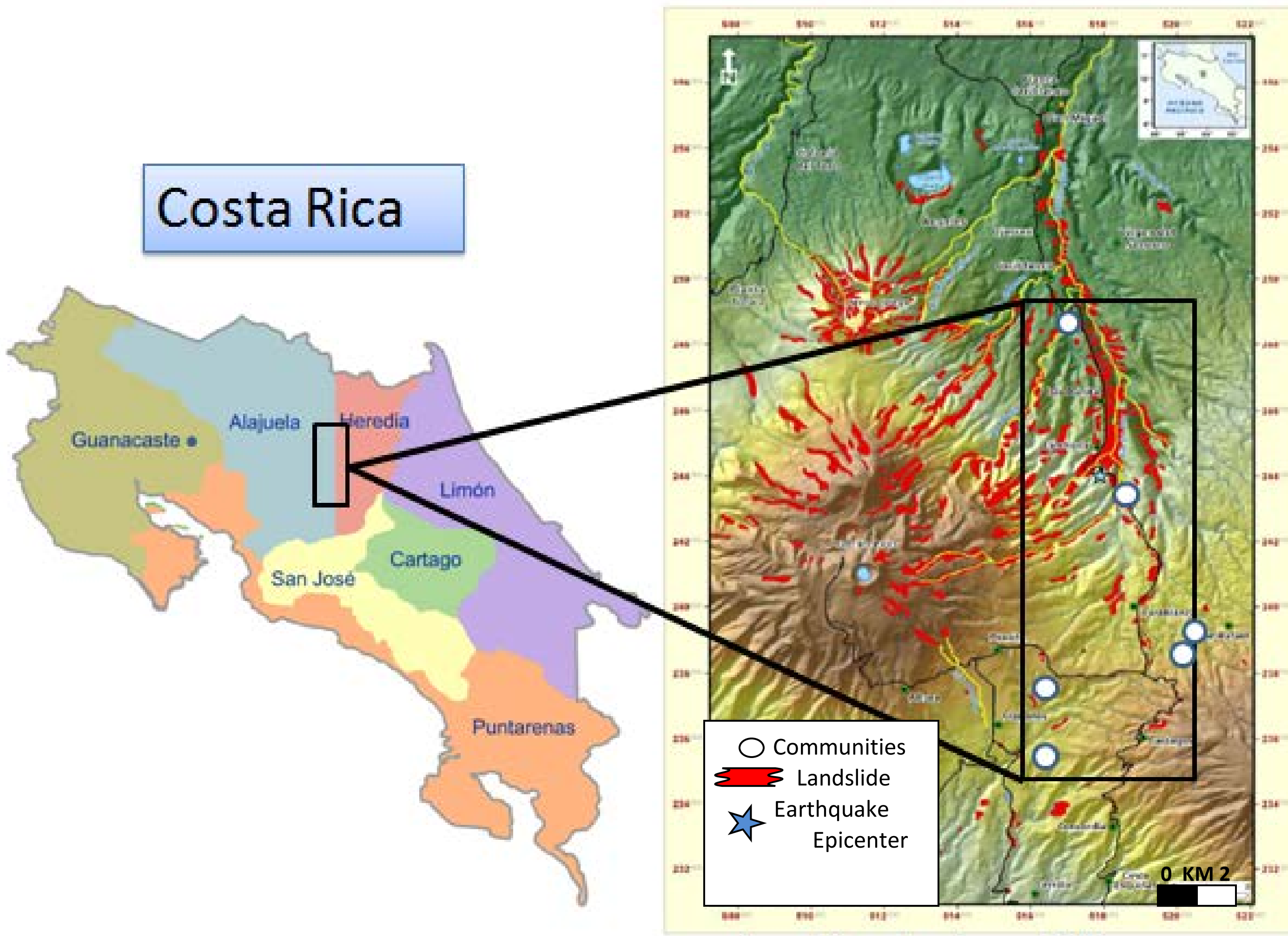


Figure 3.2: Study Area and Selected Communities. Adapted from Barquero 2009.

selected based on an extensive review of reports immediately following the earthquake that documented the types of impacts in the most affected areas close to the epicenter of the earthquake.

Table 3.1: Earthquake Impact Index (EII). Unit of Analysis: Community.

Components	**Indicator**	**Variable**	**Weights**
Environmental Impact	Landslide and mud flows	Binary: 1 if present; 0 if not	.40
Structural Impact	Services disruption	Electric power reinstated within:24 hours = 0; 48 - 72 hours = 1;72 or more = 2	.05
	Collapsed schools	Binary 1 if present; 0 if not	.15
Human Impact	Human fatalities	Number of fatalities	.40

The EII is based on secondary data from the National Seismological Network (*Red Sismológica Nacional*) of Costa Rica (Barquero 2009). The variables' weights were based on the long-term effect on livelihoods of the affected populations. Landslides and mudflows had been reported to have caused most of the damages of the Cinchona earthquake in the area of study, and their effects have been associated with long term impact in the local ecosystems and economic activities. This was confirmed during field work visits to the area through observations and interviews. Figure 3.3 compares pictures of landslide areas in the aftermath of the earthquake with pictures taken of the same area in August of 2013. These photos show only partial recovery after almost five years. The loss of household members due to an event such as an earthquake can cause economic hardship for the household, especially if the deceased household members provided the primary financial support for the household. Because of these reasons, the environmental and the human impact variables were given weights of .40 each. Structural impact, although important for the emergency response phase of the recovery process, is not considered important in the long term recovery process and was given a total of a .20 weight.

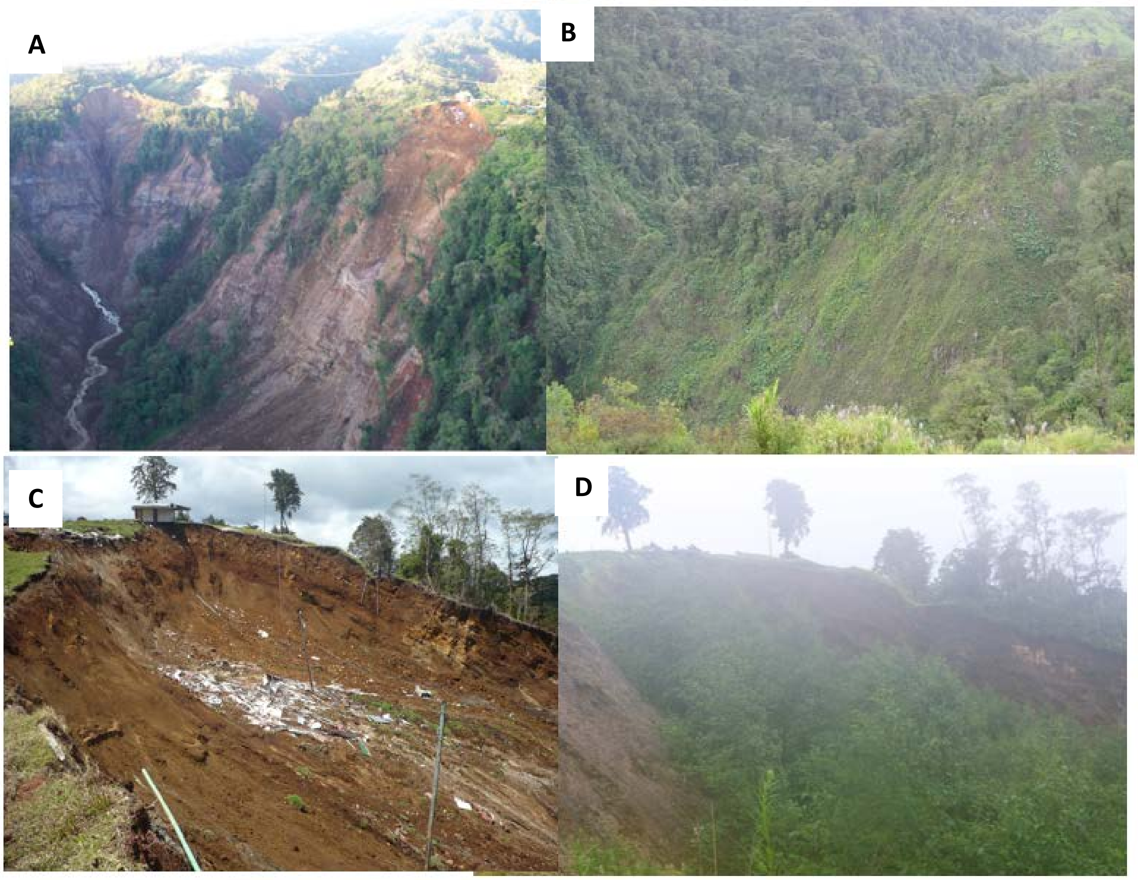


Figure 3.3: Landslide Ecological Recovery

(A)Landslide near Cinchona February 2009; (B) Ecological recovery of landslide A August 2013; (C) Landslide in San Rafael February 2009; (D) Ecological recovery of landslide C August 2013.

Note: Photo A and C provided by local community leader. Photo B and D by Laura Cano Amaya.

Out of the 16 original communities identified through the literature review 3 were excluded since no further reference to these communities were found in reports. The EII score for the final 13 communities was analyzed and 6 communities with the highest EII score were retained: Cinchona (now Nueva Cinchona), Varablanca, San Rafael, Poasito, Fraijanes and Dulce Nombre. Table 3.2 includes the list of original communities with their EII scores.

Table 3.2: Community Selection Earthquake Impact Index Scores

Province	Canton	*Affected Town	**Landslide and mud flow	**Services disruption	Human fatalities	**Infrastructure damage	EII Score
Alajuela	Alajuela, Heredia	Carrizal		<48			0
		Cinco Ezquinas		<48			0
		Los Cartagos	x	<48			.40
	Alajuela	Sabanilla		<48			0
		Jaulares		<48			0
		Fraijanes	x	<48		x	.55
		Poasito	x	<48		x	.55
		Dulce Nombre	x	<48	+x	x	.95
	Poás	***La Pradera					
		***La Santa					
		Cinchona	x	>72	**x	x	1.10
		Ujarrás		<48			.05
		San Miguel		<48			.05
		***Pata de Gallo					
Heredia	Varablanca	Varablanca	x	48-72		x	.65
		San Rafael	x	48-72	+x	x	1.05

*UNA 2009
**Barquero 2009
*** No more information found on literature reviewed
+ Interviews information

3.2 Overview and Methodology

There is not a standard set of indicators to measure resilience. An array of proposed indicators based on theoretical grounds is found in the literature, but few have been tested through empirical studies with real-world data. More specifically, there appear to be a gap in the literature on disaster resilience to food insecurity studies in the case of earthquakes in rural communities.

This chapter is concerned with the identification of variables and indicators of disaster resilience to food insecurity in case of an earthquake using Costa Rica as a case study. Resilience metrics and their predictive disaster recovery in this dissertation are within the context of a particular place and hazard. The disaster resilience to food insecurity conceptual framework presented in this dissertation integrates elements from the current resilience frameworks in the hazards and SES sub-disciplines of geography, and food security and livelihood disciplines. Elements in those frameworks deemed relevant, based on theoretical foundations for the rural context and hazard type (earthquake hazard), are considered for inclusion in the conceptual framework. The variable identification involved a number of steps guided by the Exploratory Sequential Mix-Methods Research Design selected for this study (Figure 3.4) as developed by Creswell and Clark (2011). The next section explains in more detail the conceptual framework, research design and methods for the multivariate analysis for the indicator selection of this study.

3.3 Research Design

Mixed methods research is a term used in social science to describe an approach where the researcher designs a study that mixes or combines quantitative and qualitative methods, techniques or concepts into a single study. Researchers seek to find answers to diverse questions in order to strengthen the findings from their research or in order to seek new insights into existing knowledge or phenomena (Creswell and Clark 2011).

Driving this research approach is the pragmatism paradigm. In this paradigm, reality is seen as singular (by testing hypotheses) and multiple (by providing quotes to illustrate different perspectives) (Creswell and Clark 2007). An exploratory sequential research design is implemented through this paradigm in which the results of the first method (qualitative) will inform the development of a context grounded survey instrument and provide illustration and depth for quantitative data. Refer to Figure 3.4 for a graphic representation of the research design. More specifically in this study, the qualitative technique of focus groups will test the appropriateness to the local context of the variables selected for the resilience components. Subsequently, the quantitative methods will focus on the creation and testing of the resilience index. In the exploratory sequential research design adopted, the quantitative data will build on the qualitative findings. The qualitative data will also illustrate and help in the interpretation of the findings.

3.4 Conceptual Framework

This section describes the Disaster Resilience to Food Insecurities conceptual framework (Figure 3.5) proposed in my study. At time T_0, each household has a number of antecedent conditions that contribute to its level of resilience and food security attainment depending on its livelihood strategies. Cutter et al. (2008) suggest, from a hazards perspective, that inherent resilience of a system is part of the concept of antecedent conditions. Resilience to food insecurity measurement frameworks also

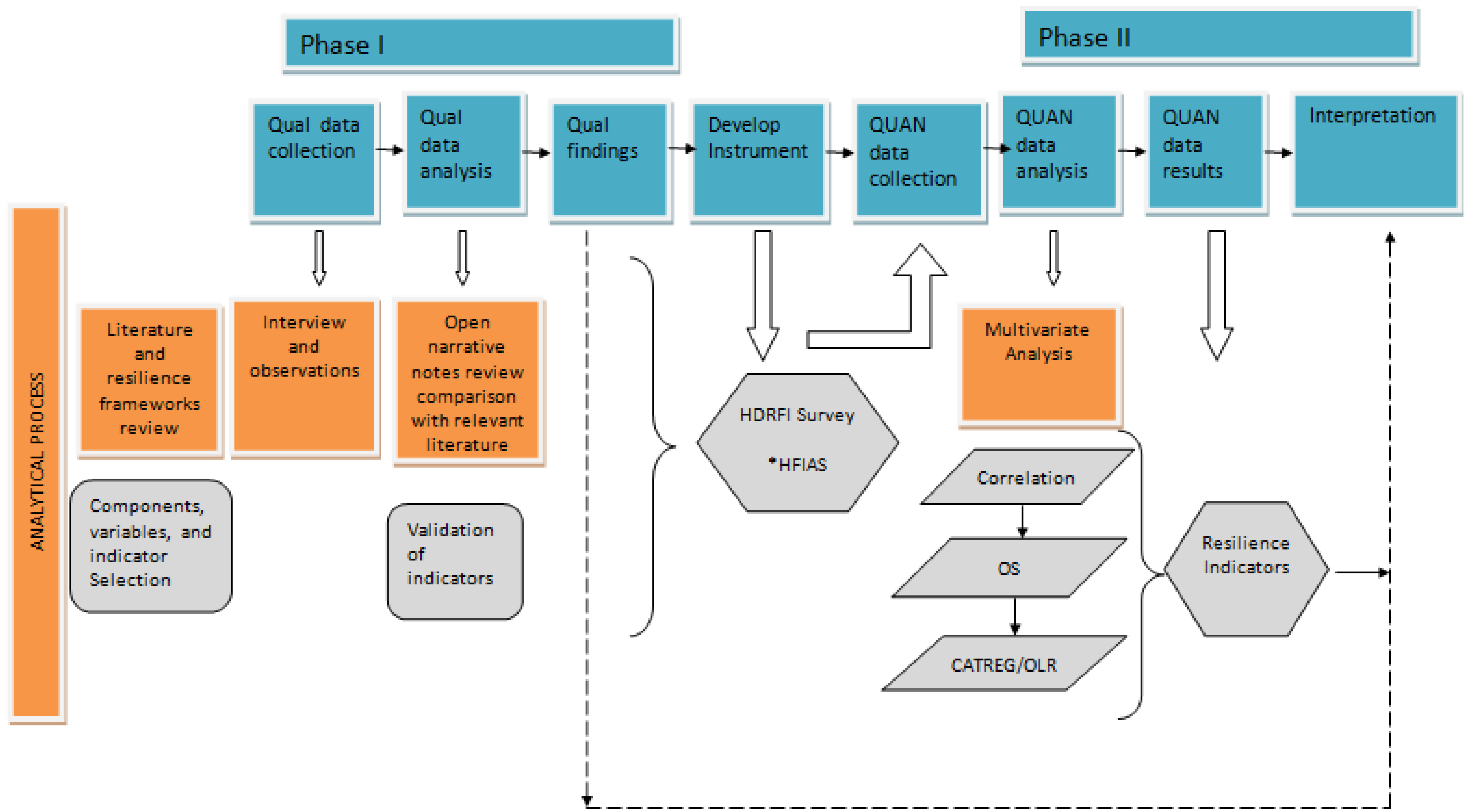


Figure 3.4: Mix-Method Exploratory Sequential Research Design

incorporate this concept of antecedent conditions (Alinovi, Mane, and Romano 2009; Frankenberger and Nelson 2013). Between T_0 and T_1, a natural hazard occurs. The level of food security at time T_1, as an outcome measurement for disaster resilience, is given by the interaction of four components as response mechanisms: 1) absorptive capacity, 2) adaptive capacity, 3) transformative capacity, and 4) natural capital. The availability and utilizations of these capacities (hereafter including natural capital) determine the ability of the household to cope with and minimize disaster impacts. I define resilience to food insecurity as follows:

> Resilience is a set of capacities that can be fostered through interventions, policies and social networks which in turn help build the ability of social systems along with the bio-physical systems upon which they depend, to respond and recover from disasters. Resilience to food insecurity represents the likelihood over time of a person, household or other unit's capacities to lead to or maintain a food secured state in the face of stressors and shocks.

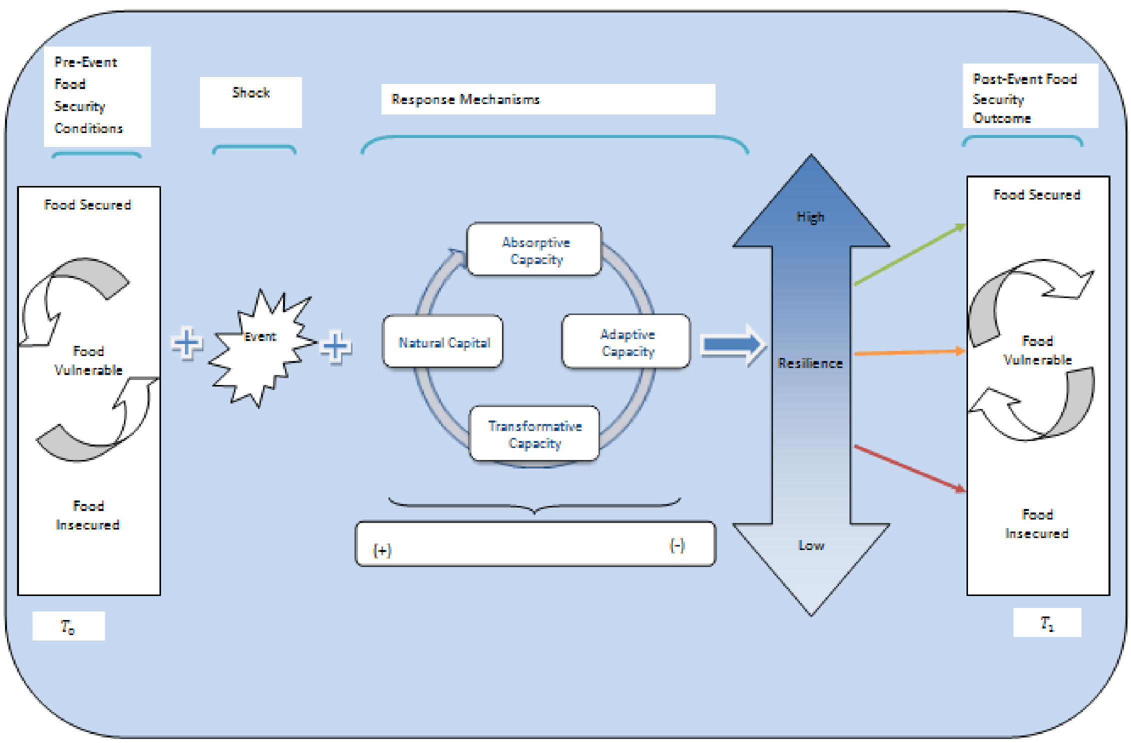


Figure 3.5: Household Disaster Resilience to Food Insecurity (HDRFI) Conceptual Framework

3.5 Multivariate Analysis for Indicator Selection

Governments and organizations are interested in evaluating the performance of communities based on their comparative disaster resilience. This is seen as important for disaster risk management and reduction as well as for policy-making processes. Recently there has been an interest among food aid organizations such as the World Food Programme and the Food and Agricultural Organization of the United Nations, and academic researchers on developing a methodology to measure resilience to food insecurities. This study seeks to incorporate the practitioners and academic research agendas to create a resilience index (also referred to as composite indicator) to measure disaster resilience to food insecurity as a tool to answer the stated research questions.

In an index individual indicators are compiled into a single aggregate measure on the basis of an underlying model (Nardo et al. 2008; Cutter et al. 2010). It usually measures multidimensional concepts which cannot be explained by a single indicator. Indicators are quantitative or qualitative measures derived from observed facts that simplify and communicate the reality of a complex situation (Cutter et al. 2010).

The resilience index in this study treats each capacity in the conceptual model (absorptive, adaptive, transformative and natural) as a component of the index. The components for this study represent an adaptation of the components identified in the Expert Consultation report (Frankenberger and Nelson 2013). The report cites three important capacities in measuring resilience to food insecurity: absorptive, adaptive and transformative. Natural capital (natural resources that are vital for life) is recognized as important for rural livelihoods (Mayunga 2007; Oxfam 2013; Frankenberger and Nelson 2013), but their operationalization requires technical skills and data that are difficult to obtain, especially in developing countries. Because of its importance in the rural context, the natural capital adapted from the livelihood resilience framework is included in this study. The following section explores the resilience components and indicators selected.

3.5.1 Identification of Indicators for the Components of the Resilience Index

The identification of variables for the four components of resilience index follows a three-step process:

1) The identified frameworks in the literature review and other works were reviewed to identify resilience variables.

2) Assessment of relevance and appropriateness of variables found in literature for the type of resilience of the study (food insecurity), type of shock (earthquake), and context.

3) Suitability for survey tool - many indicators have been proposed based on theoretical bases to measure resilience, but few have been actually tested through empirical studies.

This section will provide the justification for the four capacities selected as components of the resilience index. A list of indicators compiled based on theoretical and exploratory grounds for each component of the resilience index served to guide the survey developed for this study (Table 3.3).

Absorptive Capacity: The concept of absorptive capacity underlies the ability of a system (household, community, infrastructure, economy, etc.) to absorb event impacts of system perturbation (Cutter et al. 2008; Vugrin et al. 2010). In hazard studies absorptive capacity is seen as a threshold that impacts the degree of recovery. If the absorptive capacity is exceeded and the adaptive resilience process does not occur, a lower degree of recovery may result (Cutter et al. 2008). It is therefore considered a key factor in estimating resilience.

Adaptive Capacity: Smit and Wandel (2006) provide a good summary of disciplinary perspectives on the concept of adaptation.

> *The concept of adaptation has been used both explicitly and implicitly in the social sciences, including in natural hazards, political ecology, and the entitlements and food security scholarship… particularly [in] the natural hazards perspective focused on perception, adjustment and management of environmental hazards…Adaptation is usually implicit in the political ecology field. The relationships between ecosystems and political economy are often treated as issues of adaptive management of risks …Work on entitlements and food security considers adaptation as a stress response in light of access to resources and the abilities of people to cope* (Smit and Wandel 2006 p. 283-284).

Transformative Capacity: Transformative capacity has been identified as one of the three capacities important in resilience studies (Frankenberger and Nelson 2013; IDS 2013). As transformative capacity, power is intrinsically tied to human agency - the capability of actors to secure outcomes. Transformability means defining and creating new stability landscapes by introducing new components and ways of making a living, thereby changing the state variables, and often the scale, that define the system (Walker et al. 2004). In a social-ecological framework, Folke et al. (2010) look at the links between resilience, adaptability, and transformability and conclude that "[A]daptability is part of resilience. It represents the capacity to adjust responses to changing external drivers and internal processes and thereby allow for development along the current trajectory (stability domain). Transformability is the capacity to cross thresholds into new development trajectories" (p. 20).

Natural Capital: The direct dependence of communities on ecosystems, as it is usually the case in rural contexts, is an influence on their social resilience and ability to cope with shocks, particularly in the context of food security and coping with hazards

(Adger 2000). Natural resource-based livelihoods, such as in the case of the area of study, are highly vulnerable to changes in the ecosystem in which they operate and cannot be ignored in measuring resilience. The importance of healthy ecosystems is recognized in most resilience frameworks (Frankenberger and Nelson 2013; Oxfam GB 2011; ACCRA 2012).

3.5.2 Qualitative Methods

As explained in the Research Design section, the qualitative methods of interviews and observations prior to conducting the survey provided an in-depth insight into the study area. Data collected included availability of GIS physical maps, earthquake's social and physical impact, and selected communities' dynamics. In addition, interviews provided an opportunity to build relationships with insiders to the communities to act as guides into the selected study cases.

Table 3.3: Identified Indicator List for Resilience Index

Variable	Effect on Resilience	Measurements	Indicator	Justification
ABSORPTIVE CAPACITY				
Use of informal safety nets	Positive	Types of informal assistance received: number of types of informal assistance received after the earthquake (ratio) and type of assistance received (nominal)	Family: binary (0,1) Friends: binary (0,1) Cooperative: binary (0,1) Community: binary (0,1) NGOs: binary (0,1) 0 = not received 1= received	Frankenberger and Nelson 2013
Coping Strategy	Negative	Resettlement (ratio)	Binary (0,1) 0 = resettlement 1 = no resettlement	Maxwell 1996

Table 3.3: Continued

Physical Connectivity	Positive	Access to market or labor affected by earthquake (nominal)	Road damage: binary (0,1) 0 = damage roads affecting labor 1= no damage roads affecting labor	Ciani 2012
Infrastructure Damage	Negative	Labor activities affected by house damage by earthquake (nominal)	House damage: binary (0,1) 0 = house damage affecting labor 1 = no house damage affecting labor	Cutter et al. 2010
ADAPTIVE CAPACITY				
Human Capital	Positive	Head of household education attainment (ordinal).	0 = None 1 = Elementary 2 = Middle School 3 = High School and Beyond	Frankenberger and Nelson 2013; Cutter et al. 2003
Agricultural Assets	Positive	Number and type of agricultural assets used by household (ratio and ordinal).	Land: binary (0,1) Machinery: binary (0,1) Cattle : binary (0,1) 0 = not used 1 = used	Alinovi et al. 2010
Non-Agricultural Assets	Positive	Number and type of agricultural assets used by household (ratio and ordinal).	House: binary (0,1) Vehicle: binary (0,1) 0 = not used 1 = used	Alinovi et al. 2010
Livelihood Diversification	Positive	Primary and secondary employment: number (ratio)	Salaried Agricultural Independent Agricultural Dependent Non-Agricultural Ind. Tourism Other	Frankenberger and Nelson 2013
Social Norms	Positive	Perception on equal access to formal safety nets (ordinal)	Binary 0 = if respondent perceives no equal access 1 = if respondent perceives equal access;	DRLA 2012

Table 3.3: Continued

TRANSFORMATIVE CAPACITY				
Basic Services	Positive	Number of services present (ratio)	Water by aqueduct Electricity Land line phone or cellular	Frankenberger and Nelson 2013
Use of formal safety nets	Positive	Types of formal assistance received: number of assistance received after the earthquake (ratio) and type (nominal).	IMAS: binary (0,1) Health Care: binary (0,1) Retirement Fund: binary (0,1) CNE: binary (0,1) Other: binary (0,1) 0 = not received 1= received	U.S. Indian Ocean Tsunami Warning System Program 2007; Frankenberger and Nelson 2013
Minority	Negative	Ethnic minority household (nominal)	0 = yes minority 1 = no minority	Cutter et al. 2008
Livelihood Strategies	Positive	Types of livelihood present in the household (nominal)	Salaried: binary (0,1) Agricultural Dependent: binary (0,1) Agricultural Independent: binary (0,1) Tourism: binary (0,1) Non-Agricultural Independent: binary (0,1) Other: binary (0,1) 0 = no presence in household 1 = presence in household	DFID 1999
NATURAL CAPITAL				
Natural Resources	Positive	Recurring utilization of available natural resources: forest and river. Number of natural resources utilized by household (ratio) and type (nominal).	Forest: binary (0,1) River: binary (0,1) 0 = not used 1 = used	Frankenberger and Nelson 2013
Ecosystem Exposure	Negative	Labor affected by natural environment damage by earthquake (nominal)	Landslide: binary (0,1) Sediment: binary (0,1) Debris: binary (0,1) 0 = presence 1 = no presence	Cutter et al. 2008

3.5.2.1 Unstructured Interviews

The process involved ten unstructured interviews with different university faculty, research centers, government and tourism institutions, and community leaders (Table 3.4). The interviews were unguided (no pre-determined questions) with open-ended questions and exerted no control over informants' responses. Interviews took place in informal and formal settings on topics relevant to the study: earthquake, data availability, communities affected, recovery policies and processes, etc. The interviews also serve to evaluate the clarity of the questions, the language appropriateness, and the validation of the indicators chosen for the Household Disaster Resilience to Food Insecurity Index (hereafter referred to as the resilience index) used in the follow-up survey (Appendix A). This process grounded the questionnaire to the local context. The selection of an open narrative recording style made the interviews less intrusive and casual, providing a safe and comfortable environment for participants.

Table 3.4: Unstructured Interviews List

Date	**Institution/Group/Community leaders**
July 25, 2013	National University of Costa Rica (UNA)
July 26, 2013	National Commission for Risk Prevention and Emergency Attention (CNE)
July 29, 2013	University of Costa Rica (UCR)
July 30, 2013	CNE
	Community leader of Dulce Nombre
July 31, 2013	National Commission for Risk Prevention and Emergency Attention (CNE)
	Community leader of Varablanca
August 3, 2013	UNA
August 7, 2013	Community leader of Nueva Cinchona
August 8, 2013	National Chamber of Commerce regional representative

3.5.2.2 Unstructured Observations

Observations as a tool for data collection serve to support or challenge other data interpretations. They are also considered useful in studies that use other data collection methods which focus on experiences and views of participants. This is because they provide authenticity of the directly observed processes (O'Hara et al. 2011). Adding to the advantages of the open narrative style already expressed in the unstructured interviews section, the open narrative recording style used provided the flexibility needed for the different environments where the recorded observations took place.

3.5.3 Quantitative Methods

The data obtained through the interviews and observations informed the questionnaire tool developed for the survey and grounded the survey questions to the local context. The survey was developed and designed as follows. First, it was divided into two sections: 1) the Household Disaster Resilience to Food Insecurity (HDRFI) questionnaire (hereafter referred to as resilience questionnaire) (Appendix A); and 2) the Household Food Insecurity Access Scale (HFIAS) questionnaire adapted from the Food and Nutrition Technical Assistance (FANTA) (Appendix B). Both sections measure different processes; resilience to food insecurity and food security status respectively. Second, a cognitive pretesting was conducted. And third, a small group of survey respondents were debriefed through a focus group.

The resilience questionnaire provided the data for the variables and indicators selected to answer research Question 1: *What set of indicators are most influential in a household's disaster resilience to food insecurity in a rural context?* The questionnaire included 13 questions unique to this study (as opposed to replicated or standardized questions) with closed-ended questions with fixed responses (Appendix A).

The second part of the survey, the adapted HFIAS questionnaire developed by the FANTA Project, provided an appropriate tool for measuring households' food security for this study (Appendix B). Data obtained through this questionnaire provided the data for research Question 2: *To what extent can these indicators predict a food security outcome?* Studies on HFIAS's validity and reliability concluded that it is an effective tool in measuring food security in different contexts–especially in rural settings (Swindale and Bilinsky 2006; Salarkia et al. 2011; Cooper 2013). Attributes of the HFIAS considered as user-friendly included, but were not limited to: easily interpreted by local personnel; relatively easier to measure and more timely results; and no time consuming and not invasive. Furthermore, among the many indicators and methods that try to measure food insecurity, HFIAS is the only tool that measures a household's direct experience of food insecurity (SCN 2014).

As stated previously in this section, the survey included two questionnaires. In order to prevent participant exhaustion by limiting the number of total survey questions to the recommended 20 or below (O'Hara et al. 2011), the HFIAS tool was adapted by reducing the number of questions from nine to six. It was deemed that the elimination of one category of food security status will not significantly limit the interpretative results of the HFIAS tool. The data obtained show consistency with previous findings (Carter, Little and Mogues 2007; Ciani 2012), as explained in section 4.2, and considered reliable to assess the food security status of the population that included the three basic levels of food security: Food insecured, food vulnerable and food secured.

The draft survey went through a two-step process for validation: 1) cognitive pretesting; and 2) focus group testing. The cognitive pretesting phase of questionnaires serves to detect items that are not understood by respondents as intended by the survey developers. Two cognitive pretesting sessions took place. The first one took place at the *Comisión Nacional de Prevención de Riesgos y Atención de Emergencias* (CNE) meeting with members of their emergency response team actively involved in the Cinchona earthquake, and the second one at *Universidad Nacional de Costa Rica* (UNA) with the students that subsequently became the enumerators. At these sessions, participants were guided through questions about wording and meaning of the questionnaire in an open discussion format. These sessions provided feedback for enhancing the survey instrument. Cognitive pretesting, in this study the interviews and observations, informed the survey by providing participant feedback on its validity for the study area context.

As a last step, before surveying the study area, the survey went through a second level of validation utilizing a local group of women in the community of Dulce Nombre. After finalizing the changes to the survey, based on feedback received and addressing possible issues with questions, the information served to conduct a training session with the enumerators.

Two students from UNA acted as enumerators based on recommendations from UNA's faculty in the Geography Department. These students received training before going to the field to conduct the survey and throughout the survey time as issues arose. Two structured training sessions focused on an overview of the study, meaning of questions, participant management, and recording. Training onsite while conducting surveys or at the end of the day consisted of question clarifications.

3.5.3.1 Population and Sampling Strategy

The sample population was identified through the CNE *Actualización Consolidado General 18-08-2010* report. The report contained the coding of affected households by impact level: low, partial, and total loss. Of the 690 households identified as impacted in the area of study, 302 were coded as *total loss*. The households coded as total loss constituted the sampling frame from which the sample population was drawn.

Because of the study area geographically disperse over a large surface, and the need to produce statistical inferences, the stratified clustered sampling hybrid technique was selected. The stratification of the study area was done by location (community) and clustered areas of households affected by the earthquake and coded as total loss were identified. Households coded as total loss tended to be geographically clustered in areas were landslides were experienced unless households were resettled in another area.

Of the 302 households identified as total loss in the six communities, a total of 126 households were surveyed, constituting 42 percent of the sampling frame. In addition, in each community selected at least 32 percent–of the total number of households coded as total loss–was surveyed. The identified households in each community constituted the cases used for this study (Table 3.5). Table 3.6 shows the demographic characteristics of the survey sample obtained.

Table 3.5: Study Cases Selected

Site	Total Loss	Surveyed	Percentage of Total Loss
Case A: Cinchona	93	32	34.40
Case B: Varablanca	30	19	63.3
Case C: San Rafael	15	5	33.3
Case D: Poasito	93	30	32.2
Case E: Fraijanes	43	18	41.8
Case F: Dulce Nombre	28	22	78.5
Total	302	126	41.72

Table 3.6: Population Sample Characteristics

	Sample Characteristics	%
Respondents		
Gender	Male	32
	Female	68
Households		
Head of Household	Female	15
	Male	55
	Shared	30
Resettlement	Permanent	44
	Temporary	26
	No Resettlement	30
Educational Attainment	None	5
	Elementary	79
	Middle School	13
	High School	3

Data obtained through the surveys served to build the indicators retained for analysis after the qualitative validation process as explained previously. Table 3.7 shows the final indicators prepared for the multivariate analysis.

Table 3.7: Indicators Selected for Multivariate Analysis

Indicators	Description
ABSORPTIVE CAPACITY	
INFEX_B	Infrastructure damage affecting labor
INFEX_R	Physical connectivity affected by road damage
INFSN1_F	Informal Safety Net Family
INFSN2_FR	Informal Safety Net Friends
INFSN3_C	Informal Safety Net Cooperative
INFSN4_CM	Informal Safety Net Community
INFSN5_NGO	Informal Safety Net NGO
SUMISN_R	Total number of informal safety nets used
RESETB	Resettlement
ADAPTIVE CAPACITY	
EDU	Head of household schooling level
EQACCES	Perception on equal access to formal safety nets
SUMLIVD_R	Livelihood diversity
AGASST_L	Land access used for consumption or income generating
AGASST_M	Agricultural machines used for consumption or income generating
AGASST_C	Cattle used for consumption or income generating
SUMAG_R	Total number of agricultural assets used for consumption or income generating
ASSTHOUSE	House used for consumption or income generating
ASSTVEH	Motor vehicle used for consumption or income generating
SUMNonAG_R	Total number of non-agricultural assets used for consumption or income generating
TRANSFORMATIVE CAPACITY	
FSNIMAS	Formal Safety Net IMAS

Table 3.7: Continued

FSNHEALCA	Formal Safety Net Health Care
FSNRETFU	Formal Safety Net Retirement Fund
FSNINEC	Formal Safety Net CNE
FSNOTHER	Formal Safety Net Other
SUMFSN_R	Total number of formal safety nets used
LIVDIV_SAL	Livelihood strategy salaried
LIVDIV_AGIND	Livelihood strategy Agriculture Independent
LIVDIV_AGDEP	Livelihood strategy Ag dependent
LIVDIV_NONAGIND	Livelihood strategy non-Ag independent
LIVDIV_TOUR	Livelihood strategy tourism
LIVDIV_OTHER	Livelihood strategy other
NATIVE	Ethnic minority
BASSER1	Water provided by aqueduct
BASSER2	Electricity available
BASSER3	Landline or cell phone available
NATURAL CAPITAL	
ECOEX_S2	Ecosystem exposure sediment
ECOEX_D2	Ecosystem exposure debris
ECOEX_L2	Ecosystem exposure landslide
NATRES1_F	Utilization of forest
NATRES2_W	Utilization of water sources
SUMNAT_R	Total number of natural resources used

3.6 Multivariate Analysis for Indicator Refinement

The exploratory approach of this study provides the flexibility of allowing the data structure to reveal itself through both visual inspection of graphs and displays, and numerical techniques. The exploratory data analysis process will lead to a confirmatory process with a better understanding of the data and its applicability to the context of the study. Basic statistical analysis was conducted to inform the multivariate analysis selection process. Understanding the essential features of the data guides the selection of the multivariate methods most appropriate for this study, and allows the acquisition of information that might be lost or obscured through the creation of components and the resilience index.

As stated previously, there is not a well-established or standard list of indicators for resilience to food insecurity. The selection of resilience indicators is a very subjective process. A series of multivariate analysis were conducted on the data obtained from the survey to assess if the resilience components (Absorptive Capacity, Adaptive Capacity, Transformative Capacity and Natural Capital) are statistically well defined, and to assess whether the variables sufficiently describe disaster resilience to food insecurity.

Factor analysis (FA) is a multivariate statistical set of techniques that model observed variables as linear functions of a set of latent variables (not directly observed) known as factors or components depending on the technique used. FA and Principal Component analysis (PCA) are occasionally used interchangeably according to the discipline. In geography, these two techniques have different uses, and the distinction is made in this work. In PCA all variability of an item is used, while only the variability in an item common to other items is used in FA. In most cases these two methods yield very similar results, but PCA is often preferred as a method for data reduction while FA is used for cases when the goal of the analysis is to detect the structure in the data (Alinovi et al. 2010). PCA can be summarized as a method of transforming the original variables into new, uncorrelated variables. On the other hand, the factors obtained in factor analysis are selected mainly to explain the interrelationships among the original variables (Afifi, May, Clark 2012). The goal of PCA is to reveal how different variables change in relation to each other and how they are associated (Nardo et al. 2008).

FA is often used to assess if index components are well balanced (Nardo et al. 2008; Alinovi, Mane, and Romano 2009). The drawback to this statistical method is the assumptions of linearity and multivariate normal distribution of data. The degree of violation of these assumptions will deem FA inadequate with questionable or unacceptable results.

Analysis of some individual indicators selected for this study revealed non-parametric and non-linear relationships. In order to acquire acceptable results, non-linear and non-parametric approaches were needed to explore the structure of the data. A non-linear principle component analysis (NLPCA) that could accommodate variables of mixed measurement levels was selected. An alternative way to investigate the degree of correlation among a set of variables is to use the Cronbach coefficient alpha (hereafter referred to as c-alpha), which is the most common estimate of internal consistency of items in a model or survey (Nardo et al. 2008). Normality on data distribution is not generally an assumption needed when running c-alpha, and it is found as a cross-validation output in statistical software with NLPCAs. To examine the overall structure of the data and gain insight for its fit for the resilience index, the NLPCA and Cronbach Alpha multivariate analytical approaches were selected.

NLPCA can accommodate variables with different measurement levels (nominal, ordinal or numeric) that might not be linearly related to each other or follow a normal distribution. Although the main goal is to reduce the dataset to a smaller number of uncorrelated summary variables (or components), it also reveals relational structures of the data (Linting and van der Kooij 2012). Optimal scaling in NLPCA assigns numerical quantifications with metric properties to the categories of each variable allowing standard statistical procedures to obtain a solution on the quantified variables (Meulman and Heiser 2001). The quantification depends on the type of variables and the presumed relationship among them. In the case of a nominal analysis level, the only requirement is that cases or objects in the same category obtain the same quantified value. For an ordinal level, the quantification respects the ordering of the original variables, whilst a numeric level also requires preservation of the original relative distance among categories (Coromaldi and Zoli 2011). In NLPCA the number of components desired can be specified. As in traditional PCA, there is no standard approach to selecting the number of components. For this study, components with eigenvalues greater than 1 were retained.

The second approach selected for the refinement of the selected indicators, c-alpha, assesses how well individual indicators measure the underlying construct (capacities, components, etc.). C-alpha measures the portion of total variability of the sample of individual indicators due to the correlation of indicators. It increases with the number of individual indicators and with the covariance of each pair. If no correlation exists and individual indicators are independent, then c-alpha is equal to zero, while if individual indicators are perfectly correlated, c-alpha is equal to one (Nardo et al. 2008). C-alpha is not a statistical test, but a coefficient of reliability based on the correlation between individual indicators. If the correlation is high there is evidence that the individual indicators are measuring the same underlying construct. Therefore, a high c-alpha (or equivalently a high “reliability”) indicates that the individual indicators measure the latent phenomenon well (Nardo et al. 2008). In this second approach, Cronbach’s

Alpha in SPSS CATPCA is selected because it allows for the use of indicators with different scale levels.

Cronbach's Alpha CATPCA algorithms:

Cronbach's Alpha per dimensión (s = 1,….,p)

$$\alpha_s = m_w \left(\lambda s^{1/2} - 1\right) / \left(\lambda s^{1/2}(m_w - 1)\right) \qquad (1)$$

Total Cronbach's Alpha is:

$$\alpha = m_w\left(\sum_s \lambda s^{1/2} - 1\right) / \sum_s \lambda s^{1/2}\ (m_w - 1) \qquad (2)$$

Where m_w is the number of weighted items (indicators in this study) times the average inter-item covariance among them with λs the s^{th} diagonal element of the orthonormalization step during the last iteration. An important question is how large the c-alpha must be. This varies by discipline from 0.60 to .80 as cut-off value (Nardo et al. 2008). Generally, in the social sciences 0.60 is considered an acceptable cut-off value.

First, the indicators for the four components of the resilience index were analyzed through two multivariate analyses: NLPCA and Cronbach's coefficient alpha. For the analysis, the CATPCA (extended or categorical PCA) approach in SPSS was selected for its suitability to handle different scale levels. CATPCA, just like linear PCA, is often used for data reduction. However, in this study it is mainly used as a tool to assess the reliability of the indicators to measure the same underlying construct and to understand better the dimensionality of the components. Data reduction, in this case by indicator selection, is only considered in the components where instability is suspected in the

CATPCA solution and corrected by the exclusion of variables with a low number of observations or any other circumstances that might merit the exclusion of an indicator. In general, based on simulations, Markus (1994) advises a bottom threshold of eight observations–which has been adopted for this study. In CATPCA, Cronbach's alpha coefficient of reliability (consistency) is used as a cross-validation to measure the internal consistency of the data – meaning how closely related a set of items are as a group. It is used as evidence that the items measure an underlying construct; the higher the value the stronger the internal consistency of the indicators. As previously stated in the social sciences, an alpha equal or greater than .60 is considered acceptable in most research situations (Nardo et al. 2008). To answer research Question 1: *What set of indicators are most influential in a household's disaster resilience to food insecurity in a rural context?* The indicators being analyzed have already been grounded to the local context (section 3.5.2). Furthermore, the intent of this study is to explore the indicators relationship, not necessarily to develop a parsimonious list of indicators. Data reduction is not deemed necessary or appropriate for this study because of its exploratory nature.

3.6.1 Absorptive Capacity

The descriptive statistics conducted on the nine indicators in the Absorptive Capacity component of the resilience index revealed the indicator for the use of cooperatives as informal safety nets (INFSN3_C) unacceptable for this study. This indicator has only 5 occurrences in one of the categories while the bottom threshold in this study is 8 (as explained in the previous section). Further analysis showed that by removing this indicator, the variance accounted for in the solution with two dimensions could be increased from 53.6 percent to 59.3 percent. In addition, the indicator of coping strategy (RESETB), when plotted in a one and two dimensional table, falls outside of the main clusters based on their distances showing dissimilarity between the RESETB indicator and the rest of the indicators. It was deemed that RESETB should be eliminated based on its dissimilarities with the other indicators as a measure of this component. Furthermore, by eliminating this indicator, the total variance accounted in a two solution increased. In contrast, the sum of social safety nets indicator (SUMISN_R) was kept, albeit falling outside the main clusters (Figure 3.6) This decision was based on theoretical basis since it is important to determine which safety nets are most influential in the resilience metrics, as much as the influence of the quantity of assistance (or sum) (Frankenberger and Nelson 2013). Additionally, if the SUMISN_R indicator is removed, the variance accounted for this component decreases, as well as it increases the distance among indicators in the two dimensions of the solution. These results indicate a tendency to create instability in the solution when the SUMISN_R indicator is removed.

Solutions for pre-determined 1, 2, and 3 components show a tendency of the component to be two-dimensional with 59.3 percent of the variance accounted by dimensions one and two (Table 3.8). Table 3.9 shows the list of indicators retained for this component. Component 1 represents the physical impact of the earthquake that affected labor and physical connectivity, while component 2 represents close personal networks utilized as informal safety nets during the recovery phase by the survey participants. When the solution for pre-determined 3 components was run, no clear interpretation was found.

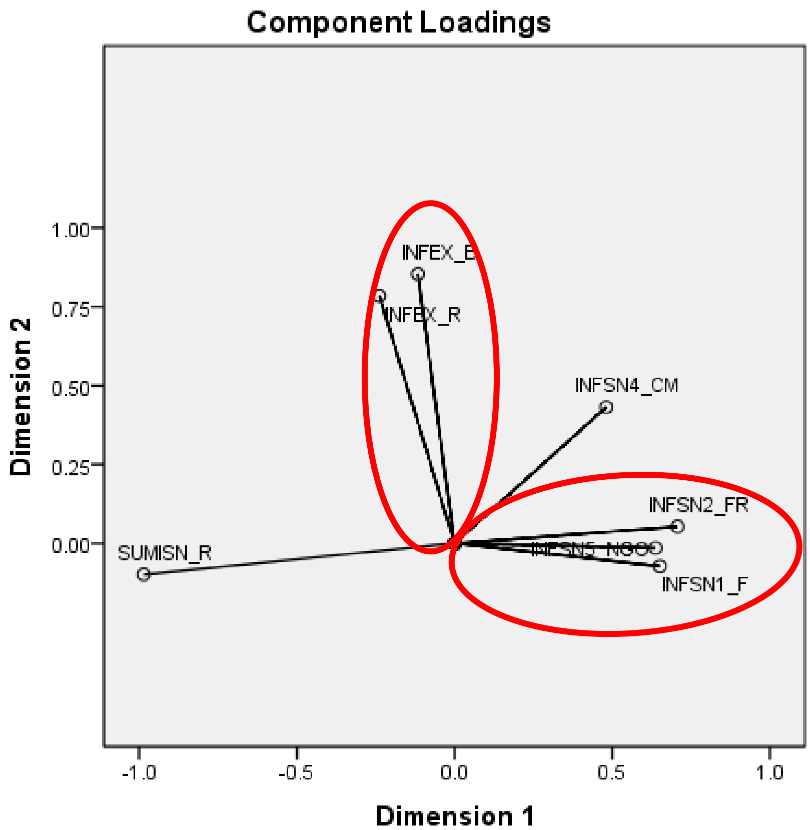


Figure 3.6: Absorptive Capacity 2 Dimension Plot Table

Table 3.8: Absorptive Capacity Cronbach's Alpha

Model Summary			
Dimension	Cronbach's Alpha	Variance Accounted For	
		Total (Eigenvalue)	% of Variance
1	.718	2.602	37.176
2	.414	1.550	22.140
Total	.886[a]	4.152	59.316

a. Total Cronbach's Alpha is based on the total Eigenvalue.

Table 3.9: Absorptive Capacity Indicators Retained

Component Loadings		
	Dimension	
	1	2
INFEX_B	-.116	.854
INFEX_R	-.238	.785
INFSN1_F	.651	-.072
INFSN2_FR	.707	.053
INFSN4_CM	.481	.432
INFSN5_NGO	.637	-.015
SUMISN_R	-.986	-.099

3.6.2 Adaptive Capacity

When analyzing the results from a pre-determined 1 dimensional solution, only 24.124 percent of the variance is accounted by the component. This points at the component's multidimensionality, which will inform the interpretation of the analysis, as reflected by the distances and direction between the loading indicators in a two dimensional plot (Figure 3.7). The total c-alpha of .922—indicating a strong internal consistency—is based on the total eigenvalue (Table 3.10). Therefore we can conclude that the component's indicators measure the same construct with three components accounting for 58.62 percent of the variance of the data.

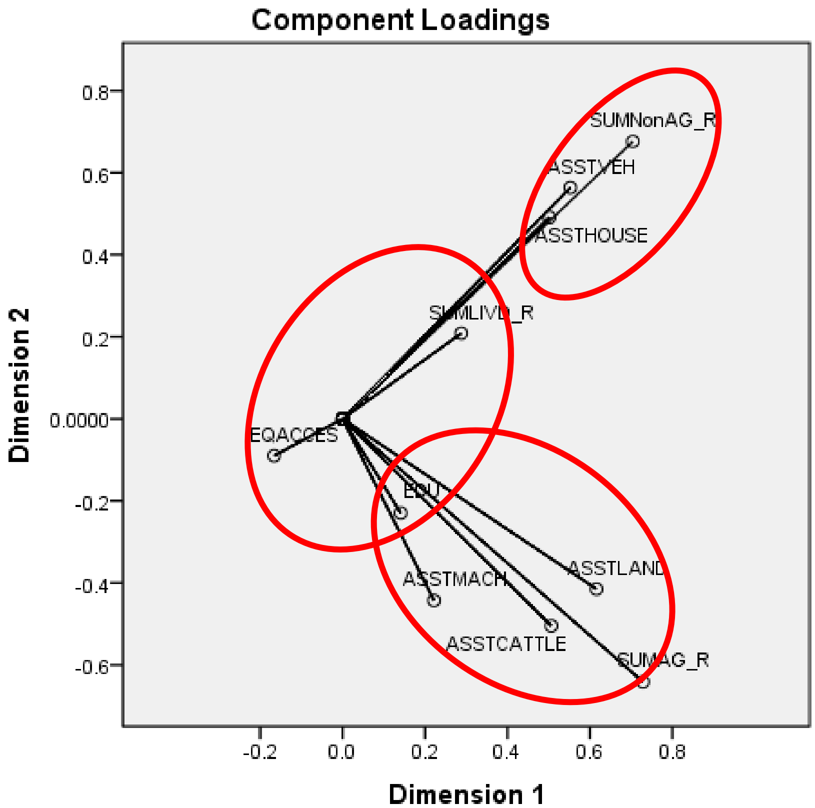


Figure 3.7: Adaptive Capacity 2 Dimension Plot Table

Various rules have been proposed for deciding how many components to retain, however, none of them appear to work well in all circumstances (Afifi, May and Clark 2012). When used as an exploratory method, investigators often retain as many components as they can either: 1) interpret or 2) find useful for analysis (Afifi, May and Clark 2012; Linting and van der Kooij 2012.). For this component, 3 dimensions representing 58.62 percent of the total variance were retained with a Cronbach's Alpha of .922 which reflects a very strong data consistency (Table 3.10). Dimensions four and higher each accounted for a small percentage of the total variance and could not be easily interpreted. Linting and van der Kooij (2012) considered 51 percent of variance accounted for as a “reasonable” fit.

Table 3.10: Adaptive Capacity Cronbach's Alpha

Model Summary			
Dimension	Cronbach's Alpha	Variance Accounted For	
		Total (Eigenvalue)	% of Variance
1	.650	2.410	24.098
2	.590	2.132	21.317
3	.270	1.321	13.206
Total	.922[a]	5.862	58.621

a. Total Cronbach's Alpha is based on the total Eigenvalue.

The Adaptive Capacity component of the resilience index clearly groups in three distinct dimensions. Agricultural assets dominate dimension 1 (Table 3.11) showing high loadings with the exception of AGASST_M. Dimension 2 loadings reflect the non-agricultural assets of this component, all with high loadings. And, dimension 3 is grouping variables of social-economic influence: education (EDU), social norms (EQACESS) and livelihood diversification (SUMLIVD_R). All variables are retained because the solution is considered to be stable.

Table 3.11: Adaptive Capacity Indicators Retained

Component Loadings			
	Dimension		
	1	2	3
EDU	.188	-.113	.601
EQACCES	-.162	-.072	.668
SUMLIVD_R	.302	.203	.383
AGASST_L	.597	-.437	-.245
AGASST_M	.216	-.452	.195
AGASST_C	.498	-.510	.104
SUMAG_R	.711	-.665	-.094
ASSTHOUSE	.510	.474	-.378
ASSTVEH	.568	.559	.326
SUMNonAG_R	.719	.662	.010

3.6.3 Transformative Capacity

For the Transformative Capacity component of the resilience index, 12 out of 16 indicators were retained. The indicators for basic services of water (BASSER1), electricity (BASSER2) and phone (BASSER3) were excluded because all of these have only 1 or 2 occurrences, far below the threshold set at 8 occurrences minimal. In addition, the socio-economic indicator to identify households of immigrants (NATIVE), when plotted in a 1 and 2 dimensional table falls outside of the main clusters based on their distances; showing dissimilarity between this indicator and the rest of the indicators. CATPCA was run for 1, 2, and 3 dimensions. The results show that this component is multidimensional, as observed by the loading of indicators in Table 3.13. The three component solution with a total Cronbach's Alpha of .883 (Table 3.12) provided the most interpretative results grouping indicators of formal safety nets programs in 2 dimensions and livelihood characteristics in one dimension (Table 3.13).

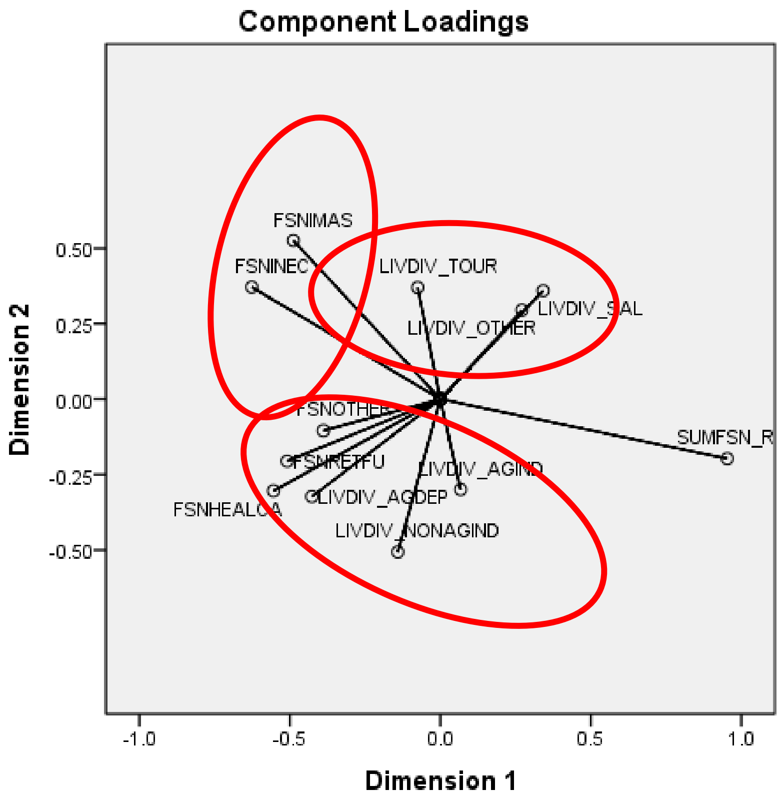


Figure 3.8: Transformative Capacity 2 Dimension Plot Table

Table 3.12: Transformative Capacity Cronbach's Alpha

Model Summary			
Dimension	Cronbach's Alpha	Variance Accounted For	
		Total (Eigenvalue)	% of Variance
1	.681	2.660	22.169
2	.314	1.404	11.701
3	.171	1.189	9.909
Total	.883[a]	5.254	43.779

a. Total Cronbach's Alpha is based on the total Eigenvalue.

Table 3.13: Transformative Capacity Indicators Retained

Component Loadings			
	Dimension		
	1	2	3
FSNIMAS	-.488	.525	.051
FSNHEALCA	-.554	-.304	.004
FSNRETFU	-.509	-.204	-.054
FSNINEC	-.627	.373	-.043
FSNOTHER	-.389	-.097	-.254
SUMFSN_R	.953	-.199	.052
LIVDIV_SAL	.341	.370	-.355
LIVDIV_AGIND	.067	-.318	.627
LIVDIV_AGDEP	-.427	-.327	.113
LIVDIV_NONAGIND	-.141	-.492	-.494
LIVDIV_TOUR	-.076	.355	.503
LIVDIV_OTHER	.271	.304	-.294

3.6.4 Natural Capital

In the Natural Capital component all 6 indicators were retained. The forest usage indicator (NATRES1_F) has only 6 occurrences in one category, which did not meet the set 8 minimum observations per category. However, excluding NATRES1_F necessitated the exclusion of SUMNAT_R. The exclusion of NATRES1_F, NATRES2_W, and SUMNAT_R created redundancy in the data. By removing the two indicators above, NATRES2_W's fit for this component was compromised. Indicators NATRES1_F, NATRES2_W and SUMNAT_R showed a strong relationship together, clearly reflecting a natural resource dimension to the Natural Capital component when running a two dimension solution. However, by omitting NATRES1_F and SUMNAT_R, NATRES2_W on its own lost the consistency and association of the dimension and accounted only for .085 of the total variance of 61.34 explained by a one dimension solution. It was determined that the exclusion of the NATRES1_F indicator effect on the stability of the solution merit its inclusion in the dimension.

The CATPCA results for 1 and 2 solutions reflected a two-dimensional data structure for the Natural Capital component. The loading indicators' plotting Figure 3.9 and the loading Table 3.15 reveal the natural system services of water and forest resources as one dimension and the ecosystem perturbation after the earthquake (sediment, landslides, and debris) as a separate dimension. The two solution yields a Cronbach's Alpha of .954 and accounted for 81.2 percent of the total variance in the data (Table 3.14).

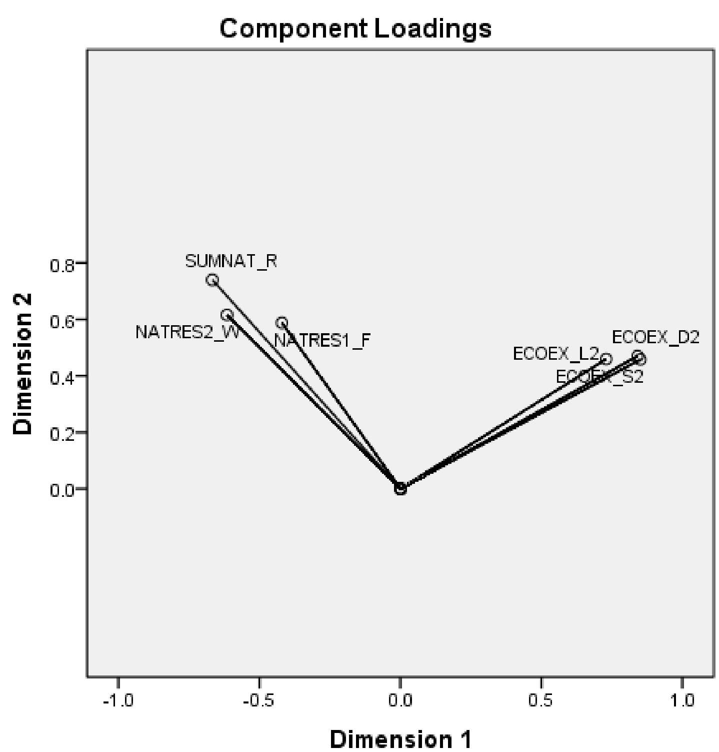


Figure 3.9: Natural Capital 2 Dimension Plot Table

Table 3.14: Natural Capital Cronbach's Alpha

Model Summary			
Dimension	Cronbach's Alpha	Variance Accounted For	
		Total (Eigenvalue)	% of Variance
1	.795	2.962	49.371
2	.573	1.913	31.878
Total	.954[a]	4.875	81.250

a. Total Cronbach's Alpha is based on the total Eigenvalue.

Table 3.15: Natural Capital Indicators Retained

Component Loadings		
	Dimension	
	1	2
ECOEX_S2	.851	.458
ECOEX_D2	.841	.470
ECOEX_L2	.729	.459
NATRES1_F	-.421	.588
NATRES2_W	-.615	.616
SUMNAT_R	-.667	.740

3.7 Summary

An index is formed when individual indicators are summed into a single quantitative value on the basis of an underlying model. The resulting index is only as reliable and sound as its individual indicators. Two multivariate analyses were performed for each component of the resilience index to assess their reliability and fit for the study. First, Cronbach's coefficient alpha was performed to assess whether the indicators of a single component were measuring the same underlying construct. Second, to obtain a more comprehensive understanding of the dimensionality of the data, a NLPCA was performed for each component. From these results, of the original 41 indicators 35 were retained for further analysis (Table 3.16). The informal safety net cooperative (INFSN2_C), and basic services (BASSER1, BASSER2, and BASSER3) indicators lacked the 8 occurrences set in this study as a threshold for inclusion. The ethnic minority (NATIVE) and the resettlement (RESETB) indicators did not fit the component they were considered to measure. The next chapter will validate the index through the outcome measurement of food security in the study area.

Table 3.16: Final List of Retained Indicators

Indicators	Description
Absorptive Capacity	
INFEX_B	Infrastructure damage affecting labor
INFEX_R	Physical connectivity affected by road damage
INFSN1_F	Informal Safety Net Family
INFSN2_FR	Informal Safety Net Friends
INFSN4_CM	Informal Safety Net Community
INFSN5_NGO	Informal Safety Net NGO
SUMISN_R	Total number of informal safety nets used

Table 3.16: Continued

Adaptive Capacity	
EDU	Head of household schooling level
EQACCES	Perception on equal access to formal safety nets
SUMLIVD_R	Livelihood diversity
AGASST_L	Land access used for consumption or income generating
AGASST_M	Agricultural machines used for consumption or income generating
AGASST_C	Cattle used for consumption or income generating
SUMAG_R	Total number of agricultural assets used for consumption or income generating
ASSTHOUSE	House used for consumption or income generating
ASSTVEH	Motor vehicle used for consumption or income generating
SUMNonAG_R	Total number of non-agricultural assets used for consumption or income generating
Transformative Capacity	
FSNIMAS	Formal Safety Net IMAS
FSNHEALCA	Formal Safety Net Health Care
FSNRETFU	Formal Safety Net Retirement Fund
FSNINEC	Formal Safety Net CNE
FSNOTHER	Formal Safety Net Other
SUMFSN_R	Total number of formal safety nets used
LIVDIV_SAL	Livelihood strategy salaried
LIVDIV_AGIND	Livelihood strategy Agriculture Independent
LIVDIV_AGDEP	Livelihood strategy Ag dependent
LIVDIV_NONAGIND	Livelihood strategy non-ag independent
LIVDIV_TOUR	Livelihood strategy tourism
LIVDIV_OTHER	Livelihood strategy other
Natural Capital	
ECOEX_S2	Ecosystem exposure sediment
ECOEX_D2	Ecosystem exposure debris
ECOEX_L2	Ecosystem exposure landslide
NATRES1_F	Utilization of forest
NATRES2_W	Utilization of water sources
SUMNAT_R	Total number of natural resources used

IV. RESILIENCE TO FOOD INSECURITY METRICS AND MEASURMENTS

4.1 Overview and Methodology

There are several frameworks being developed and operationalized to measure disaster resilience. These frameworks rely on secondary data and have been applied in developed countries where secondary data for selected indicators are available (Tobin 1999; Cutter et al. 2008, 2010; Peacock et al. 2010). The Disaster Resilience of Place (DROP)(Cutter et al. 2008) presents a list of proposed variables and indicators of resilience. The Baseline Resilience Indicators for Communities (BRIC) model (Cutter , Burton, and Emrich 2010) is based on the DROP model and proposes composite indicators comprised of data available through secondary sources such as the U.S. Census. Research on resilience to food insecurity has resulted in proposals for analytical framework to measure resilience to food insecurity (DFIF 1999; Frankenberg and Nelson 2013; Constas and Barrett 2013) and attempts to operationalize conceptual frameworks (Alinovi, Mane, and Romano 2009; Alinovi et al. 2010; DRLA 2012; Ciani 2012). However, with the exception of the DRLA (2012) and Alinovi et al. (2009; 2010), these studies use secondary data.

This chapter presents a refinement of the indicators selected in the previous chapter to assess which indicators are most influential for comparative analysis among households that will answer research Question 1*: What set of indicators are most influential in a household's disaster resilience to food insecurity in a rural context?* To this end, a series of non-parametric regression models using the indicators retained in each capacity component in the previous chapter are conducted. The selected indicators for each component are used as predictor or independent variables, and the household post-event food security status is used as the response or dependent variable. The results give us a set of empirical tested variables for the measurement of disaster resilience to food insecurity.

Scientific inquiry makes use of mathematical models to solve real world problems. Successful use of these models requires understanding of the theoretical underpinnings of the phenomenon, the characteristics of the mathematical model, and the practical problems encountered when using these models in real-life situations (Freund and Wilson 2006). The literature review in chapter two explores the theoretical propositions of disaster resilience and serves as the basis for the selection of multivariate regression as the stochastic model for this study.

In general terms, regression models analyze samples of observed or experimental data (predictor or independent variables) in an attempt to explain the behavior of the response variable (dependent variable) through an algebraic equation. This algebraic equation includes an error parameter which represents the behavior of the response variable that is not completely explained by the model chosen. A multivariate regression model was chosen for this study because it provides a view of the relationship between variables in a way that facilitates its interpretation, and it also allows for assessment of the fit of the model (Nardo et al. 2005; 2008). In addition, this statistical analysis has been used in previous studies and will facilitate the comparison of study results (Alinovi et al. 2009, 2010; Ciani 2012; Cutter et al. 2010).

Multivariate regression models usually take the linear form:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} \ldots \beta_m X_{mi} + \varepsilon_i$$

Where *Y* is the dependent or response variable and *X* are the predictor or independent variables. The analysis then fits a straight line to the experimental or observed data where the effects of variables *X* on *Y* take place and result in β which is the regression coefficient that indicate how much change in the dependent variable is produced by a change in each of the predictor or independent variables when the others are controlled for. The resulting error represented by ε can represent errors in the data, poor choice of model, and other violations of assumptions underlying the inference procedures (Freund and Wilson 2006).

There are four assumptions in linear regression models: 1) linearity, 2) homoscedasticity, 3) independence, and 4) normality. There are two main strategies for testing the conformity of a particular relationship to the assumptions. The first strategy examines how well the variables satisfy the assumptions before the regression is computed by computing diagnostic statistics. The second strategy examines the residuals after the regression has been computed. This study takes the first approach for its clarity of results and ease of interpretation. While conducting the normality tests on the ratio data, it was found that these assumptions were violated by several variables. Therefore, the linear model was not the correct one for this study. The relationships uncovered in the exploratory analysis of the data reveal a real world phenomenon difficult to fit into a mathematical model which doesn't account for real life circumstances. An example is the lack of employment sources in the study area that limits the livelihood diversification of the communities selected, which skews the data distribution of this variable. Another example is the level of education in the area. As it is usually found in rural areas as a consequence of limited access to schools, the great majority of the heads of the households that participated in the survey only counted with elementary education which resulted in a right skewed data distribution.

This dissertation adopted a categorical regression model deemed more appropriate to fit the different levels of measurements and patterns present in the data. Categorical regression, with optimal scaling using alternating least squares, quantifies categorical variables using optimal scaling. The variables can be given mixed optimal scaling levels and no distributional assumptions about the variables are made (IBM online; "SPSS Statistics"). Regression with optimal scaling offers three scaling levels for each variable. Combinations of these levels can account for a wide range of nonlinear relationships and offer greater flexibility than other standard approaches such as analysis of variance or logistic regression (IBM online; "SPSS Statistics"). The categorical regression model selected for this study is the SPSS CATREG approach, which incorporates optimal scaling and can be used when the predictor(s) and response variables are any combination of numeric, ordinal or nominal.

4.2 Food Security Status Validation

For the regression analysis (Section 4.4), Post-Event Food Security Status (SPSTFS) is the outcome selected as the dependent variable (also referred to as the response variable) which is designed to answer research question #2: *To what extent can these indicators predict a food security outcome?* The data for the Post-Event Food Security Status variable came from the adapted HFIAS questionnaire (Appendix B). As indicated in the conceptual framework (Section 3.4), households have a number of antecedent conditions (pre-event) that contribute to their level of resilience and food security attainment. Information about the pre-event food security status of households obtained through question four in the resilience questionnaire served two purposes. First, to validate the results obtained from the adapted HFIAS questionnaire the patterns of food security recovery were analyzed. To assess if the patterns of recovery shown in the data were consistent with expected outcomes as shown in previous works or theory, before and after the earthquake food security status were compared and recovery paths analyzed. Second, to capture the resilience dynamic processes as denoted in the conceptual framework since resilience to food insecurity is not a static process.

To tabulate the categorical Pre-event Food Security Status (PREFS_CAT) indicator, the coding below was used. The categories follow the HFIAS categories (secured, mildly insecured, moderately insecured, and severely insecured) combining two categories, as explain in Section 3.5.3, for a total of three food security status categories for this study.

If: 4a = yes THEN Food Secured (little to no hunger in the household) = coding 3

4b = yes THEN Food Vulnerable (mildly food insecure) = coding 2

4c = yes THEN Food Insecured (moderately and severely food insecured) = 1

This coding ensures that a higher score signifies higher level of food security, as a higher score of recovery reflects a higher level of resilience.

4.2.1 Household Food Insecurity Access Scale (HFIAS) Score

The HFIAS score is a continuous measure of the degree of food insecurity in the household in the past four weeks (30 days). First, the HFIAS score variable in this study reflects the post-event food security status of households and it is calculated for each household by summing the codes for each frequency-of-occurrence question (SPSTFS). A zero was assigned to all cases where the answer to the corresponding occurrence question was "No" (i.e., if Q1=0, then Q1a=0, if Q2=0, then Q2a =0, etc.). The maximum score for a household is 18. The higher the score, the more food insecurity the household experienced, and the lower the score, the less food insecurity a household experienced (Coates, Swindale, and Bilinsky 2007). When tabulating the Post-event Food Security Status Categories (SPSTFS_CAT) indicator, the categories used in Pre-event Food Security Status (PREFS_CAT) were also used in this process for consistency purposes. Table 4.1 illustrates this categorization. The categorization scheme is designed to ensure that a household's set of responses will place them in a single, unique category.

Table 4.1: Adapted HFIAS Score Categorization

Adapted HFIAS Question	**Frequency**		
	Rarely 1	Sometimes 2	Often 3
1a	0-1	2	3
2a	4	5	6
3a	7	8	9
4a	10	11	12
5a	13	14	16
6a	17	18	19

The scoring reflected in the frequency columns is cumulative.

Categorization color key:

Food Secured	**Food Vulnerable**	**Food Insecured**

By cross-tabulating the Pre-Event Food Security Status (PREFS_CAT) and Post-Event Food Security Status (SPSTFS_CAT) indicators, the results obtained were compared with expected food security recovery patterns based in the literature. The Crosstabs procedure forms a two-way table and provides a variety of tests and measures of association. The structure of the table, and whether categories are ordered, determines what test or measure to use. Spearman's Rank Correlation Coefficient is a non-parametric measure of association between the rankings of two variables measured on N cases appropriate for the data structure of the two food security variables. The Spearman’s results (Table 4.2) show expected data patterns when compared with previous works.

Rural food secured households tend to have relatively higher levels of asset accumulation and economic resources to respond to a natural disaster. In contrast, for the least wealthy groups, the effects of natural disasters on assets are of longer duration and are felt much more acutely (Carter, Little and Mogues 2007). Food vulnerable populations are at risk of becoming food-insecure and those factors that put them at risk also affect their ability to respond to shocks or stressors. Ciani (2012) reports in his study of the impact of Hurricane Mitch in rural households in Nicaragua that food secured or “non-poor food” households (as coded in work) were twice as likely to obtain or recover their food secured status after the event than the “poor food” households. The results of the cross-tabulation in this study show the same patterns as the previous works cited. Sixty-two percent of the pre-event food secured households were able to recover their food secured status post-event. Thirty-seven percent of the pre-event food vulnerable households became food insecured after the event. And, one hundred percent of the pre-

Table 4.2: Pre-Event and Post-Event Cross-tabulation.

			Post-Event Food Security			
			Food Insecured	Food Vulnerable	Food Secured	Total
Pre-Event Food Security	Food Insecured	Count	5	1	0	6
		% within Pre-Event	83.3%	16.7%	0.0%	100.0%
		% within Post-Event	23.8%	2.0%	0.0%	4.8%
	Food Vulnerable	Count	15	28	19	62
		% within Pre-Event	24.2%	45.2%	30.6%	100.0%
		% within Post-Event	71.4%	57.1%	35.2%	50.0%
	Food Secured	Count	1	20	35	56
		% within Pre-Event	1.8%	35.7%	62.5%	100.0%
		% within Post-Event	4.8%	40.8%	64.8%	45.2%
Total		Count	21	49	54	124
		% within Pre-Event	16.9%	39.5%	39.5%	100.0%
		% within Post-Event	100.0%	100.0%	100.0%	100.0%

event food insecured households retained their food insecurity after the event. The results show consistency with previous findings and theoretical expectations, and therefore, the adjusted HFIAS questionnaire is considered appropriate for the study and the results reliable.

4.3 Results of Food Security Recovery Analysis

The outcome selected for this study to measure resilience is households' food security status. For this purpose, food security status data pre-event and post-event were derived from the survey tool designed for this study, as explained in Section 3.4.5. The categories assigned to households based on their food security status are: food insecured, food vulnerable, and food secured. Results show that overall, households tended to recover, but generally with a decreased level of food security than before the earthquake (Figure 4.2). A total of 16.9 percent of households surveyed stayed or became food insecured after the event – a significant increase from only 4.8 percent pre-event. This increase was mainly caused by vulnerable households becoming food insecured. The number of secured households only dropped by 1.7 percent after the earthquake with only one household that reported being food secured before the event that became food insecured after the event. The main difference between the characteristics of this particular household and the majority of other households was the reliability on natural resources, such as forest and water (mainly from rivers) for cattle ranching as an income generation activity. Only 4.8 percent of households reported the use of forest services. Only 15.8 percent of the households interviewed were able to recover better than before– mostly moving from food vulnerable to food secured.

When the data are analyzed at the case level, the patterns of food recovery and food collapse are more informative. Prior to the event according to the data collected, only the most vulnerable community's case based on socio-economic characteristics showed cases of food insecurity in its population, however, after the earthquake all cases with the exception of case B (in the community of Varablanca) showed signs of food insecurity among their population. Case C (in San Rafael) was the only case to show a recovery better than before, however, this is a case with only five surveyed households.

4.4 Regression Results

4.4.1 Absorptive Capacity

The results of the categorical regression analysis for the Absorptive Capacity component of the resilience index are reported in Table 4.3. The R-square value for this capacity is .153, which represents a low explanatory power. However, the Absorptive Capacity component represents ¼ of the index as a whole. Previous studies have recognized the accumulative explanatory power of sub-indexes (referred to as components in this study) (Nardo et al. 2008; Cutter et al. 2010; DRLA 2012; Burton 2012). In addition, in social science research, an R-square value ranging from 0.10 to 0.20 is considered acceptable (Gaur and Gaur 2009).

When all the indicators retained were run through the regression model, a poor association with the dependent variable was obtained. The indicator for community assistance received (INFSN_CM) had a very low beta value in comparison with the rest of the indicators. By removing this indicator, a stronger Fisher (F) value was obtained as well as a higher number of statistically significant indicators. Table 4.3 shows all the variables retained for the component with the statistical significant variables identified.

Out of the 6 variables retained, 3 are statistically significant at the 99% and 95% confidence levels. The identified variables represent the relationships between the household recovery measured by their food security status (dependent variable) and independent variables that are less likely to have occurred by chance. The standardized coefficient or beta value indicates how much change (measured by standard deviation) in the dependent variable is produced by a change in each of the independent variables when others remain constant. In categorical regression, the beta value is interpreted as the difference in the predicted value of the dependent variable for each one-unit difference in each independent variable when others remain constant. The estimated relationship between the dependent variable and each independent variable as represented by their statistical significance and beta values answer research Question 1: "*What set of indicators are most influential in a household's disaster resilience to food insecurity in a rural context?*"

Table 4.3: Absorptive Capacity Regression Results

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	19.237	6	3.206	3.574	.003
Residual	106.763	119	.897		
Total	126.000	125			

Table 4.3: Continued

	Standardized Coefficients				
	Beta	Bootstrap (1000) Estimate of Std. Error	df	F	Sig.
INFEX_B	.153	.092	1	2.789	.098
INFEX_R	.169	.091	1	3.442	.066
INFSN1_F	.468	.133	1	12.433	.001***
INFSN2_FR	.306	.132	1	5.384	.022*
INFSN5_NGO	.240	.152	1	2.503	.116
SUMISN_R	-.578	.299	1	3.733	.056*

Dependent Variable: SPSTFS_CAT2
R-square = 0.153; Variables Significant at 5% (0.05)*, 1% (0.01)** and 0.1% (0.001)***

Inbuilt in the above research question is the need to assess the most influential informal safety nets usually encountered during a disaster recovery trajectory by rural households, as it pertains to this component. This will allow governments, NGOs, and humanitarian organizations to engage in policy driven changes that invest in the most successful recovery practices guided by measurable outcomes. The results of the model suggest that family assistance (INFSN1_F) exerts the greatest influence in the ability of households to absorb the impact of the earthquake. Some of the most cited assistance received by family members was shelter and money. In order of importance, the next significant variable is the safety nets provided by friends, which included food, clothes, and in some instances money.

The third statistically significant indicator is the SUMISN_R, which represents the total number of informal assistance received after the earthquake. Of interest is the negative beta value obtained by this indicator and the dependent variable. As the number of informal safety nets used went down the recovery went up. This seems to indicate that there is greater influence by the type of safety nets available and used than the number of them. Overall, the Absorption Capacity component appears to indicate a pattern of importance of close support networks such as family and friends. Caution should be taken interpreting these results when considering the potential effect of respondent recall bias–respondents may forget or misremember crucial information. Field observations and accounts of local guides seem to reflect the importance of a very specific service provided by one NGO that had a long term positive effect in the recovery process of the affected communities, however, this indicator was not statistically significant.

TECHO, also known as *Un Techo para mi País* (UTPMP) (A Roof For My Country), is a nonprofit organization that mobilizes youth volunteers to fight extreme poverty in Latin America by constructing transitional housing and implementing social inclusion programs. TECHO also provides transitional housing in poor areas that are affected by natural hazards, which was the case in Costa Rica. Transitional housing was observed mainly in the community of Varablanca, which was affected by several landslides. Illustration 4.1 shows pictures of the transitional housing provided in 2009 right after the earthquake. These transitional houses are still inhabited by residents waiting for their houses as part of the housing project being built by government agencies on the same locality of Varablanca. These “temporary” houses provided immediate

Illustration 4.1: Temporary Housing in Varablanca.

Photo by Laura Cano Amaya

Illustration 4.2: New Residential Project in Varablanca.

Photo by Laura Cano Amaya

shelter without the need to relocate. This allowed residents to stay close to their productive assets, minimizing income generating activities disruption.

There are two possible explanations for the lack of statistical significance of this type of assistance received. First, the construction of the temporary housing requires local volunteers, and therefore, this assistance might be associated with friends and family that helped built these houses. Second, several of the participants living in the temporary houses were not the original recipients of this assistance. When interviewing people in the temporary houses, some of them indicated that they were renting the houses from their previous owners.

4.4.2 Adaptive Capacity

The results of the categorical regression analysis for the Adaptive Capacity component of the resilience index are reported in Table 4.4 showing all the variables retained for the component with the statistical significant variables identified. The R-square value for this capacity is .242. Out of the 10 variables included in the regression model, four were found statistically significant: education level of the head of the household (EDU), sum of agricultural assets (SUMAG), cattle assets (AGASST_C), and perception of equal access to formal assistance (EQUACC). As stated in Section 3.5.1, works of entitlements and food security considers adaptation as a stress response in light of access to resources, whereas the natural hazards discipline focuses on perceptions and adjustments to hazards. Both of these views were represented by the variables retained in this component. Where the agricultural and non-agricultural assets represented the food security perspective on adaptive capacity, the education and livelihood diversity represented the hazards perspective of adjustment in response to a natural hazard.

Table 4.4: Adaptive Capacity Regression Results

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	30.440	12	2.537	3.000	.001
Residual	95.560	113	.846		
Total	126.000	125			

	Standardized Coefficients		df	F	Sig.
	Beta	Bootstrap (1000) Estimate of Std. Error			
EDU	.206	.091	3	5.160	.002**
EQACCS	.387	.089	1	18.860	.000***
SUMLIVD_R	-.011	.109	1	.010	.921
AGASST_L	.199	.166	1	1.438	.233
AGASST_M	.182	.113	1	2.584	.111
AGASST_C	.230	.110	1	4.397	.038*
SUMAG_R	.548	.253	1	4.708	.032*
NAGAST_H	.206	.153	1	1.816	.181
NAGAST_MV	.381	.241	1	2.500	.117
SUMNonAG_R	-.380	.340	1	1.254	.265

Dependent Variable: SPSTFS_CAT2

R-square = 0.242; Variables Significant at 5% (0.05)*, 1% (0.01)** and 0.1% (0.001)***

The education level of the head of household indicator (EDU) is statistically significant at the 99.9% confidence level, the same as the sum of agricultural assets variable (SUMAG). However, the beta value of the two variables is significantly different with .206 and .548 respectively. The variable with the largest impact on the dependent variable is the one with the largest beta value. These results indicate that agricultural assets in this component have the largest impact on the dependent variable or the recovery level of the households by far. Of the agricultural assets present in the area, the results on the regression model show cattle as statistically significant although the beta value was very similar to the other two agricultural assets included in the study, namely land (AGASST_L) and agricultural machinery (AGASST_M). The perception of equal access to formal assistance is the fourth variable with a statistical significant result. This variable has a negative beta value which indicates an inverse relationship with the dependent variable. In other words, if people perceive that their access to future government formal assistance is questionable or they are afraid that they might not receive it, their recovery level tends to drop. This indicator will have to be recoded when aggregating the components' sub-indexes so that all components of the resilience index measures follow the same interpretation; a higher value reflects a higher recovery level.

4.4.3 Transformative Capacity

The results of the categorical regression analysis for the Transformative Capacity component of the resilience index are reported in Table 4.5. The R-square value for this capacity is .225; this result is shows very similar explanatory power with the Adaptive Capacity solution. Table 4.5 shows all the variables retained for the component with the statistically significant variables identified. In the rural context, informal social safety nets in Latin America have shown to be deficient when shocks are extreme, as in the case of the Cinchona earthquake (Heemskerk, Norton, de Dehn 2004). Public or government assistance (formal safety nets) is believed to be capable of strengthening transformative capacities in these communities, although, the evidence is not concrete (Heemskerk, Norton, de Dehn 2004).

Table 4.5: Transformative Capacity Regression Results

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	28.388	9	3.154	3.748	.000
Residual	97.612	116	.841		
Total	126.000	125			

	Standardized Coefficients		df	F	Sig.
	Beta	Bootstrap (1000) Estimate of Std. Error			
FSNIMAS	.178	.090	1	3.921	.050*
FSNHEALCA	.141	.085	1	2.777	.098
FSNINEC	.087	.071	1	1.518	.220
LIVDIV_SAL	.174	.090	1	3.787	.054*
LIVDIV_AGIND	.084	.073	1	1.292	.258
LIVDIV_AGDEP	.041	.073	1	.321	.572
LIVDIV_NONAGIND	.105	.078	1	1.822	.180
LIVDIV_TOUR	.297	.091	1	10.574	.002**
LIVDIV_OTHER	.211	.088	1	5.802	.018**

Dependent Variable: SPSTFS_CAT2
R-square = 0.225; Variables Significant at 5% (0.05)*, and 1% (0.01)**

The recovery phase in the impacted area of the Cinchona earthquake is still ongoing. Several governmental institutions at different jurisdictional levels have been engaged in recovery programming in the area of study. As in the case of the Absorptive

Capacity component, built into research Question 1 is the need to assess the most influential formal safety nets usually encountered during a disaster recovery trajectory by rural households. The Costa Rican case is especially important in assessing the importance of transformative capacity as impacted by formal safety nets because, in contrast with most other Central American countries, it has the most developed and comprehensive emergency response model in the region. As a result, the assessment of the different types of formal safety nets used as part of the recovery process in the Cinchona earthquake can inform other governments in the region on which safety net programs or government interventions largely contribute in creating disaster resilient communities. Limited resources can be utilized towards proven, successful formal safety nets or social programming that can contribute to resiliency in communities exposed to earthquakes.

Initially results of the regression model showed only one type of formal safety net (FSNIMAS) that was statistically significant, and therefore, it is less likely that it occurred by chance. Twelve indicators were retained for this component in the indicator refinement process in Section 3.6.3, which represent human agency or capability of actors to secure a desirable outcome through new trajectories or transformations. However, the indicators FSNRETFU, FSNOTHER, and SUMFSN_R were excluded because of their very low beta value. By removing these indicators a better model fit was obtained. The resulting statistically significant indicators reflect the importance of the social services received through IMAS (the federal social services office) and the households' livelihood strategies (type of income generating activity) on people's recovery. The survey participants often associated IMAS with long-term assistance such as rent money for displaced families, food subsidies, and education scholarships. Other formal assistance such as health care (FSNHEALCA), access to retirement funds (FSNRETFU), and emergency and reconstruction assistance, usually provided by CNE (FSNCNE), were not statistically significant. These results should be interpreted with caution since response bias is possible. During the unstructured interviews with CNE, staff remarks were made about peoples' lack of accuracy to identify or remember the institutions that were providing the assistance. This was especially the case in the immediate aftermath of the event. Nonetheless, the results obtained are deemed reliable since, to obtain IMAS assistance, recipients had to engage closely with this office and the office provided more long term recovery assistance in comparison with short term assistance received through other agencies.

The livelihood strategy's statistically significant indicators (LIVDIV_SAL, LIVDIV_TOUR and LIVDIV_OTHER) reflect an expected outcome based on theoretical basis and field work observations. The great majority of people engaged in salaried work in the communities selected work for one of two companies, El Angel or Dos Pinos. Both of these companies are food processing companies. These companies provided significant assistance to their employees during and after the disaster. Employees of both companies continued to receive salary payments regardless of production disruption caused by infrastructure damage. El Angel offered their employees to continue operations in the area as long as their employees would help rebuild the warehouse. The company was relocated close to Nueva Cinchona (formally Cinchona and declared uninhabitable). This was crucial to the recovery of this community. With the relocation, the residents of Nueva Cinchona lost their connection with their productive assets. No longer could they grow their food for consumption or production. In addition, in the new residential area no farm animals and livestock could be housed. Given this situation, El Angel became the only alternative for most of the people of Nueva Cinchona. It is estimated by a local resident that more than 80 percent of the working residents in Nueva Cinchona work in El Angel.

The livelihood strategy of tourism (LIVDIV_TOUR) also had a strong association with households' food security status, as depicted by its beta value and statistical significance. Although tourism dramatically dropped in the area the first few years after the earthquake, because of road conditions and tourism's safety concerns, by the time the survey was conducted people felt that in the preceding year tourism had partially recovered to the levels prior to the earthquake. The "other" livelihood strategy category reflects mainly households with retirement pensions. This case is harder to interpret; however, elderly respondents were more likely to be concerned with health care access than having enough food to eat. For this population of participants, religion plays an important factor in their response bias since they "didn't wanted to complain" about their food insecurity because they were afraid that "God might punish them."

4.4.4 Natural Capital

The results of the categorical regression analysis for the Natural Capital component of the resilience index are reported in Table 4.6, showing all the indicators retained for the component with the identification of two statistically significant indicators. This component has the lowest explanatory power of all the components with an R-square value for this capacity of .048. By calibrating several regression models, and excluding the NATRES2_W indicator, a better fit model was achieved. Nonetheless, as stated before, it is considered to account only for ¼ of the resilience index and deemed acceptable for the purposes of the study. Households whose labor activities were reported *not* to have been impacted by debris and sediment showed a positive relationship with their recovery level. It is considered that since most households experience landslide impact, the lack of higher variability of this indicator among households resulted in the low beta value reported. In the case of the natural resources used indicators, the explanation might be the same.

Table 4.6: Natural Capital Regression Results

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.985	5	1.197	1.197	.315
Residual	120.015	120	1.000		
Total	126.000	125			

	Standardized Coefficients		df	F	Sig.
	Beta	Bootstrap (1000) Estimate of Std. Error			
ECOEX_S2	.579	.227	1	6.521	.012**
ECOEX_D2	.582	.191	1	9.242	.003**
ECOEX_L2	.003	.090	1	.001	.976
NATRES1_F	.175	.116	1	2.272	.134
SUMNAT_R	.207	.164	1	1.604	.208

Dependent Variable: SPSTFS_CAT2

R-square = 0.048; Variables Significant at 5% (0.05)*, and 1% (0.01)**

4.5 Summary

This chapter utilized primary data from the resilience questionnaire as an objective measure of disaster recovery. Categorical regression models were calibrated to select statistically significant variables for each component of the resilience index using food security status as the dependent variable (also referred to as response variable). Out of the 30 indicators retained in Chapter 3 for the categorical regression analyses to be tested against the Post-Event Food Security status (dependent variable), 13 were statistically significant or 43 percent.

From an absorptive capacity perspective, friends, community, and NGOs provided services that contributed to the households' recovery. The pattern of assistance denoted through this component of the resilience index was that of post-event temporary shelter. From the adaptive capacity perspective, the educational level of the head of household and the sum of agricultural assets, particularly cattle, contributed significantly to the households' recovery. The perception of future access to formal assistance by survey participants also influenced the recovery outcome of the households. With respect to the transformative capacity perspective, only the formal social safety nets provided through IMAS were statistically significant. Interesting is the fact that this is one of the few institutions that provided long term direct assistance to affected households that qualified. The regression results for the Natural Capital component resulted in only two statistically significant indicators which indicate the influence of physical impact on household recovery.

Table 4.7: Final Indicator Selection for the Resilience Index

Indicators	Description
ABSORPTIVE CAPACITY	
INFSN1_F	Informal Safety Net Family
INFSN2_FR	Informal Safety Net Friends
SUMISN_R	Total number of informal safety nets used
ADAPTIVE CAPACITY	
EDU	Head of household schooling level
EQACCES	Perception on equal access to formal safety nets
AGASST_C	Cattle used for consumption or income generating
SUMAG_R	Total number of agricultural assets used for consumption or income generating
TRANSFORMATIVE CAPACITY	
FSNIMAS	Formal Safety Net IMAS
LIVDIV_SAL	Livelihood strategy salaried
LIVDIV_TOUR	Livelihood strategy tourism
LIVDIV_OTHER	Livelihood strategy other
NATURAL CAPITAL	
ECOEX_S2	Ecosystem exposure sediment
ECOEX_D2	Ecosystem exposure debris

V. THE RESILIENCE INDEX AND THE FOOD SECURITY RECOVERY OF RURAL COSTA RICA

5.1 Overview and Methodology

In the previous chapter, the identification of indicators for measuring resilience to food insecurity (in the case of an earthquake in a rural context) went through both qualitative and quantitative methodologies that resulted in 13 statistically significant indicators. This chapter utilizes the identified indicators to develop a resilience index for the selected context of this study. To this end, individual indicators were aggregated at the component level – Absorptive Capacity, Adaptive Capacity, Transformative Capacity and Natural Capital.

To address research Question 2–*"To what extent can these indicators predict a food security recovery outcome?"*–each aggregated component score was input into a series of multiple linear regression analyses for comparison among the selected cases' food security recovery outcomes. As a subsequent step, the calibration of the regression models was extended to include the gender of the household head, the EII score, minority status, and community capital. These indicators were chosen because they are associated with community recovery processes after a disaster, and their integration to the linear regression analysis allows for a more comprehensive understanding of the resilience index influence on community recovery as measured by the household's food security outcome.

5.2 The Resilience Index

Critical steps to the development of an index are the selection of variables or indicators based on their relevance to the phenomenon they are to measure, to normalization or to scale adjustments if necessary, and the selection of appropriate aggregation procedures (Nardo et al 2008). Of the indicators selected, the variables SUMISN_R and SUMAG_R were normalized using the Mix-Max rescaling scheme to synchronize these variables on a similar measurement scale. Mix-Max rescaling is a method in which each variable is decomposed into an identical range between zero and one (a score of 0 being the worst rank for a specific indicator and a score of 1 being the best) and all values are scaled in between the minimum and maximum values (Nardo et al. 2008; Cutter et al. 2010). This scaling procedure subtracted the minimum value and divided by the range of the indicator values. For the variable EQACCS, in which high values corresponded to low levels of resilience, the order of their contribution to the overall resilience index was changed by reversing the coding of the observation so that 0 reflected low resilience and 1 reflected high resilience. This transformation was recorded into a new indicator with label EQACCS_R. All other indicators had a binary coding of 0 and 1, where 0 reflected low resilience and 1 high resilience. The household resilience index score (INDEX_S_R) used an equally weighted average aggregation method deemed the most appropriate for this exploratory study because no assumptions are made on the importance of each component. In this method, the indicator scores in each component were averaged to reduce the influence of the different number of indicators in each component (See Formula 3). Cutter et al. (2010) advocate for this method in their study of community resilience by stating that this simple method of aggregation is transparent, easy to understand, and a criteria considered important for potential users. Furthermore, the authors found no theoretical or practical justification for the differential allocation of importance across indicators.

$$\text{INDEX\_S\_R} = (\text{ABS\_CAP} / 3) + (\text{ADAP\_CAP} / 4) + (\text{TRANS\_CAP} / 4) + (\text{NAT\_CAP} / 2) \quad (3)$$

To be able to map and compare case resilience, the household resilience index scores (INDEX_S_R), and the post-event food security scores (SPTSFS) were aggregated at the case level and averaged. When comparing the results of the aggregation with and without outliers in the data, there was a clear indication that outliers were influencing the results, therefore, they were excluded. The scores are mapped as standard deviations from the mean. The color scheme runs from green denoting more resilient to red denoting less resilient (Figure 5.1).

When mapping the case resilience scores, the results show a clear spatial variation (Figure 5.1). Cases A, B, and C show the lowest resilience levels. Case A (located in Nueva Cinchona) is a new residential community that was built to resettle the residents of Cinchona when it was declared uninhabitable after the 2009 earthquake. Landslides in this community destroyed most houses and buildings in the community and caused most of the human losses from the earthquake. Cinchona was a typical rural community in Central America where people’s productive assets, such as land and livestock are in close

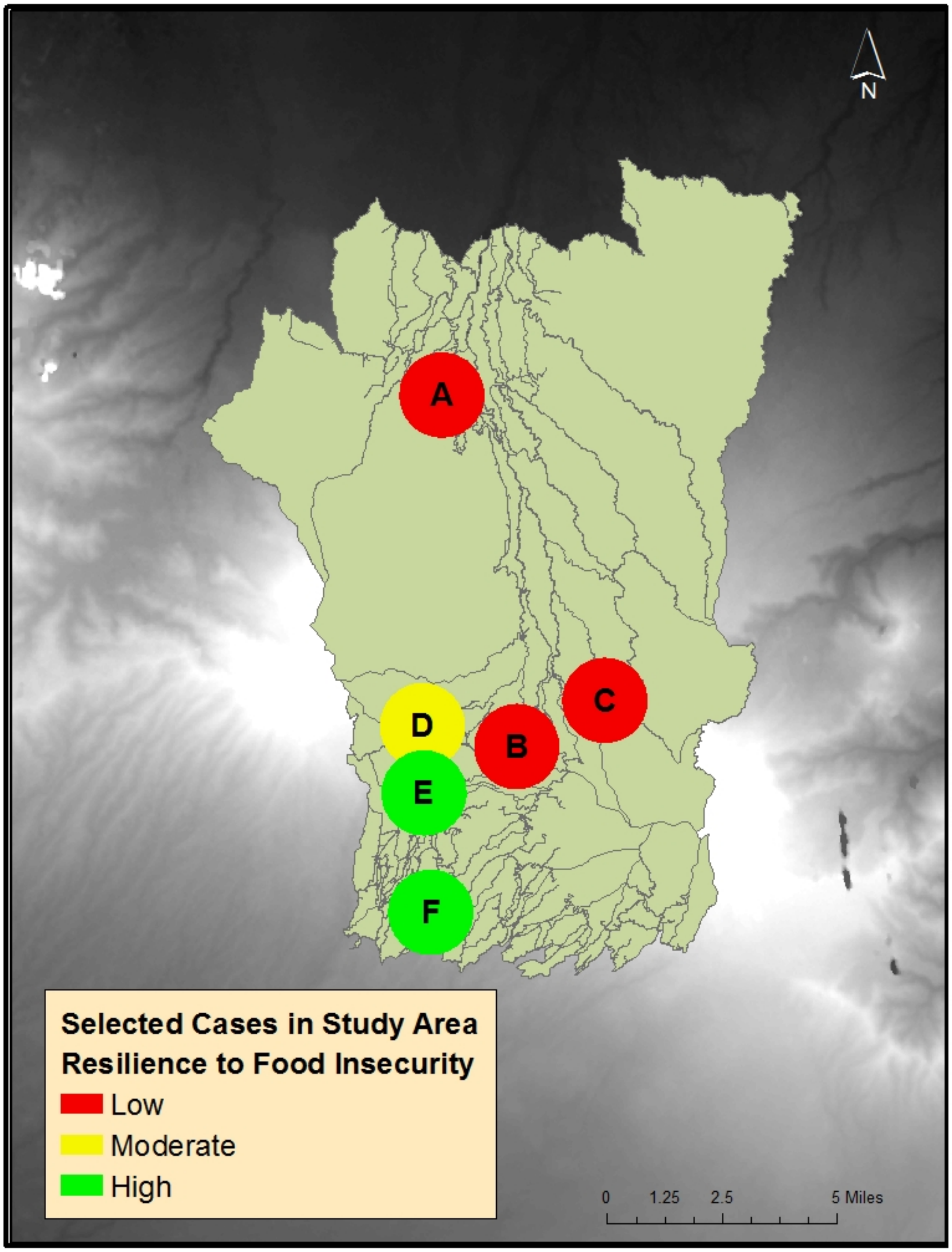
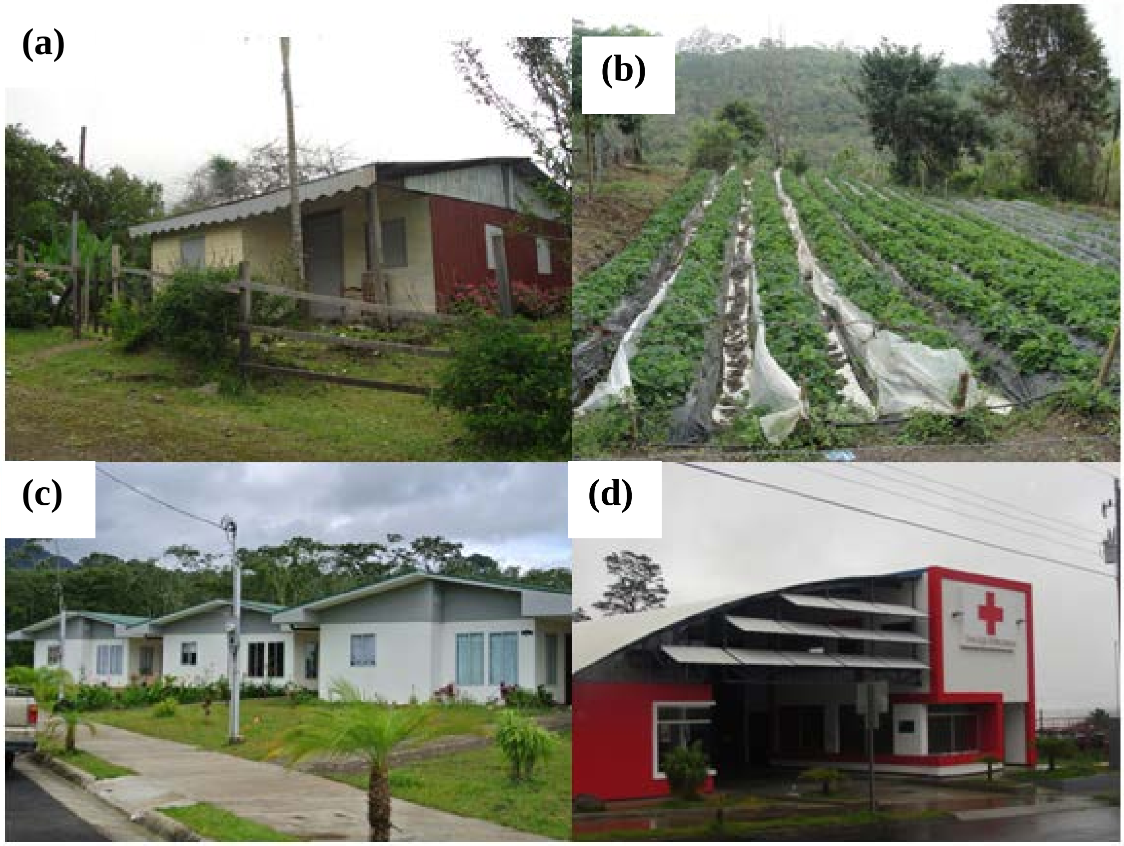


Figure 5.1: Mapped Resilience of Selected Cases

proximity to the household (Illustration 5.1). The change from this setting to what could be considered a suburban residential complex with amenities and restrictions on productive activities in Nueva Cinchona necessitated a drastic change in the lives of its residents. One resident surveyed stated, *"Salimos de campo a ciudad. No se tiene donde sembrar. Fue un cambio de la noche a la mañana"* ("We went from the country side to the city. There is no place to grow our crops. This was an overnight change"). Now, most people are employed in El Angel (food processing and packing company) and some of them are starting to go back to Cinchona to try to reactivate their agricultural activities.

In the case of the Varablanca (where Case B is located) and San Rafael (where Case C is located) communities, they didn't have to be relocated, although they also incurred extensive ecological and infrastructural damage. These two communities were the closest to the epicenter of the earthquake on the Varablanca fault. Few deaths were also reported in these communities. Two of the primary economic activities in the area are the production of strawberries and cattle ranching for milk production which were reported as the most affected by the Cinchona earthquake (Barquero 2009; Quiróz 2009). In Varablanca and San Rafael, strawberry production is characterized by small farmer cooperatives where two or more families work together on a small plot. Landslides in the area destroyed most of the strawberry production and left the local people without employment since most of them worked as laborers in strawberry production (Quiróz 2009). Not only was the production for the year lost, the irrigation systems and high tunnels were destroyed. This meant significant economic losses for these small growers.

Illustration 5.1: Cinchona and Nueva Cinchona after the Earthquake.



Photos taken by Laura Cano Amaya in August 2013: (a) Cinchona house being rebuilt; (b) strawberry production right next to photo a; (c) Nueva Cinchona houses; (d) Red Cross emergency response center.

Cases D (located in Poasito) and E (located in Fraijanes) share a similar community profile. Both rely heavily on tourism, they also engage in strawberry and ornamental flower production and cattle ranching for milk production. These communities suffered some infrastructural damage – mostly destroyed or damage houses – although, not to the extent of Varablanca and Cinchona. Fewer landslides were present in these communities, which minimized the impact on agricultural production, however, road damage severely impacted the tourism industry. According to a representative of the regional chamber of commerce, after three and one-half years, tourists couldn't get to these communities because of the damaged roads. The interviewee further indicated that many small businesses had to close and people left because no bank loans were approved to keep their businesses operating. It wasn't until 2013, almost five years later, that tourism had recovered–almost to pre-earthquake levels, as stated by interviewee. This might be the primary reason for the resilience level shown by these two communities.

Case F, located in the community of Dulce Nombre, is an interesting one. This was perhaps the most vulnerable population pre-event based on socio-economic characteristics. In Dulce Nombre, the area most affected was visited to conduct the surveys; these households were part of an unofficial settlement referred to as "*precario*" (Illustration 5.2). Elderly, immigrants and low income families constituted these households. The primary economic activity in Dulce Nombre is the cultivation of ornamental plants. This activity decreased after the earthquake because companies started leaving the area after the event, and plant disease. Coffee production and salaried work are also important economic activities in which people work for large companies and do not own land. People tend to commute to nearby cities for employment and the earthquake mainly impacted their ability to travel to work.

Survey participants living in the *precario* stated that they were asked to leave their houses because of the likelihood of future landslides. However, people decided to stay until the time that the housing project that had been promised to them by the government was completed, citing fear that their belongings would be stolen. Observations support the data analysis, which indicate that Case F's high resilience level that allowed them to recover resulted from the low physical impact level these households suffered and the low impact the event had on their economic activities. For a more holistic view of the results, the resilience scores at the component level were analyzed to further understand the multidimensionality of the dynamics of disaster resilience.

Illustration 5.2: Informal Settlement (*precario*) in Dulce Nombre

Photo by: Laura Cano Amaya

Absorptive capacity, as stated in section 3.5.1, is seen as a threshold that, if surpassed, affects the recovery process resulting in a lower level of resilience (Cutter et al. 2008). In this study, this concept (or latent variable) was measured by the availability and usage of informal assistance that absorbed the effects of the earthquake. When mapping the absorptive capacity of the communities, again, there is a clear spatial distribution as shown in Figure 5.2(a) and 5.2(b). Data obtained through field observations and interviews can inform the interpretation of these results. The communities of Cinchona and Varablanca were the most affected communities in the study area based on landslide damage and human loss. Therefore, most people from these communities needed assistance and could not provide assistance to others. Furthermore, families in rural areas tend to live in close proximity to other family members. Consequently, extended families were impacted as well. Without the ability to absorb the shock impact through family and friends, these two communities' absorptive capacity was compromised.

In the case of the adaptive capacity resilience levels, the perception of equal access to formal safety nets in the form of social programs (EQACCS_R), qualitatively, represented a significant driver. Survey respondents expressed their frustration and concern about the apparent lack of assistance received in their community after the earthquake. One respondent stated that "They [government agencies] said that if we didn't leave our houses we couldn't receive assistance. We didn't have a place to go and we were afraid someone might steal our stuff". Of the 22 survey respondents in Case F, only one answered "No" to the question: *"Do you worry about not having access to assistance through social programs?"* Further qualifying that: "*para que me preocupo si no se puede cambiar la situation*" ("there is no reason to worry about it if I cannot change the situation"). In contrast, in Case A, 47 percent of the respondents were not concerned about future access to programs. The main reason for these results appears to be the overwhelming assistance that the community received after the earthquake. Cinchona

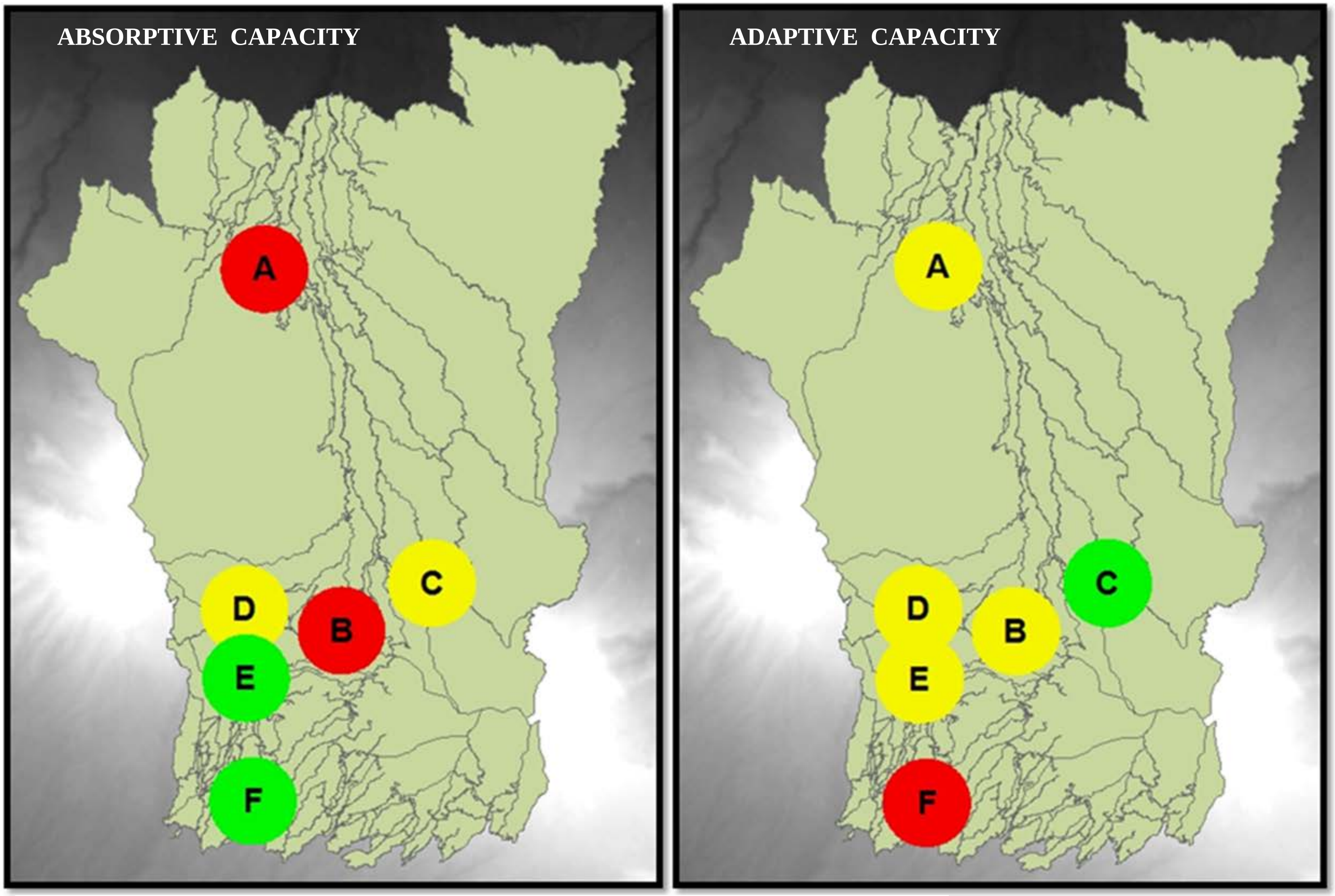


Figure 5.2(a): Decomposing Community Resilience by Index Component

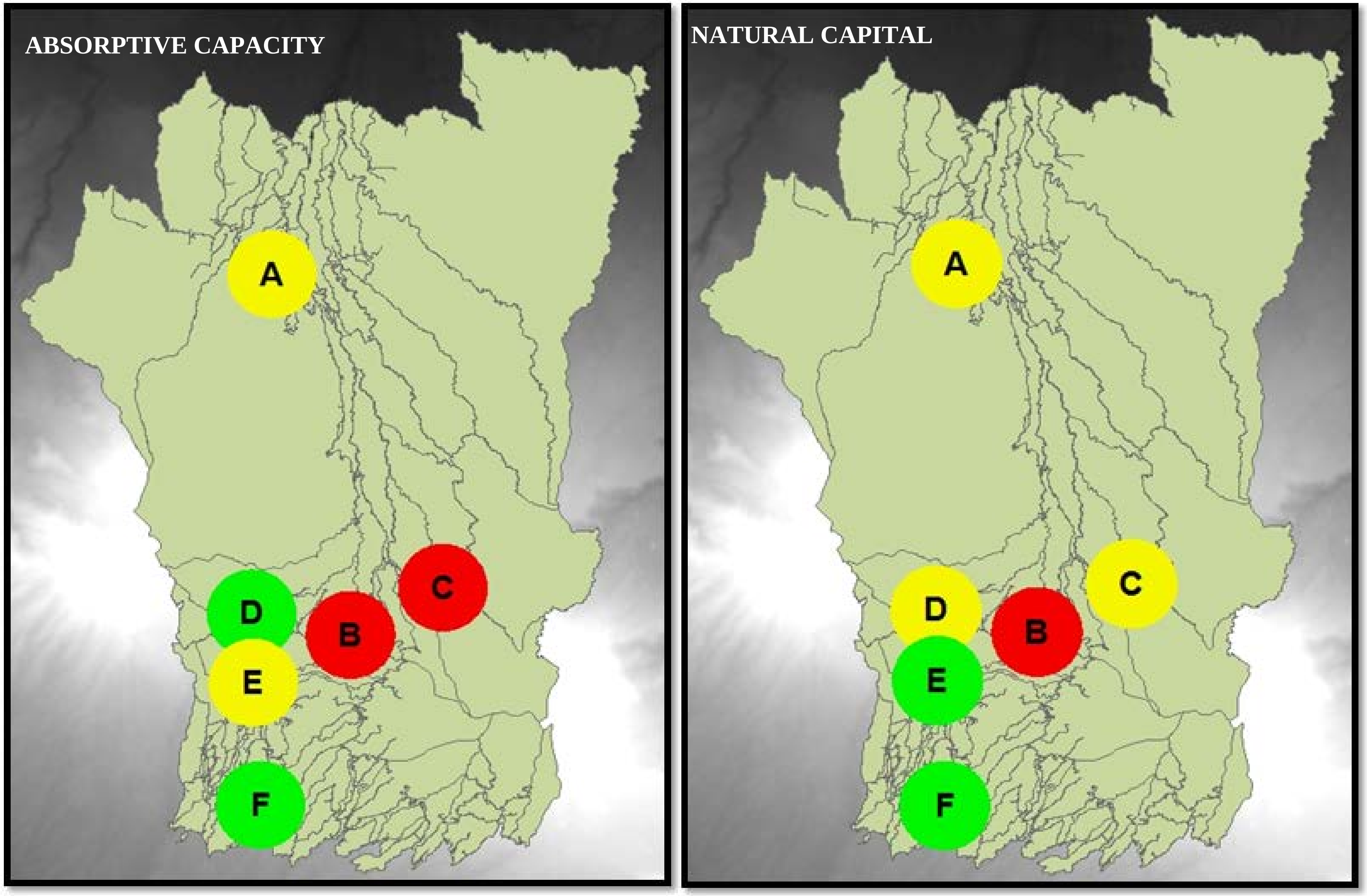


Figure 5.2(b): Decomposing Community Resilience by Index Component

became the "poster child" for the recovery from the Cinchona earthquake. The residents of Varablanca resented the media and government attention given to Cinchona with a respondent commenting, "All the help went to Nueva Cinchona but we were also greatly affected. I have been living in this temporary house for almost five years and they [government] have not finished the houses they promised to us." In this community, 75 percent of respondents expressed concern about their future access to needed assistance. Cases B and C had moderate to high adaptive capacity resilience levels primarily driven by their cumulative agricultural assets–namely land and cattle. As stated before, the two main economic activities for these communities are strawberry production and milk producing cattle ranching.

The transformative capacity clearly represents the livelihood strategies prevalent in the communities. The cases with high to moderate levels of transformative capacity are characterized by salaried and tourism industry employment which includes small business ownership (cases in Nueva Cinchona, Poasito, Fraijanes and Dulce Nombre). Cases B and C, because of their agribusiness characteristics, reflect a low transformative capacity level. The Natural Capital component shows Case B with the highest ecosystem impact, which yields lower resilience scores; and Case F with the lowest ecosystem impact, which yields higher resilience scores. This is consistent with the EII results and the overall resilience index levels.

5.3 Role of the Resilience Index in Estimating Food Security Recovery

The findings presented in this chapter illustrate that the geographic variation of impact and resilience to food insecurity are not random. The spatial variations have resulted from the interactions of location, dynamics of food security, sense of community, livelihood strategies and social characteristics of households in the different communities. Estimating the role of the resilience index and its components would increase our understanding of its contribution to the food security recovery of the area of study. To this end, a series of ordinal logistic regression models where the dependent variable was the food security outcomes obtained, and the independent variables the components of the resilience index scores, EII, community and household characteristics known to influence food security. The objective is to learn how the dependent variable relates to the independent variables at the household level. The household characteristics considered for inclusion were minority household (native and immigrants or indigenous), and gender of household head. Minority household caused instability in the solution because of the low variability of the data and it was excluded from the model. The ordinal logistic regression model handles multinomial dependent variables where the classes are ranked (i.e. food insecured, food vulnerable, food secured). This type of model doesn't assume normality of data or linear relationship between the dependent and independent variables. The following regression model was built:

$$y_1 = x_\alpha + x_1\ ABS\_CAP + x_2\ ADAP\_CAP + x_3\ TRANS\_CAP + x_4\ NAT\_CAP + x_5\ EII + x_6\ COMM + x_7\ HOHE + \epsilon \qquad (4)$$

Where y is the dependent variable represented by the household's post-event food security status. ABS_CAP, ADAPT_CAP, TRANS_CAP and NAT_CAP represent the resilience component for each household. The EII aggregated at the community level representing household exposure. COMM and HOHE are the household characteristics representing community type and gender of household head, respectively.

All parameters achieved statistical significance in the regression model ranging from .10 to .000 with the exception of NAT_CAP. The explanatory power is considered high with a pseudo-R square of .391 (Nagelkerke) and the model fit statistically significant. The results obtained suggest that the most influential predictor is the level of impact incurred (Wald 10.164) and adaptive capacity (Wald 11.695) (Table 5.1). When modifying the regression model to substitute the individual components by the total resilience index score, the results show the parameter as statistically significant although with weaker predicting influence (Wald 3.722) (Table 5.2).

Table 5.1: Regression Results for Estimating Food Recovery (Individual Components)

		Wald	**Sig.**
Threshold	[SPSTFS_CAT2 = 1]	19.501	.000
	[SPSTFS_CAT2 = 2]	7.658	.006
Location	EII	10.164	.001**
	ABS_CAP	6.458	.011*
	ADAP_CAP	11.695	.001
	NAT_CAP	.288	.591
	TRANS_CAP	5.805	.016
	[HOHE=1]	.170	.680
	[HOHE=2]	.219	.640
	[HOHE=3]	.	.
	[COMM=1]	9.995	.002
	[COMM=2]	4.167	.041
	[COMM=3]	1.888	.169
	[COMM=4]	2.901	.089
	[COMM=5]	.	.
	[COMM=6]	.	.

Pseudo-R Square: .391 (Nagelkerke); Variables/Indicators Significant at 5% (0.05)* and 1% (0.01)**

Table 2.2: Regression Results for Estimating Food Recovery (Resilience Index)

		Wald	**Sig.**
Threshold	[SPSTFS_CAT2 = 1]	22.257	.000
	[SPSTFS_CAT2 = 2]	8.302	.004
Location	EII	18.671	.000***
	INDEX_S_R	3.722	.054*
	[HOHE=1]	.105	.746
	[HOHE=2]	.653	.419
	[HOHE=3]	.	.
	[COMM=1]	22.172	.000***
	[COMM=2]	3.929	.047*
	[COMM=3]	5.285	.022*
	[COMM=4]	6.393	.011**
	[COMM=5]	.	.
	[COMM=6]	.	.

Pseudo-R Square: .270 (Nagelkerke); Variables/Indicators Significant at 5% (0.05)*, 1% (0.01)** and 0.1% (0.001)***

5.4 Summary

This chapter dealt with the construction of the resilience index by aggregating the components' scores of the four capacities. When mapped, these scores clearly showed a spatial pattern for the recovery process. Overall, the Cinchona earthquake appears to have surpassed the absorptive capacity of Cases A, B, and C which were the communities that incurred the highest physical impact (ecological and infrastructural) of the selected communities for this study. To understand better the influence of the resilience index in measuring resilience to food insecurity, ordinal logistic regression models were calibrated. The results of the regression model reflect biophysical and social aspects contributing to the impact and recovery of the cases in the selected communities from the

Cinchona earthquake. These results advance the argument made in this study that the natural-human coupled system approach provides a more holistic view of the drivers of resilience to food insecurity and their incorporation in future methodological frameworks need further exploration. Figure 5.3 summarizes the quantitative methods for both the development of the resilience index and the assessment of its resilience to food insecurity predictive power.

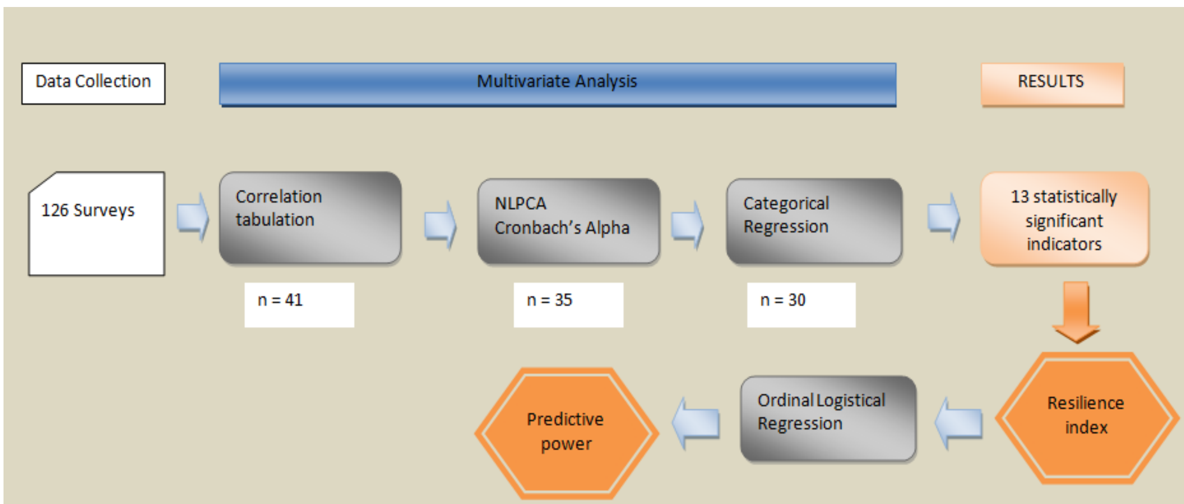


Figure 5.3: Quantitative Methods Summary

VI. SUMMARY AND CONCLUSIONS

6.1 Overview

Natural hazards continue to pose a significant threat to livelihoods and local economies, affecting disproportionally those most vulnerable. The international community's realization that technological fixes for disaster mitigation are insufficient because of natural disasters' unpredictable nature, coupled with the continued settlement of hazardous places, has lead to the new science of disaster resilience. A paradigm shift has occurred in disaster risk management (DRM). The new paradigm places greater emphasis in understanding what makes communities resilient to disasters. In the food security discipline, this conversation further explores the characteristics of households resilient to food insecurity. In addition, the food security and the community development disciplines focus on assessing the effectiveness of programming assistance in supporting households and communities recover or transform to a food secured status in their recovery process after a natural disaster. Many conceptual models have been proposed based on theoretical assumptions for resilience to food insecurity, but lack evidence on their validity. This study seeks to address the need for the development of resilience to food insecurity metrics based on empirical data. With this end in mind, this study was concerned with the identification of indicators that would increase our understanding of the influential factors in creating resiliency to earthquakes in rural settings. By furthering our understanding on resilience, governments and organizations can target limited resources to proven strategies in creating resilient communities.

6.2 Summary of Research Findings

The Cinchona earthquake affected many communities in Costa Rica, but the greatest effect was felt in the rural area around the Poás volcano. According to scientists and residents of these communities, this event took everyone by surprise. There had not been seismic activity in this area in recent history, and the inhabitants did not count with the knowledge and preparation to respond to this type of event. Almost five years after the earthquake, the study area was still in reconstruction mode; segments of main roads in the area were still under reconstruction, landslides caused by the event were still very visible, and livelihoods affected showed different levels of recovery or collapse trajectory. The study of earthquake resilience to food insecurity metrics of rural Central America is important given this region's high seismic activity, and its vulnerability as a result of exposure to multiple natural hazards and high poverty levels.

Resilience to food insecurity as a science is a recent research development in the food security and community development disciplines. As such, incremental advances in its understanding through empirical evidence will offer more insights into the multidimensional and dynamic nature or resilience. More importantly it will provide metrics that are easily understood and applicable to the decision making process (Cutter et al. 2010). There are many challenges in creating resilience metrics for developing countries since secondary data is not usually as readily available as in developed countries, where most attempts to measure resilience have taken place. The time and resources it takes to collect primary data to conduct this type of analysis can sometimes be prohibitive for the interested parties or the skills needed might be absent. In the cases where the data is obtained, other difficulties have to be addressed. Real-world data, as the data utilized in this dissertation, can be difficult to fit into mathematical models with strict data structures assumptions. This complicates the standardization of methodologies that could facilitate comparative analysis among studies. Notwithstanding the challenges, the potential policy implications of incremental advances in this scientific research agenda and its potential positive effects in disaster risk reduction makes this a worthy endeavor.

The resilience index developed for this study has provided insight into important aspects of resilience. As the previous chapter reflects, when looking at resilience, it is important to deconstruct the concept into its building blocks to better understand its multidimensional and dynamic nature. The study, overall, reaffirms Alinovi et al.'s (2010) findings that salaried workers are more resilient than other livelihoods such as small farmers. However, Case F in Dulce Nombre, which is a community primarily of salaried workers and the one showing the highest resilience score, is also the most food insecured community in this study. Pre-event or antecedent conditions of households are important in the recovery process. These results reject the vulnerability and resilience proposed link that sees resilience as the opposite of vulnerability. Proponents of this relationship between vulnerability and resilience contend that high vulnerability results in less resilience and low vulnerability results in high resilience. It is important to acknowledge the complementary nature of vulnerability and resilience assessments and their policy implications in DRR.

When the resilience is decomposed into its individual capacities, more is learned. There is a need to better understand the drivers of transformative capacity in disaster resilience. Although data seem to indicate that the transformative capacity of Case F was higher than the other cases, most households didn't show signs of a transformative trajectory of recovery. In other words, most households were worse than before (i.e. their food access decreased) and there was no indication of change to a more desirable state. One important aspect present in the qualitative data for community transformation that was not captured by the quantitative data is the sense of community (what Paton and Johnston (2001) describe as a feeling of belonging and attachment to people and places) and community organization. Case A obtained one of the lowest resilience scores of the study, however, people recovered after losing all their possessions (e.g. houses, livestock, and land). Below is a quote from a community leader in Nueva Cinchona on her perspective on the factors that contributed to the recovery of the community:

> "[S]ome people are upset at what we have been able to accomplish, but what we have we have worked for. To start even when we lived in Cinchona we were formally organized as a community – we had our papers of incorporation. After the event, we were all involved in the resettlement process meetings. When we [the community] were invited to appear for meetings to talk about the resettlement project every family was represented sometimes by the whole family. After a while they [government agencies] asked us to limit attendance to only one family representative."

The community leader further explained that other communities lacked the representation and organization Cinchona (now Nueva Cinchona) had prior and after the earthquake. When looking at Case F in Dulce Nombre, it presents a clear contrast with Case A in Nueva Cinchona. Observations seem to indicate a lack of "sense of community" which might be the result of living in a community built out of necessity. Nonetheless, there were some signs of efforts in the *precario* to organize as a community to re-start the negotiations with the government's new housing project for the residents of this community. This project has been on hold for several months. Interestingly, these organizational efforts flourishing in Dulce Nombre (and other communities in the area) are being channeled through formal and informal women entrepreneur groups. This is another possible indicator of transformative capacity that needs further investigation. Another critical consideration is the temporal nature of the results observed in the transformative capacity component. The tourism livelihood strategy according to the qualitative data analysis had just started to recover a year prior to the survey. When people in the tourism industry were interviewed, most stated that their lack of economic access to food was severe in the years immediately following the earthquake. Most tourism businesses in the area are family owned businesses that employ mainly immediate and extended family. The lack of livelihood diversity of these households had a temporal negative impact on households' resilience to food insecurity. These results have programming and policy implications. By having a better understanding on temporal considerations of livelihood resilience, governments and organizations can strategically target limited resources to specific livelihoods at different time periods. In this manner, resources can be utilized when they can be most effective in creating resilient communities.

When looking at the influence of the different components of the resilience index in the food security attainment of households after the earthquake, the absorptive capacity of households was one of the most influential components. When the absorptive capacity is exceeded, this result in lower resilience levels that are only attenuated by the adaptive capacity of the communities affected. In the rural context in particular, the absorptive capacity of communities is compromised during high impact earthquakes such as in the case of the Cinchona earthquake. Families and friends tend to live in close proximity in rural areas, and when a natural disaster with widespread impact strikes, social networks are disrupted, impacting the ability of the affected population to receive informal help. However, the adaptive capacity of small farmers, in this study, was higher than other livelihoods. This is mostly driven by their ability to utilize their agricultural assets, not only for income generating activities, but for household consumption as well. These findings inform policy on the importance of programming that supports and enhances the adaptive capacity of communities. Adaptive capacity can increase the resilience of households when a natural disaster surpasses their absorptive capacity.

6.3 Research Questions Discussion

RQ1: What set of indicators are most influential in a household's disaster resilience to food insecurity in a rural context?

This study was concerned with moving from theoretical and conceptual frameworks to metrics of resilience to food insecurity to advance this research agenda. The first step towards this objective required the identification and validation of indicators through an empirical study. This required finding the right statistical techniques to analyze the study data which didn't fit linear and normal data structures. The uncertainty of data structures in food security measurements and resilience metrics present challenges in the standardization of a methodology to advance the science of resilience.

The identification of sound and statistically significant indicators followed a three step process. First, a list of 42 indicators identified through reviews of the food security and hazards literature on disaster resilience were grounded to the local rural context of the study area. Second, the collected data went through a series of multivariate analysis that rendered the indicators that best measured the four components of the resilience index and were statistically significant at the 95, 99 and 99.9 confidence levels. In the Absorptive Capacity component, the informal assistance received through family and friends, as well as the total sum of the informal assistance received, were the best predictors of recovery. For the adaptive capacity component, the stronger indicators of recovery were education, perception of equal access to formal assistance, cattle ownership, and total sum of agricultural assets. The perception of equal access reflected people's concerns with their heighted vulnerability after the earthquake. The Transformative Capacity and Natural Capital components in this study were less influential in the food security recovery of the cases explored, but important insights were gained. The transformative capacity indicators showing statistical significance were the salaried, tourism, and other livelihood types, together with assistance received by the federal social program office (IMAS) of Costa Rica. Although natural capital is considered important in socio-ecological resilience, a viable methodological measure in resilience to food insecurity in the rural context needs further exploration. The first law of geography–near things are more related than distant things– results in low variability of natural capital indicators at the household, community, and regional level. When using metrics to assess the influence of natural capital, this lack of variability hinders its inclusion in most multivariate analysis.

When mapping the different components of the resilience level, aggregation to the case level was necessary. The mapping of the resilience components reflected the spatial variations of the different components. The interpretation of the spatial resilience variations were informed by the data obtained through observation, interviews, and the multivariate analysis. The spatial variation present is the result of interacting conditions and not a random process.

RQ2: To what extent these indicators can predict a food security outcome?

A second objective of this study was to determine if resilience to food insecurity could be measured through the methodology proposed. To this end, a series of regression analyses were conducted to understand the predicting power of the resilience index components. For a more comprehensive and holistic assessment, other parameters considered important in food security attainment were incorporated into the regression model. These parameters included the EII, community type, and gender of head of household. Overall the model had a moderate to high explanatory power. The results obtained suggest that the most influential predictor is the level of impact incurred-Burton's (2012) study of Hurricane Katrina resilience measures show the same results. The second most influential parameter was adaptive capacity. Adaptive capacity, throughout the study, has been an influential component in food security attainment. These findings present an opportunity to further explore and advance methodological approaches to measure resilience to food insecurity that are easy to interpret and can inform DRR policy.

6.4 Research Areas of Opportunity

Disaster resilience to food insecurity science is in its infancy. The advances presented in this study lead to fertile grounds for further exploration. The characteristics of the study area selected for this dissertation provided a valuable setting for conducting this research. Although rural communities share many characteristics such as livelihoods, education level of its residents, similar ecological systems, etc., there are some other characteristics that are not as overt or public. Take for instance the idea of “sense of community” introduced in Section 6.2, and the statistically significant indicator of the perception of equal access to future formal assistance. Data appear to indicate that both of these notions were instrumental in the recovery process of the selected communities. These findings point to the need for further research on how to effectively measure “sense of community” and perception of equal access, as well as how to incorporate them into the metrics for resilience to food insecurity measurement.

Continuing with the advancement of metrics, another area of research opportunity is the effect and impact of religious beliefs in the accurate measurement of households’ food security status. Field work observations reflect a tendency of respondents to try to avoid what could be constructed as a complaint on their food access. When some of the survey participants were confronted with questions such as, “Do you have enough food to eat?” their responses were, *“No puedo decir que no. No vaya hacer que Dios me castige.”* (I can not say no. God could punish me.). To the question of “Do you worry about having enough food to eat?” a typical response was *“No por que Dios proveera.”* (No because God will provide for us.).

Another area of research opportunity is the impact of forced or voluntary resettlement as a policy in post-disaster recovery in Central America. Badri et al. (2006) state that relocated families face difficult socio-economic challenges after relocation and regrouping, specially with respect to employment, income, the empowerment of women, and lifestyle issues. This was the case of the Nueva Cinchona community in this study. This study sought to address the negative impact of resettlement in food security, but the quantitative analysis didn’t yield it statistically significant. This result was driven primarily by the lack of indicator variability that prevented its inclusion on multivariate analysis–most people had to resettle either temporarily or permanently. Nonetheless, there is a need to further explore how resettlement affects resilience to food insecurity and its possible temporal considerations and interactions with other conditions.

6.5 Research Limitations

Resilience is a dynamic, multi-scalar, multidimensional concept. As such, moving from conceptual frameworks to measurement presents many challenges. Some of these challenges are represented in the research limitations of this study.

The modifiable areal unit problem (MAUP) in geography is the outcome of two different geographic (or spatial) aggregations that produce different degrees of within-area homogeneity. It requires the researcher to ask how relationships between variables change as the resolution (scale of measurement) increases or decreases, and to what extent information on geographic relationships at one scale can be used to make inferences about relationships at other scales (Fogarty 2010). In resilience study, resilient individuals and households are the foundation of resilient communities, but resilience at one level does not automatically result in resilience at a higher level of analysis (Frankenberger and Nelson 2013). This study has attempted when appropriate to present information at both the household and the community level, but other geographic scales are beyond the scope of this study.

Preferably, measurement of resilience should be done through panel data collection from the same household over time to capture its dynamic nature. Regrettably, panel data, especially in developing countries, is difficult to obtain. In this study, the dynamic and temporal aspects of resilience measurement are addressed through the assessment of *ex ante* and *ex post* household food security as an outcome of household resilience. This assessment is incorporated in the HRFII survey where respondents are asked questions about their food security status. However, this method also has its limitations.

Recall bias, sometimes also referred to as response bias, is a systematic error common to survey methods. Respondents may forget or misremember crucial information or misunderstand the questions. Although steps have been taken to ensure the validity of the questions and language used, it is more difficult, if not impossible, to minimize misremembering or misjudging the information respondents recall. The earthquake occurred four years ago and this might have an impact on the accuracy of their responses. Nonetheless, the benefits of capturing the dynamic nature of resilience may far outweigh-the possible bias or systematic error that could occur.

There is also a spatial limitation that will impact the interpretation of the data. Because of the cost and time challenges that are associated with this type of work, cross scale analysis is beyond the focus of this study. The five preselected communities are located in relatively close proximity to each other and have similar livelihood characteristics. This is important for comparison purposes. There are several other communities that were also affected that were not surveyed because of their location outside the selected geographic area. In addition, the population selected are households that were directly affected by the earthquake, and therefore, indirectly affected households or households of people that did not live in the area at the time of the event are not represented in this study.

There are many challenges to the study of resilience to food insecurity as reflected by this study's limitations. Nevertheless, the insights gained through this study are significant and its contributions will outweigh its limitations.

6.6 Research Contributions

Food insecurities are exacerbated among the most vulnerable populations in the aftermath of a natural disaster. The impact can be devastating, especially in rural settings where livelihoods are closely tied to their productive assets, and social networks are disrupted when entire communities are affected. There is growing adoption by governments and organizations of the resilience approach for DRM. Creating resilient communities has become a core initiative in the international agenda.

The literature review revealed three main challenges for the incorporation of disaster resilience into practice. First, the many definitions and conceptualizations of resilience hinder interdisciplinary collaboration. This study sought to develop an integrated conceptual and methodological framework for measuring resilience to food insecurity from a multidisciplinary approach that integrated two main perspectives, hazards and food security. The integrated definition of resilience to food insecurity proposed in this study guided the indicator selection and methodology for the creation of metrics and measurements that incorporate both the natural and human systems in the measurement of resilience. Previous studies have limited their scope to the social aspects of resilience to food insecurity, and although the natural environment is theoretically acknowledged as an important factor, proposed metrics have lacked its incorporation. Within the past couple of years, hazards researchers have started to explore the dual or coupled system approach into the study of community resilience. There is a potential opportunity to incorporate new insights into the coupled system approach by both the hazards and food security disciplines.

As stated in several occasions in this dissertation, many indicators of resilience to food insecurity have been proposed, but less than a handful of studies have actually tried to test and validate those indicators. This study validated a set of indicators through an empirical study in the context of Central America. In this region, only one study on resilience to food insecurity was found in the literature review, and it was conducted through secondary data (Ciani 2012). Furthermore, this study advances the development of an operational tool to measure household and community resilience to food insecurity. Methodological challenges of real-world data have been explored and statistical techniques for addressing these challenges proposed.

Throughout the development of this dissertation study, innovative approaches were proposed such as the integration of the natural and human systems for a more holistic approach to the study of resilience to food insecurity. In addition, commonalities among different disciplines moving forward resilience research were identified and incorporated into an integrated definition and methodological framework in an effort to facilitate communication among disciplinary boundaries. Furthermore, an important aspect of this study is its integration of GIS technology in the spatial visualization of resilience and food security recovery lacking in previous works on resilience to food insecurity studies. Being able to communicate complex processes in a clear and understandable manner among different constituencies is vital to further the collaborative work of agencies, governments, and disciplines within and among them. Geovisualization provides a venue to communicate important scientific discoveries across discipline boundaries, and limits the negative effects of discipline jargon that prevents the advancement of this scientific community.

APPENDIX SECTION

APPENDIX A

Household Resilience to Food Insecurity Index (HRFII)

District: ______________________ Address: ______________________________________

Community: ______________________ GPS Location: ______________________________________

Visits			
No.	Date	Time	Outcome
1			
2			
Enumerator: _______________________________________			

1. Have you lived here since the Cinchona earthquake in 2009? Yes☐ No ☐Go to1b.

   1b. did you relocate here because of the earthquake effects? Yes ☐Go to 1c No☐ End

   1c. from where were you relocated? _______________________

2. Select the sex of the household head: Men… ☐ Women… ☐ Shared… ☐

3. ¿Are you originally from Costa Rica? Yes… ☐ No… ☐ Go to 3a

   3a. ¿Where are you from? _________________________

4. Do you think you and your family before the earthquake...?
   Choose only one answer

	Si	No	NR
…always had enough food for everyone			
… you or any household member have to eat a limited variety of foods due to a lack of resources (2 to 10 times a month)			

… you or any household member have to eat fewer meals in a day because there was not enough food (more than 10 times a month)			

5. ¿During the years after the earthquake, did a household member received help from…?

	Yes	No	Type of assistance
…family			
…friends			
…cooperative			
…community			
…non-profit organizations			
…government			
IMAS			
Social Security			
Retirement fund			
CNE			
Other			

6. Educational level

Level	**Completed**	**Incomplete**
Elementary		
Middle school / High school		
College / University		
Other		

7. What type (s) of work did you have last week excluding household chores?

Activity	**Primary**	**Secondary**	**Family members**	**Name and place**
Salaried				
Agricultural Independent				
Agricultural Dependent				
Non-Agricultural Independent				
Tourism				
Other				

8. Did the following physical impacts caused by the earthquake of 2009 affect your labor tasks?
Activities Codes

Agricultural	1
Non-Agricultural	2
Tourism	3
Other	4

	Yes	No	Activities
Sedimentation and river overflow			
Loose material (mud, organic, rocks, etc.)			
Landslides			
Structural collapse			
Road damage			

9. Which resources do you use frequently (more than 10 times a month) for income generation or consumption in your household?

		Income generation	Consumption	Distance (mts)
Natural	Forest resources			
	Water (except pipeline)			
Agriculture	Land quality and productivity			
	Machinery			
	Cattle			
Non-Agricultural	House			
	Motorized transportation			

10. Do you worry about not having access to assistance through social programs?
Si… ☐ No… ☐

10b. Why? ____

11. **Is this house** supplied with water by aqueduct**?** Yes… ☐ No… ☐

12. **Is this house supplied with electricity?** Yes… ☐No… ☐

13. **Do you have a phone land line or cellular**? Yes… ☐ No… ☐

APPENDIX B

Household Food Insecurity Access Scale (HFIAS) – Adapted*

No.	Question	Answer Options	Code
1.	In the past 4 weeks (30 days), did you worry that your household would not have enough food?	0 = No (skip to Q2) 1 = Yes	
1.a	How often did this happen?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
2.	In the past 4 weeks (30 days), were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = No (skip to Q3) 1 = Yes	
2.a	How often did this happen?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
3.	In the past 4 weeks (30 days), did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = No (skip to Q4) 1 = Yes	
3.a	How often did this happen?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
4.	In the past 4 weeks (30 days), did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	0 = No (skip to Q5) 1 = Yes	
4.a	How often did this happen?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times)	

		3 = Often (more than 10 times)	
5	In the past 4 weeks (30 days), did you or any household member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to Q6) 1 = Yes	
5.a	How often did this happen?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
6.	In the past 4 weeks (30 days), did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No 1 = Yes	
6.a	How often did this happen?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	

* Adapted from the Food and Nutrition Technical Assistance (FANTA).

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