# EXPLORING THE RELATIONSHIPS BETWEEN LIVELIHOOD DIMENSIONS AND SOCIO-ECOLOGICAL RESILIENCE IN THE BOLIVIAN ALTIPLANO

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

EXPLORING THE RELATIONSHIPS BETWEEN LIVELIHOOD DIMENSIONS AND SOCIO-ECOLOGICAL RESILIENCE IN THE BOLIVIAN ALTIPLANO

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A candidate for the degree of Master of Science,

And hereby certify that, in their opinion, it is worthy of acceptance.

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Dr. Laura McCann

Dr. Jere L. Gilles

To my wife Jennifer.

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# ABSTRACT

Households in the Bolivian Altiplano construct their livelihood strategies in a system marked by changing climate and volatile social systems. The strategies that they choose must work to decrease the household's vulnerability to shocks, such as drought and frost, and increase its ability to adapt to longer term changes, for instance the affects of globalization. Their strategies may also influence the resilience of their community and environment, either increasing or decreasing the likelihood of catastrophe.

This research uses canonical correlation analysis to analyze survey data collected from 330 rural households in two regions of the Bolivian Altiplano. It examines the impact that dominant livelihood strategies have on the resilience of the household and its socio-ecological environment. The analysis shows that access to land and lifecycle are two household characteristics most highly associated with resilience; that diversification into labor markets often works towards increasing resilience; and that many households use livestock as an insurance mechanism. The results suggest that policies that work towards increasing crop yields and reducing livestock loss in the face of climate change could effectively target the households that are most vulnerable. Programs that include transfer payments to older households for providing services, such as increasing ecosystem resilience by placing land in fallow, could reduce the negative impact of lifecycle experienced by many across both regions.

# Chapter 1: Introduction

## 1.1 Research Problem

The sustainable use of landscapes is a key consideration for the long-term economic, social, and environmental stability of developing nations across the world. In landscapes of all kinds, "the goal of sustainable development is to create and maintain a permanent balance between human and natural environments by dealing with economic, social, and environmental issues on an equal basis" (Villeneuve et al. 2004). Mountain areas in developing nations present particular challenges to sustainable landscapes and livelihoods.

Mountains and highland areas cover nearly 24% of the Earth's surface. Mountainous environments are specifically vulnerable to climate and human changes that can result in deforestation, landslides, land degradation, desertification, glacial lake outburst flooding, and drought (Iyngararasan et al. 2004). Furthermore, communities in mountain areas are often characterized by low access to transportation, health services, markets, education, information services, and energy. These services are key to sustainable development in mountain regions (Kohler et al. 2004). The isolation of mountain communities often impairs the transfer of information and development of infrastructure that may relieve some of the pressure caused by population growth and

environmental degradation. The ability of a mountain region to develop sustainably depends both on policy decisions made at the government level and the individual decisions that are made by people living in the region. Sustainable development requires that the economic social and environmental interests of the region and individual households are met both currently and in the future.

In 1998, the Food and Agriculture Organization of the United Nations (FAO) declared that 2002 would be the International Year of Mountains. The focus on mountains was meant to bring together different parties that were working in mountain regions to share knowledge and coordinate their activities. One of their objectives was to "ensure the present and future of mountain communities by promoting the conservation and sustainable development of mountain regions" (FAO 2000, 14).

The Andes Mountains lie along the western portion of South America, crossing the borders of Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, and Venezuela. The range averages about 4,000 meters above sea level and stretches over 7,000 kilometers long, making them the world's longest continental mountain range. In areas of Argentina, Bolivia, Chile, and Peru, the Andes split into two mountain ranges, the *Cordillera Oriental* and *Cordillera Occidental*. The valley between the two ranges has filled with sediment from the peaks, creating an area of high plains called the Altiplano.

The Aymara people have been practicing agro-pastoralism for more than 2,000 years in parts of the Altiplano. For much of that history, a system of *ayllus*, or kinship groups, provided individuals with access to resources from across geographically and ecologically diverse regions. The system has been largely dismantled by over 250 years of colonialism followed by many wars and a system of *haciendas* that kept indigenous

land holdings to a minimum. The Aymara in the central Bolivian Altiplano still practice agro-pastoralism, but have become partially integrated into agricultural and labor markets to obtain goods that they cannot produce locally.

In 2005, Evo Morales, a Bolivian man of Aymara descent, was elected president by the indigenous majority of Bolivia. Although many of the Aymara have benefited from Mr. Morales' policies, the rural indigenous people of the Altiplano remain far below national averages for income levels, which are already some of the lowest in South America. In 2007, 75.8% of rural Bolivians lived in poverty, and 59% lived in extreme poverty (Economic Commission for Latin America and the Caribbean 2010). Aymaran and agropastoral communities in the Bolivian Altiplano are faced daily with livelihood decisions that affect their current and future economic plight.

Households in the Altiplano must adapt to a changing human and natural environment. Climate change, increased population pressures, changes in production methods, and evolving incentive structures are a few of the pressures that they face. Natural shocks, such as drought and floods, compounded by social instability create a high risk environment for agricultural households. According to climate change projection models applied to the region, the future holds increased incidence of extreme events as the general trend moves towards drying and warming (Valdivia et al. 2009). To stay viable, the livelihood strategies of the Aymara on the Altiplano must buffer them from shocks and cope with the stress of change in a sustainable manner. This thesis explores the connections between the household-level economic decisions of smallholder farmers, their ability to create resilient livelihoods and their impact on the resilience of

the environment in two regions of the Bolivian Altiplano. The sustainable livelihoods framework is used to model the households' access to resources and how they are used to fulfill household needs. A systems approach known as the socio-ecological systems model is used to account for the high degree of interconnectedness between economic livelihoods and the mountain environment of the Altiplano.

This research explores how a household's accesses to capitals, livelihood strategies and their impact on the socio-ecological system are related?

## 1.2 Justification

This research investigates how the portfolio of assets that a household controls affects the livelihood strategies that it chooses and the impact of those strategies on the natural and human systems of the Bolivian Altiplano. It aims to identify livelihood strategies that may be especially successful from a perspective informed by the resilience framework. Although there has been extensive research on how the control of assets influences livelihood strategies and well being (capitals framework, e.g. Bebbington 1999; Valdivia 2004; Winters, Davis, and Corral 2002) and how human structures impact both livelihoods (transaction costs, social capital and new institutional economics; e.g. North 1995; Omamo 1998; Reardon, Delgado, and Matlon 1992) and the natural environment (management of private and common pool resources; e.g. Gunderson and Holling 2002; Ostrom 1990; Walker et al. 2004), there has been little research published on the impact that individual livelihood choices have on their natural and human systems. This research studies the relationship between individual households and their socio-ecological systems. It brings together the knowledge from two fields of research to

examine how households with unequal access to capitals and differing capacities impact their natural and social environments.

The livelihoods framework is one model that researchers and development agencies have found useful for investigating and addressing poverty, vulnerability, and security among communities and individuals. The sustainable livelihoods framework focuses on the household's access to assets and capacity to construct a strategy that meets its needs over time (Scoones 1998). Chambers and Conway defined livelihood as "[compromising] people, their capabilities and their means of living, including food, income and assets" (1991, 1). This definition provides a framework for analyzing the household in the context assets that it controls and the results of its activities. The livelihoods framework has proven to be fertile ground for poverty studies and concerns about human impact on the environment. Since its conception, researchers have incorporated concepts from institutional economics, environmental dynamics, and social, political and cultural contexts to create a broader picture of livelihoods (Scoones 1998). Although the sustainable livelihoods framework can incorporate changes in the household's social and natural environment, the household is most often reactionary. In most uses of the framework, the actions of the households rarely, with the exception of changes to stock of natural capital, impact the larger environment.

The socio-ecological systems approach includes the feedback loops that exist between natural and human systems. Human actions can strengthen or degrade natural and human structures. The socio-ecological systems conceptual framework (SES) models the highly interrelated and complex systems that create an environment (Gunderson and Holling 2002). It describes the inherent complexity and adaptability of the systems that

describe the interface between humans and environmental systems. The SES framework is an extension of earlier work in ecology used to study resilience within ecosystems. It has been used extensively in order to investigate multiple-user land management practices. Its weakness lies in the difficulties that arise when operationalizing the complexity imbedded in its theories for research. By necessity, researchers must reduce the number of variables and interactions that they consider. Often, the cost of using the SES model is the use of aggregates and averages on the levels above and below the level of analysis. For example, Ostrom (2009) creates a framework for analyzing the likelihood that users of a resource will self-organize in order to manage its use. In the analysis, the user population may or may not self-organize, assuming that individuals act within very similar incentive structures and can be described by their average capacity to self-organize. From a livelihoods approach there may exist incentives that push specific individuals over the threshold to organize but not others.

This project places the sustainable livelihoods framework into the context of the SES model in order to better understand how household variables, such as control of assets and participation in organizations, impact the construction of livelihood strategies and how those strategies in turn impact the household's environment. Although this thesis is not the first to analyze the impact of livelihoods on their environment or the relationship between control of assets and construction of livelihood strategies, this study provides a broader perspective across three scales (assets, livelihood strategies, and environment) that does not exist elsewhere. This research aims to provide useful insight into both the SES and livelihoods approaches. It contributes new information to households and organizations in the Altiplano that are working towards sustainability and

reduced vulnerability by identifying aspects of livelihood strategies that impact the entire socio-ecological system. It focuses on key characteristics of strategies that households use to reduce vulnerability and their impact on the rest of the SES.

## 1.3 Objectives

This study aims to identify the general livelihood characteristics that increase the resilience and decrease the vulnerability of socio-ecological systems in the Bolivian Altiplano. Specific community factors that are especially informative or unique in the region will also be considered.

Principle Objective: Determine if specific characteristics of livelihood strategies can decrease household vulnerability while increasing resilience in the social and ecological system.

Objective 1: Create a livelihoods model that is supported by the literature and adequately describes the relationship between a household's access to capitals and its relative ability to provide for itself.

Objective 2: Investigate regional trends in household-level access to assets, livelihood strategies, and impacts on the social and ecological system.

Objective 3: Indentify how households within communities confront their specific obstacles successfully, and if those strategies are transferable to other households and communities.

## 1.4 Outline of the Thesis

Chapter II provides the historical and geographical context of the study, including the recent history of the Altiplano followed by a description of the two survey regions. Chapter III reviews the literature on socio-ecological systems and the sustainable livelihoods framework, and discusses the implications of combining the two approaches. Chapter IV begins by describing the conceptual framework and methods of analysis that are used in this research. The second section of the chapter contains the empirical framework and a description of how each variable is constructed. Empirical analysis and results are found in Chapter V. The chapter begins with an analysis of the livelihoods framework to identify which capitals are major factors in determining the relative success of livelihoods in the Altiplano. These capitals are used in canonical correlation analysis to reveal dominant relationships between access to capitals, livelihood strategies, and impact on the socio-ecological systems. Analysis is performed on the regional and community levels to compare general similarities across the region with the more unique differences between communities. Chapter VI begins by returning to the hypotheses formed while constructing the conceptual framework. That discussion leads to the conclusions, policy implications, and avenues for further investigation that can be drawn from the results, as well as the limitations of this project.

# Chapter 2: Historic, Cultural, and Regional Context

## 2.1 Introduction

The objective of this chapter is to provide the context for the two study regions in the Bolivian Altiplano in order to better understand and account for the role of path dependence. History, culture, and regional differences influence the trajectory of economic change in a location and determine the options that households perceive. The household's historic and cultural context provides an understanding of the historic drivers of change and methods that have traditionally been used to adapt and adjust to a changing environment. The regional context focuses on the differences in infrastructure and institutions such as access to transportation, markets, and education that vary widely across the Bolivian Altiplano.

The chapter begins with a brief introduction to Bolivia's economy and the geography of the Altiplano. That is followed by a more in-depth summary of the history of the dominate ethnic group of the region, the Aymara, on the Altiplano in order to provide historic context leading up to their current situation and to better understand the traditional livelihoods and culture of the Aymara. The chapter will conclude with a description of the data this is used in this research and a preliminary examination of the data in order to illuminate the similarities and differences between the two regions.

## 2.2 Bolivia: An Overview

The Plurinational State of Bolivia is a landlocked country in South America bordered by Brazil, Paraguay, Argentina, Chile, and Peru. It is the 28th largest country in the world with 1.1 million square kilometers. Over 6,450 meters of elevation differential and 12 eco-regions (Ibisch et al. 2003) within Bolivia "make it one of the most biogeographic regions in South America" (López and Zambrana-Torrelio 2005, 2).

Bolivia is divided into nine departments, each with an administrative capital. Those departments are divided up into provinces composed of municipalities and at the local level, cantons. The capital of Bolivia is La Paz, the world's highest capital city with an elevation varying between 3,000 and 4,000 meters. The metropolitan area of La Paz includes two other cities, with a total population of about 2.3 million.

In 2008 Bolivia had a population of nearly 9.7 million (US Central Intelligence Agency). The population is 54%indigenous, the majority of which are Quechua (30%) and Aymara (24%). The remaining population is made up of mestizo (30%) white (15%) and other (1%). The per capita GDP is estimated at $4,600 for 2009 composed of 51.8% service, 36.9% industry, and 11.3% agriculture. Its current account balance is positive $725 million. Principle exports in order of importance are natural gas, soybeans and soy products, crude petroleum, zinc ore, and tin (US Central Intelligence Agency).

In 2009, Bolivia had a Human Development Index (HDI) score of 0.729, ranking 113 out of the 182 countries for which the United Nations Development Project has calculated values. According to the Economic Commission for Latin America and the Caribbean (ECLAC), 54% of Bolivian citizens lived in poverty and 16.2% lived in

extreme poverty in 2007. In rural areas, the conditions are worse, with 75.8% living in poverty and 59.0% in extreme poverty. The Gini coefficient, a measure of income equality where zero represents equality and one represents inequality, was 0.592 in 2006 ranking the seventh least equal country among the 134 countries ranked by the US Central Intelligence Agency (2010).

## 2.3 Geography of the Bolivian Altiplano

The Altiplano is an area of inland drainage lying in the central Andes, occupying parts of Chile, Argentina, Bolivia, Peru, and Ecuador. It describes the basin of plains and isolated mountains and ridges between *Cordillera Oriental* and *Cordillera Occidental*, two ranges that are part of the Andes. The Altiplano's height averages about 3,750 meters, and it covers about 149,980 $km^2$ within Bolivia, or about 14% of the country.

The plain that makes up the Altiplano is actually the valley between the *Cordilleras* that has been filled by sediment. Lake Titicaca, Lake Poopó and the *salares* are the remains of Lake Ballivián, which used to cover the entire area that is now the Altiplano. Currently, the River Desaguadero connects the two, moving water from the higher Lake Titicaca region down and south into Lake Poopó. The valley floor is broken up by geographic features which create sub-regions characterized by different climate and edaphic features (Coppock and Valdivia 2001). Peoples of the Altiplano have historically exploited this great variation in elevation and habitat through a system of *ayllus* that will be discussed below.

The climate on the Altiplano is cool and semi-arid to arid, with mean annual temperatures that vary from 3°C near the western mountain range to 12°C near Lake

Titicaca, and total annual rainfalls that range between less than 200 mm to the south west to more than 800 mm near Lake Titicaca. The average daily temperature cycle is very wide, with maximum temperatures on the order of 12 to 24°C and minimum temperatures of -20 to 10°C, creating a danger of frost in every season in some locations (SANREM CRSP 2008).

## 2.4 History of the Aymara in the Bolivian Altiplano

*"The history of the Aymara has been characterized by shifting pressures from dominant groups." (Swanson and Lagace n.d.)*

The Aymara population is estimated at 2 million across Chili, Peru, and Bolivia. They have been living in the eastern valleys and Lake Titicaca region for more than 2,000 years. The lake provides humidity and warmth for the region surrounding it, and the fertile soils have sustained large populations in the past. A tradition of camelid pastoralism and arid agriculture on the Altiplano was historically supplemented by trade for goods from other ecological zones. Goods such as livestock byproducts, potatoes, and cereals that grew well in the upper plains were traded for fruits, coca, and maize produced in the lowlands. The system was supported by kin groupings called *ayllus,* which controlled land across different ecological zones (Klein 2003).

The *ayllus* formed the basic unit of political and social Aymara life. They performed the function of creating formal relationships between households across the landscape. A process of reciprocity called *ayni* exchanged labor for goods, providing members with access to goods produced over a wide variety of climates. The *ayllus*

system itself was diversified across ecological regions, providing a buffer against climatic events. At their greatest extent, Aymara *ayllus* controlled lands from the Pacific coast to the Yungas (Murra 1975, from Coppock and Valdivia 2001).

When the Incas conquered the Aymara in the 15th century they treated the *ayllus* as the basic unit of control and taxation. They allowed the Aymara a degree of self governance, and extracted taxes in the form of labor (*mita)* directly from the Aymara rulers. Maintaining local self sufficiency and thus the linkages between highland and lowland regions became a matter of state policy for the Inca (Painter and Durham 1995). Autonomy allowed the Aymara culture, languages, social organizations, and tradition to remain largely intact during the Inca rule (Good 2006).

The Spanish Empire conquered the area from the Incas in the 16th century. The region now within Bolivia was part of a colonial region called "Upper Peru". The Spaniards reorganized the state in order to facilitate the extraction of resources from the region. The responsibility fell on local communities to maintain the vertical linkages on which they depended. During this time, the majority of agricultural lands were held in *haciendas*, large estates run by Spanish patrons and worked by indigenous peoples in exchange for rent.

In 1545, the mining town of Potosi was founded on large silver deposits in the eastern portion of the Altiplano. In order to fulfill the labor needs of the large mines, the Inca system of taxation through in-kind labor (*mita*) was reintroduced by the Spaniards. In a system of drafts, 4,500 indigenous laborers were rotated through Potosi every four months (Good 2006). Between labor for the Crown and Church and responsibilities to

their local *hacienda*, peasants had few excess resources with which to maintain their vertical linkages.

Bolivia declared independence from Spain in 1809, and the republic was proclaimed in 1825. The Mestizos took the place of the Spaniards. The indigenous peoples remained relatively powerless with very few rights. The Mestizos did not yet have the political infrastructure required to fill the void left by the Spaniards, and between 1825 and 1879 Bolivia had 24 presidents. In 75 years, there were more than 100 coup attempts. "The root cause of the instability lay not in the army but in the lack of a dominant, economic elite in the absence of legitimate authority such as the Crown and the Church" (Good 2006, 47).

High silver prices during the later part of the 19th century created income and the potential to improve the state. Instead, most of the income went to funding a series of eight wars between 1862 and 1935. In that time period, Bolivia lost over 50% of its land area to Brazil, Peru, and Chile; including valuable access to the western coast of South America. During this period, native people in the Altiplano were conscripted as soldiers or forced to work in the mines, creating very poor living conditions and further fragmenting households and communities.

The Bolivian National Revolution of 1952 resulted in the nationalization of many of the largest tin mines, abolishment of literacy requirements for voting, and the institution of sweeping land reforms. The land reforms abolished the *hacienda* system and redistributed the land to the peasants that worked them. Each peasant gained full ownership of the land which they had worked, and lands worked for the *patron* of *haciendas* that surpassed 80 hectares were divided up among the peasants. Households

also suddenly had access to the labor that they had been required to pay to the patron of the hacienda. According to Buelchler (1971), some of the additional labor went towards increasing leisure, but the majority went to increasing agricultural production and marketing. Increased production and marketing by the peasants lead to growth in rural markets and migration to larger cities such as La Paz. A large educational campaign accompanied the land reform, leading to the creation of schools in many Altiplano communities.

After the crash of the world tin market in 1985, Bolivia adopted neoliberal free market policies. The "shock policies" focused on the "deregulation of prices, exchange rates and trade; elimination of subsidies and price supports; and the dismantling of the state enterprises dominant since the revolution of 1952" (NACLA 1991). Although the measures were touted amongst neoliberal economists for halting runaway inflation and reducing the deficit, the measures also cut education funds and privatized many of the mines and factories. Liberal trade policies and international food donations undermined the country's agricultural sector, further increasing an already growing unemployed population. According to Painter and Durham, the loss of vertically integrated production has established "downward spirals of economic underdevelopment and environmental destruction" (1995, 134) in Bolivia.

In 1993, the government began to pass a series of reforms meant to address issues of inequality that have resulted from the exclusion of indigenous population from governance (Grootaert and Narayan 2004). The federal government began to redirect large portions of funding from the cities to rural areas. A movement toward

decentralization provided greater resources and responsibility on municipalities, and local organizations were recognized as legitimate organizations.

The reforms were successful in stimulating indigenous involvement in politics, and in 2006 the first indigenous president, Evo Morales, was elected. Morales' election was a response by indigenous peoples to the vast inequalities between indigenous people and the decedents of Europeans, and to the neoliberal policies that had reduced their well-being (Hylton and Thomson 2007). For the first time in 500 years, the indigenous majority controlled Bolivia.

Morales has enacted many of the changes that he promised during his campaign. In November 2006, Mr. Morales pressured Congress to pass a bill that gave the federal government the ability to redistribute land that is unused or was corruptly obtained. New taxes on oil and gas revenues provided the state with revenue to fund new public works, education, and pension programs (Shultz 2010). In 2009, 61% of voters voted in favor of approving a new constitution. The new constitution fulfills several longstanding demands of the indigenous peoples. It recognizes 36 indigenous languages, guarantees broad social rights and access to services to the entire population, public ownership of natural resources, and puts an upper limit on the size of large farms (Hammond 2009).

Today, the Aymara represent 24% of the Bolivian population. Those that remain in the rural Altiplano continue with their agropastoral traditions. Households still tend to be involved in a diverse set of activities that help to reduce vulnerability to economic shocks (Valdivia et. al. 2003). They rely heavily on both crops and livestock. Caro (1992) describes the three main three types of agropastoalism in the Bolivian highlands: agriculture and herding are fairly equal and the herd consists of mostly sheep, herding

llama and sheep is the primary source of income complemented by some agricultural activities, camelid pastoralism (alpaca, llama, sheep; in order of importance) is accompanied by occasional use of agriculture. Each system allows the household to utilize lands across elevations in order to cope with risk of frosts, flooding, and drought.

Although the system of *ayllus* is no longer intact, communities still rely on reciprocity and communal action. According to Mayer, "the capacity to act collectively is the most outstanding characteristic of Andean households" (2002, 35). Households continue to exchange labor for food by *ayni* within the communities but now rely on local markets and fairs to buy products from other regions.

During the 1990s, the Bolivian government began to heavily promote dairying. Programs were created to introduce improved dairy breeds and alfalfa and price supports were placed on milk. The national dairy coop, PIL Andina, was created and collection centers have been installed in some communities. In some regions, dairying is changing the landscape more than any other factor (Valdivia and Quiroz 2001).

## 2.5 Climate Change in the Altiplano

Although climate change in the Andes is poorly documented, there are indicators that provide basic empirical evidence of change. For example, the Chacaltaya ski center, located in the Chacaltaya mountain range on the Altiplano, is the highest ski resort in the world. In 1940 the Chacaltaya glacier covered 0.22 $km^2$ (Magrin et al. 2007). During the warm season in 2009-2010 the glacier, which is estimated to have been 18,000 years old (Painter 2007), melted away completely. The glacier had lost 80% of its surface area in the last 20 years. The loss of glaciers is especially alarming for cities like

La Paz that depends on glacial melt for 80% of its drinking water and agricultural households that use glacial melt for irrigation.

Vuille et al. (2003) searched for potential causes of glacial melt in the Altiplano. Using precipitation, cloud cover, and temperature data from 1950-1994 they found evidence that temperatures had risen 0.15°C per decade and there has been an increase in relative humidity of between 0.0% and 2.5%.

In a second study, Seth, Garcia and Thibeault (2008) used nine models from the Coupled Model Intercomparison Project in order to study climate change in the Altiplano. Their projections indicate that temperature mean will increase by 1.5-2°C by 2030, from their current levels of between 2 and 12°C depending on location. In the Southeast they expect to see increased precipitation during the monsoon season but possibly a weaker early monsoon season and increased drying in the spring. Should these projections prove true, the result is increased intensity of precipitation during precipitation days and increased grouping of those precipitation days; resulting in a longer dryer winter and a shorter summer.

Households in the Altiplano are especially sensitive to climate variability and shocks. The Intergovernmental Panel on Climate Change (IPCC) has been monitoring climate change and impacts; it warns that glacial loss will cause "serious problems in agriculture, sustainability of 'bofedales'[1] and socio-economic impacts for the rural populations" (Magrin et al. 2007, 589). Currently fifty percent of households in the Altiplano are involved with agriculture. These households will need to adapt agricultural

[1] Bofedales refer to the wetlands and humid areas of the Altiplano.

practices to increased risk of drought and flooding, greater volatility in precipitation distribution, and continued risk of frost (Garcia et al. 2007).

## 2.6 Survey Regions

The data used in this research was collected by survey of randomly chosen households in nine communities across two regions in the central Bolivian Altiplano in 2006 (Figure 2.1). Each household completed a survey of over a hundred questions concerning many aspects of their lives. Follow-up focus groups and key interviews were conducted by the author during July and August 2009.

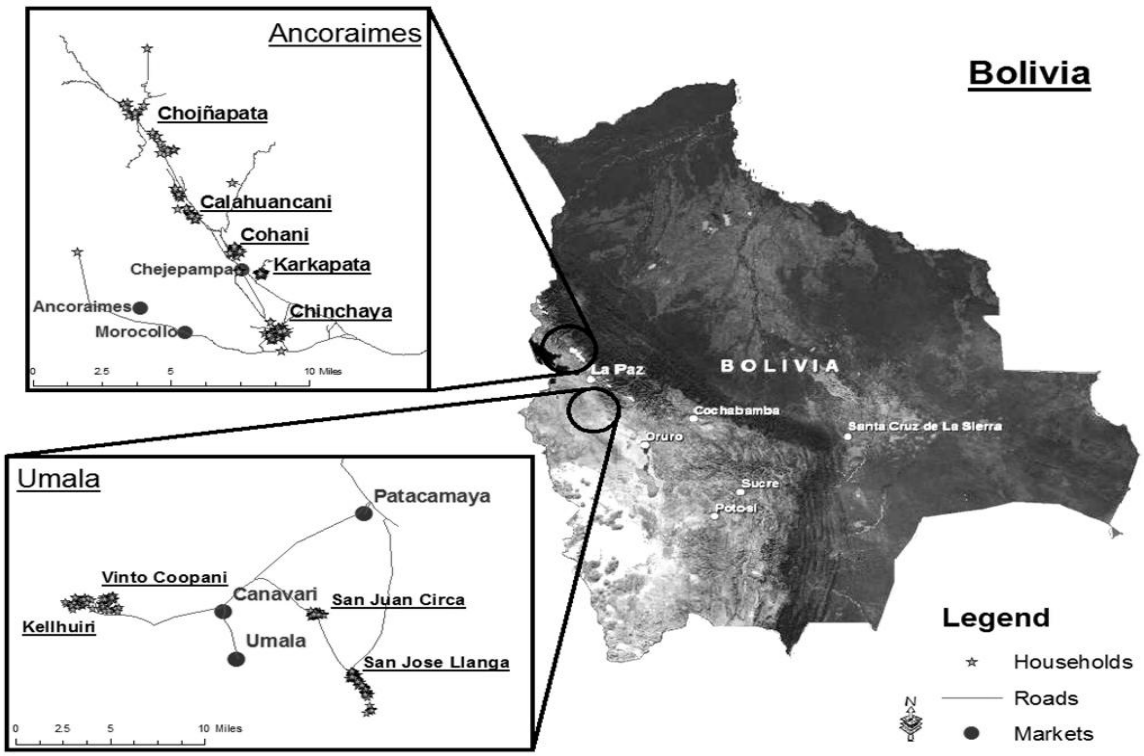


Figure 2.1The nine survey communities are drawn from two distinct regions of the Bolivian Altiplano.

**Data Source:** SANREM CRSP 2006

The household survey *Cuestionario de Estrategias de Vida, Capitales, y Prácticas Ciclo 2005-2006*[2] was collected in the Bolivian Altiplano during the off-season of 2006 (SANREM CRSP 2006). The survey includes 330 Aymara households in nine communities in two different regions. The survey regions, Umala and Ancoraimes, were selected in order to include a variety of institutional, geographic, and economic characteristics in the dataset. They are nearly 200 km from each other and are characterized by different climate and infrastructure. Within each region, communities also vary in wealth, access to infrastructure and formal institutions, and livelihood activities. The survey consists of questions concerning livelihood strategies, household demographics, assets, and perceptions of risk. Each household pursues a unique livelihood strategy, although all of them draw a portion of their income from agriculturally related activities and are highly affected by climate events.

The final portion of this chapter provides the regional context of the dataset. Although literature and other studies are used where appropriate, the majority of fallowing information relies on the Sustainable Agriculture and Natural Resources Management Collaborative Research Support Program (SANREM CRSP) survey data for Long Term Research Project No 4 and data collected on-site by the author.

[2] Organizations that contributed to the creation of the survey and collection of survey interviews include: Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP), Universidad Mayor de San Andres (UMSA), Promocion e Investigacion de Productos Andinos (PROINPA), Universidad de la Cordillera, and the University of Missouri. For more information on the survey methods please see Appendix 1.

### *2.6.1 Regional Context: Umala*

The municipality of Umala is located in Aroma, one of the twenty provinces that make up the department of La Paz. In 2001 it had a population of 9,583 (Instituto Nacional de Estadistica). It lies about 120km southeast of La Paz. The altitude of the region is between 3,750 and 4,100 meters. The majority of the populations are Aymaran agro-pastoralists. It has a semi-arid *puna*[3] ecosystem. Precipitation records at an experiment station that is less than 30 km away from any of the survey households recorded an average annual precipitation of 402 mm between 1952 and 1992 (Coppock and Valdivia 2001).

The town of Umala was once the center of commerce and governance for the region. Reportedly, an inscription in the town center dating from 1878 lists all of the *ayllus* of the region (Stephenson 2000). The construction of a main road that connects La Paz to large cities to the south but passes to the east of Umala has eroded the economic significance of Umala in the region.

Currently the primary marketing center for the municipality of Umala is Patacamaya which lies on the cross-roads of two main transportation routes. Patacamaya is located on the main road to La Paz from the major production areas around Santa Cruz and the cities of Sucre and Potosi. A high density of truck traffic moves through the community of Patacamaya via these production centers providing low cost transportation opportunities for the local people between Patacamaya and other urban centers. The Patacamaya market has a high number of intermediaries that purchase goods from locals

[3] *Puna* is often used to describe the biological community that is original to the Altiplano. The word originates in the Quechua word *púna* which means 'high summit'.

for resale in urban areas (Coppock and Valdivia 2001). Because of the high demand for and ease of access to the Patacamaya market, there are few other local markets in the area that households reported using.

According to the survey data, the average *Gini Index* of the survey communities in Umala is 0.32, indicating greater income equality in those communities than the population of Bolivia. According to Bebbington (2001), the viability of the rural Altiplano is dependent on the dairy sector. All four communities have residents that are members of PIL Andina, an example of global markets affecting local livelihoods and markets.

Although the four survey communities in Umala are within 20 km of each other, they have very large differences in income, field size and livestock (Table 2.1). Some of these differences, such as field size, can be partially attributed to physical geography. San José Llanga and San Juan Circa both lie on relatively low and level ground that allows them to have large field sizes while Vinto Coopani and Kellhuiri are on steep hilly ground, much of which cannot be farmed**.**

Table 2.1Baseline statistics from survey of the four survey communities in Umala

| Community | | Members in Household | Education[1] | Cropland (ha) | Cattle | Alpaca & Llama | Total Income (Bs.[2]) | Gini Coefficient |
|---|---|---|---|---|---|---|---|---|
| San José Llanga | Mean | 5.75 | 8.13 | 5.64 | 5.89 | 0.00 | 21936 | 0.333 |
| **(N=96)** | SD | 2.46 | 4.06 | 3.32 | 3.43 | n/a | 1430 | - |
| San Juan Circa | Mean | 5.13 | 6.23 | 7.37 | 6.77 | 0.00 | 18479 | 0.296 |
| **(N=31)** | SD | 2.66 | 4.42 | 4.47 | 3.84 | n/a | 1740 | - |
| Vinto Coopani | Mean | 6.21 | 5.52 | 1.91 | 3.34 | 0.00 | 9192 | 0.344 |
| **(N=29)** | SD | 2.87 | 2.32 | 1.25 | 1.65 | n/a | 1256 | - |
| Kellhuiri | Mean | 4.96 | 6.28 | 1.97 | 3.72 | 14.60 | 13180 | 0.274 |
| **(N=25)** | SD | 2.54 | 4.72 | 1.31 | 2.15 | 14.94 | 1351 | - |
| Region | Mean | 5.61 | 7.13 | 4.83 | 5.33 | 14.60 | 18092 | 0.312 |
| **(N=181)** | SD | 2.59 | 4.12 | 3.69 | 3.35 | 14.94 | 12510 | - |

**Data Source:** SANREM CRSP 2006. [1]Education refers to the education of the head of household. [2]1 USD = 7.9 Bolivianos in 2004.

The large variation in income between the upper and lower regions is in part due to field size but also to issues associated with economic isolation. Access to transportation, labor markets, agricultural markets and infrastructure are factors of income and differ greatly between the upper and lower communities. San José Llanga lies on a route that has public transportation more than once each day. Residents of San Juan Circa reported that they have poor access to public transportation but are able to use their networks of friends and neighbors that own means of transportation to gain access to transportation. Both communities report that infrequently middlemen travel to the communities with large trucks to purchase potatoes.

During a focus group, households from San Juan Circa and San José Llanga were asked about their position in the Patacamaya market. Venders from both locations mentioned that the middlemen were organized and set low prices for their crops. Venders from San José Llanga said that they had organized the six *cantons* to set the price of their

potatoes, agreeing not to sell below a certain price. San José Llanga venders also have contracts with quinoa buyers in La Paz. Households in both communities are integrated into agricultural markets and rely on social capital and formal networks in order to navigate barriers to market and negotiate prices.

In the more distant Umala towns of Vinto Coopani and Kellhuiri, many of the households felt that the barriers to selling goods at Patacamaya were too high to justify vending. These two towns are further from Patacamaya and have much less access to transportation. Their fields are much smaller than those of San José Llanga and San Juan Circa. During a focus group with members from these communities, households were asked about their market participation. Below is a sample of their responses.

> *I no longer sell a lot of potatoes because they do not produce well in my plots and it is troublesome to sell because I no longer have a stall to sell from. Also the intermediaries in Patacamaya give low prices. Now the potatoes and chuño are for consumption by my family.*
>
> *I no longer sell in the markets because of the effort involved in bringing my products from my house to the market. In the small plot I now harvest 1 quitale*[4] *where I once harvested 10 cargas*[5]*. I used to bring 10, 15, or 20 cargas to sell. It is very expensive to sell and the price of using the animals* [to carry the freight] *is not considered.*
>
> *I do not sell anything, not even a ¼ arroba*[6] *because my field is small. If my field was big I would produce to sell….What we sow each year is only for consumption because we do not get enough to use in other ways.*

It is evident from their responses that field size, productivity, and marketing costs are major constraints for producers in this area. Participants reported that the terrain, which is very rough in that area, was a major constraint to field size. On average,

[4] 1 quintale=100kg
[5] 1 cargas~35kg
[6] 1 arroba=12.5 kg

fields in Vinto Coopani and Kellhuiri are less than half the size of those in San José Llanga and San Juan Circa. Members of Vinto Coopani and Kellhuiri are generally less educated, and have fewer cattle.

Income composition is an indicator of the livelihood strategies that households in the communities are using. Both San José Llanga and San Juan Circa generate the majority of their income from crops (Figure 2.2). Kellhuiri and Vinto Coopani are more evenly spread across activities.

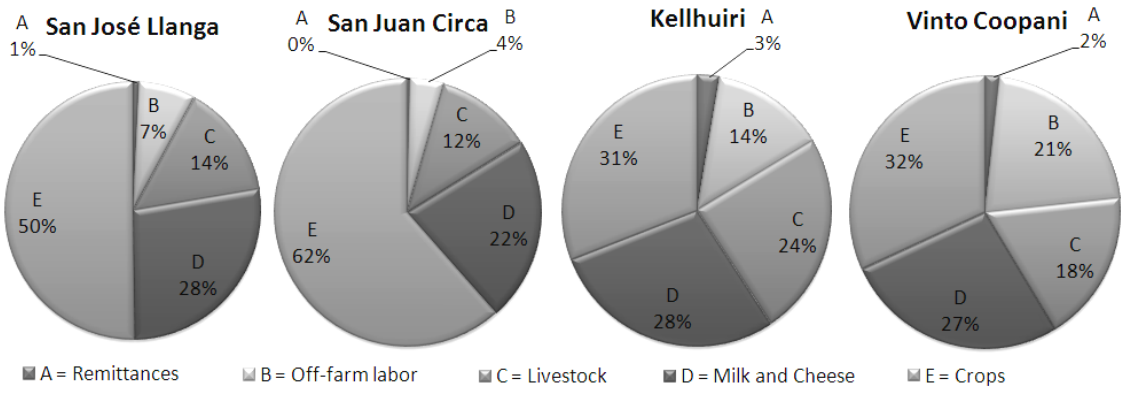


Figure 2.2 The income compositions by community in the region of Umala.*

**Data Source:** SANREM CRSP 2006. *For a complete decomposition of income, see appendix II.

The income data supports the general theories of resource constraint and substitution discussed in the literature review. Kellhuiri and Vinto Coopani both have land constraints which translate into underutilized labor in the household. Those households allocate proportionally more labor to off-farm income than the households in San José Llanga and San Juan Circa, which have access to larger parcels of land and able to utilize greater amounts of labor to work it.

### *2.6.2 Regional Context: Ancoraimes*

The municipality of Ancoraimes is located in the province of Omasuyos in the department of La Paz. It is about 90km Northwest of La Paz. It has a population of 15,199 and the altitude ranges from 3,750 to 4,300 meters. The four survey communities lie along a watershed that flows down from the northwest towards Lake Titicaca. The region is able to benefit from a lake effect, increased precipitation and temperature, especially the communities nearer the lake. The average annual precipitation is between 530 and 638 mm. The average *Gini Index* of the survey communities in Ancoraimes is 0.33, 0.1 greater than Umala but still much below the county statistic of 0.592.

A long history of high human populations and immigration has resulted in fragmented fields. SANREM CRSP has reported that "greater intensity of land use, smaller land holdings, increased land area in forages, and reduction in animal stocks" (SANREM CRSP 2008) have reduced fallow periods in the two study regions, but most markedly in Ancoraimes.

A road running through the watershed provides the only option for transportation. Residents reported that public transportation exists along the main road but is not dependable. On days that there is not a market near-by individuals often spend hours on the side of the road waiting for a truck or car to pass and pick them up. On market days, a small bus usually drives up the watershed two times, once in the morning and once in the evening.

Households reported selling goods in a variety of markets, both local and urban. Nearly all the households reported using the local market at Chejepampa, which is

less than 15 km from all the households. Members also reported selling in the urban markets of La Paz and El Alto and the regional markets in Morocollo and Achacachi.

During a focus group of residents in the area, participants from each community were divided up according to their relative market use. They were asked to discuss their perceptions of the markets and the barriers to entry. The individuals that sold less often in the markets cited production of unmarketable products, opportunity cost of going to market, cost of selling, and a wide variety of social constraints such as safety concerns and discrimination that takes place in the city. These individuals also expressed that they would like to sell in the bigger cities but that they did not have a stall to sell from and that they are charged if they sell on the streets. Those individuals that often sold in markets cited low access to transportation and product as their larges constraints. Many of these individuals sell through family members that live in cities or use agencies to overcome barriers to entry into the city markets. Both groups indicated that low price was a barrier to selling. See Appendix II for a summary of the focus group findings.

The communities in the Ancoraimes region also have a wide variety of household characteristics (Table 2.2). The average income in this region is lower than in the Umala region. Chinchaya has the largest income, more than five times the income of Cohani, while Chojñapata has the lowest Gini index.

Table 2.2 Baseline statistics of the four survey communities in Ancoraimes

| Community | | Members in Household | Education[1] | Cropland (ha) | Cattle | Alpaca & Llama | Total Income (Bs.) | Gini Coefficient |
|---|---|---|---|---|---|---|---|---|
| **Calahuancani** | Mean | 3.87 | 6.74 | 0.51 | 2.00 | 7.88 | 7260 | 0.360 |
| (N=23) | SD | 1.49 | 5.17 | 0.30 | 1.45 | 5.16 | 1074 | - |
| **Cohani** | Mean | 4.37 | 5.19 | 0.22 | 1.22 | 4.80 | 2816 | 0.369 |
| (N=27) | SD | 2.15 | 3.17 | 0.13 | 1.05 | 3.27 | 404 | - |
| **Chinchaya** | Mean | 5.04 | 8.30 | 0.88 | 3.58 | 2.00 | 10092 | 0.384 |
| (N=57) | SD | 2.19 | 4.75 | 0.61 | 1.65 | n/a | 853 | - |
| **Karkapata** | Mean | 5.40 | 6.00 | 0.38 | 1.80 | 4.00 | 3596 | 0.301 |
| (N=15) | SD | 2.20 | 4.77 | 0.23 | 1.47 | n/a | 536 | - |
| **Chojñapata** | Mean | 4.67 | 5.04 | 0.35 | 3.30 | 27.74 | 5506 | 0.228 |
| (N=27) | SD | 2.99 | 2.86 | 0.19 | 2.00 | 17.50 | 433 | - |
| **Region** | Mean | 4.70 | 6.67 | 0.56 | 2.68 | 16.26 | 6851 | 0.327 |
| (N=149) | SD | 2.28 | 4.45 | 0.49 | 1.83 | 16.07 | 5490 | - |

**Data Source:** SANREM CRSP 2006. [1]Education refers to the education of the head of household. [2]1 USD = 7.9 Bolivianos (2004).

Chinchaya is only a little more than a mile from the water's edge. Households there are able to take advantage of the flat, fertile land surrounding the lake and a strong lake effect on climate. The bottom of the watershed also has much greater access to the local market and transportation out of the region. Note that Chinchaya has a markedly higher income, higher education, and larger fields. Chojñapata is both furthest from the lake and the community at the highest altitude of the region (4,300 m). In this higher and colder climate, households are more dependent on camelid pastoralism than the households in the lower communities.

Once again the income composition expresses a relationship between access to land, cropping income, and access to crop land (Figure 2.3). The camelid agropastoralist strategy is obvious in Chojñapata's assets and income composition. Households there

have both the greatest number of camelids and draw the larger percent of income from both livestock sales and livestock byproducts. Chinchaya successfully takes advantage of the fertile shore of Lake Titicaca. On average, households in Chinchaya are able to generate more income from growing onions than the average total income of households in Cohani or Karkapata. Cohani, the community with the least access to cropland, generates more than half of its income in labor markets off the farm.

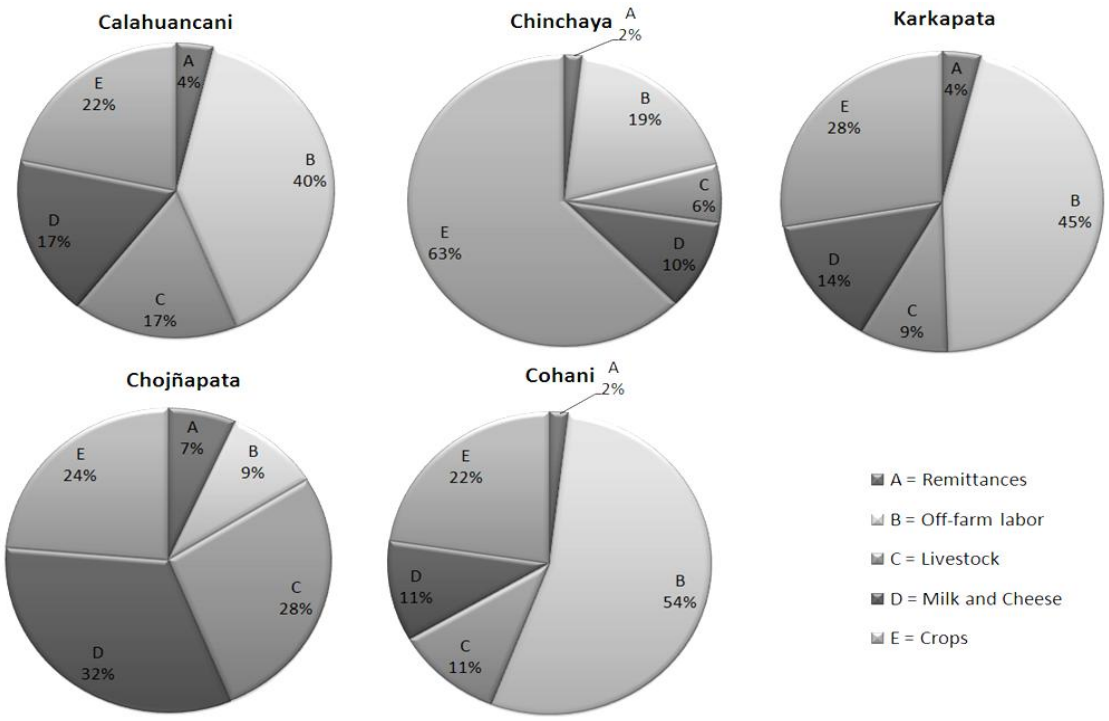


Figure 2.3 The income compositions by community in the region of Ancoraimes.*

**Source:** SANREM CRSP 2006. *For a complete decomposition of income, see Appendix III.

## 2.7 Concluding Remarks

The Aymara have a long history of coping and adaptation in the Altiplano. Their system of *ayllus* has historically allowed them access to different ecological zones and a mobile labor force. The Incas allowed the *ayllus* to remain and even strengthened them as a means to conserve sustainability of Altiplano populations and as a unit to be taxed. Colonization replaced the *ayllus* with *haciendas* which taxed the Aymara through labor for rent schemes. Furthermore, Aymara were taxed through labor by the Spanish crown in order to work the mines that funded much of the Spanish conquest.

Independence and multiple land reforms have returned ownership of the land to the indigenous groups of the Altiplano. Although the *ayllus* no longer exist, households still practice reciprocity in the form of labor and community labor.

The regions of Umala and Ancoraimes have many differences. Initial land ownership was determined by releasing *hacienda* lands back to those that worked it. This may mean that in some locations current population densities and plot sizes are, in part, a residue of the *hacienda* system. In Ancoraimes, land fragmentation is driving some communities to invest more heavily in labor markets while others have begun to specialize in onions as a cash crop. In Umala, San José Llanga's large fields have led to prosperity though cropping and dairy while low access to cropland has pushed households in Vinto Coopani and Kellhuiri into labor markets. Each community has had to adapt to its unique historical and geographic characteristics.

# Chapter 3: Literature Review

Smallholder and subsistence farmers' decisions are made within highly linked and complex systems. The variety of livelihood strategies these farmers have developed falls on a continuum between subsistence production and specialized production for market (Morton 2007). A household's location on that spectrum is determined by its production capabilities, the benefits it perceives associated with specific activities, and the opportunities provided by the natural and human environment. In addition to their own well-being, household actions affect their natural (Gunderson and Holling 2002) and human environments (North 2005; Ostrom 2009), their access to assets in the future, and their own capability (Chambers and Conway 1991) to use those assets in a meaningful way (Ellis 1998; Bebbington 1999).

The sustainable livelihoods framework is used to investigate household decision making and ability to provide for its needs. A systems approach is required to model the highly interconnected relationships that exist across many scales within and between ecosystems and human systems. Although "there is no single accepted way of formulating the linkages between human and natural systems" (Berkes and Folke 1998, 9), research originating from multiple disciplines has found the concepts of systemic sustainability, resilience, and adaptability useful when thinking about complex systems.

The following literature review will provide a summary of the theories and empirical evidence that this research draws on for its conceptual framework. It begins with an introduction to the systems approach to human and natural landscapes, sometimes called the socio-ecological systems (SES) framework. A review of literature about interactions at a finer, household scale follows. The sustainable livelihoods approach is used to investigate how households choose their economic strategies and provide for their needs. Finally, several themes discussing the relationship between livelihoods and SES are presented. Ultimately, this research aims to examine the impact that specific household characteristics and livelihood strategies have on SESs.

## 3.1 Socio-Ecological Systems

Where humans manage landscapes and use the resulting ecological services, their action can work towards depreciating or appreciating the health and stability of the landscape. Land management practices must accommodate the human needs for services and while maintaining environmental health, working between and across the systems to be successful (Walker and Salt 2006). The term socio-ecological system (SES) is used to describe the entire domain of human-nature interactions. Gunderson, Holling and Light (1995) coined the term "panarchy" to emphasize that interactions take place across all levels of hierarchy within SES. This section begins with a brief description of complex systems theory and then uses the analogy of the adaptive cycle to set the stage for a discussion of the socio-ecological systems (SES) approach.

### *3.1.1 Complex Systems*

> *Simple things interacting in simple ways can yield surprisingly complex outcomes (Serendip 1995).*

In 1928, Ludwig von Bertalanffy proposed that the reductionist and linearity assumptions of the "scientific method" were not valid methods for analyzing complex systems (Henshaw 2010). Bertalanffy claimed that complex systems were governed by non-linear relationships, and components of a system must be examined within the context of all other parts of the system. Specific relationships between components cannot be studied in isolation of their entire system of relationships. Analytical findings made by extracting individual variables from the system cannot be generalized onto the system. Eoyang (2001) discussed the problems with applying a reductionist approach to human behavior and other complex systems.

> Traditional social science research methods depend on a variety of assumptions about the nature of change and the nature of evidence. Many of those assumptions are not accurate in systems involving humans and their complex relationships. Complex adaptive systems share a variety of characteristics that make standard research and data analysis methods ineffective. Six of these characteristics and their effects on research methods are described below: Nonlinear causality; high dimensionality; dependence on context; discontinuity; sensitive dependence on initial conditions; and massively entangled levels. (Eoyang 2001, 50)

The systems approach describes a holistic (as opposed to reductionist) method for analyzing characteristics that result from interactions within complex systems. It is often used to study subjects that are known to have a high degree of interconnectedness and be sensitive to initial conditions, such as ecological and weather systems. Bar-Yam of the New England Complex Systems Institute (2002) compiled a list

of key insights that the study of complex systems has produced. The list includes multiple scales of interactions, nonlinearity, pattern formation, and multiple stable states.

Much of the vocabulary used in the systems approach has its origins in the field of mathematics. “Phase space” describes the environment of total possible configurations of a system (Gibbs 1901). The phase space is described by the complete set of possible variable value combinations. The topology of the phase space is the result of relationships between the variables that compose the system. If those relationships are dynamic, they create a nonlinear topology that varies through the phase space. Variation in the topography of the phase space can result in pattern formation, in which a system oscillates through a sub-region of its phase space. The system continues to be dynamic and exhibit nonlinear properties, but oscillates around a set of variable values. Those values are known as “attractors” and may be metaphorically compared to equilibrium values in linear systems. All the locations within the phase space that are dominated by an attraction to a specific attractor are said to be in its “basin of attraction” (Figure 3.1a).

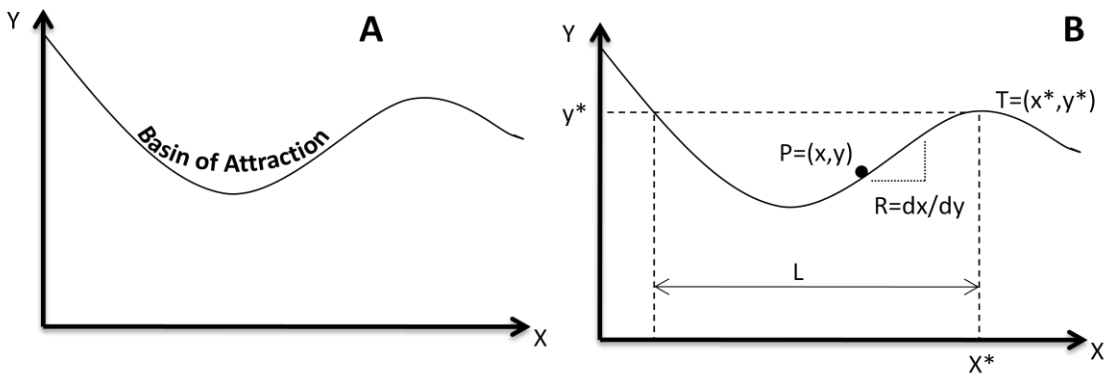


Figure 3.1 Illustrations of phase space topology and a basin of attraction.
A. The basin of attraction is metaphorically described by the set of points that are attracted to a local minimum; determined by the topography and relationships within the system.
B. Resilience is the characteristics of the system that work towards keeping the system within its current basin of attraction.
**Source:** Adapted from Walker et al. 2004.

Within a phase space, there may be many possible basins of attraction, or multiple stable states. A system may enter a basin of attraction, remain there for a period of time, and then become unstable. It may overcome the dynamics that attracted it into the basin and exit, where it may eventually fall into another basin. The "threshold" is the point or set of points at which the system leaves one basin of attraction and is dominated by a different set of relationships ("T" in Figure 3.1b).

The resilience of a system "is the capacity of a system to absorb disturbances and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al. 2004, 2). Pushed beyond a threshold, a system is dominated by a different set of attractors and moves into a new basin of attraction. Such a regime change may result in a very different set of characteristics. There are four aspects that are crucial to a system's resilience (Ibid.):

1. Latitude or the maximum amount of distortion a system can accommodate before it can no longer recover (L in Figure 3.1b).
2. The resistance of the system to change (R in Figure 3.1b).
3. The current position of the system in relation to its critical points (P in Figure 3.1b).
4. The cross-scale influences of all the systems in its environment (changing topography of the phase space).

The above four factors of resilience can be illustrated in a very simple and commonly used application of systems theory: the predator-prey dynamics of foxes and rabbits. This example is a "coupled system" that only has two components. Within this example, the population of each animal is a function of the population of the other in the previous time step. As the rabbits' population increases, so does the foxes' food supply which is the only constraint to the fox population in this model. The result is an increase in the fox population and with it an increase in the number of rabbits consumed, causing a decrease in the rabbit population. As the foxes' reduce the rabbit population, their food becomes scarcer and they die off allowing the rabbits begin to repopulate. The two-species system is within a basin of attraction described by their population oscillations. If the fox population becomes too great, a threshold may be reached (R* in Figure 3.2a) where the rabbit population has been reduced below the critical mass that it needs to repopulate. In that case, the topology of the coupled system will draw both populations to zero (Figure 3.2b).

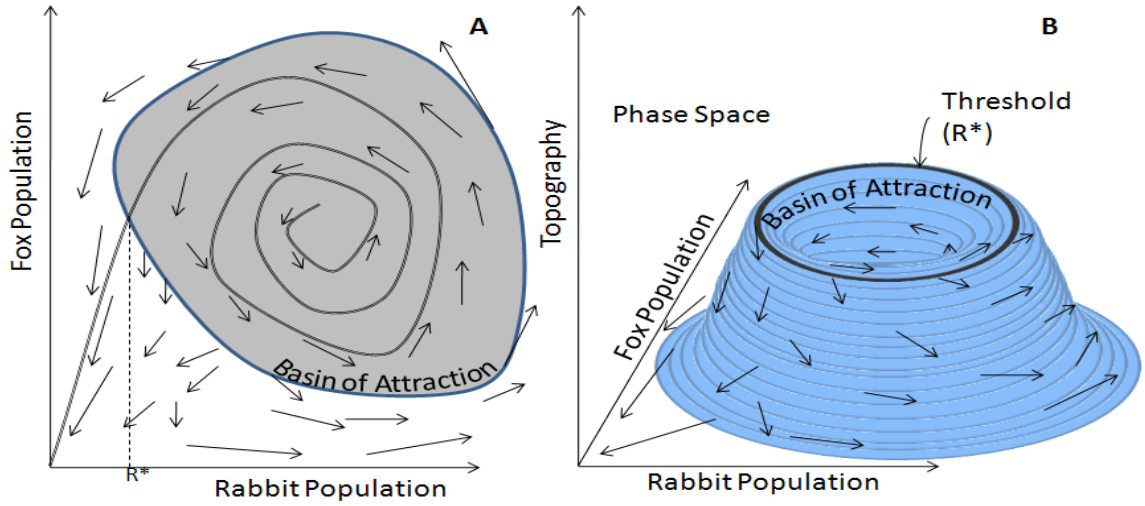


Figure 3.2 The topology governing the coupled populations of predator-prey model, illustrated by the relationship between fox and rabbit populations.

A. A coupled predator prey model using foxes and rabbits illustrates the existence of a basin of attraction with both populations greater than zero and a threshold (R*), of which beyond both populations die off. The arrows indicate the population change vector.

B. The systems topology is determined by the relationships between fox and rabbit populations. Outside of a small set of population values, both populations will be drawn down to zero.

If the rabbits have truly been eliminated, the phase-space of the system has been reduced by one dimension and the original configuration is no longer an option. Returning to the parameters defined by Walker et al. (2004), "latitude" is the critical mass of rabbits and foxes required for repopulation. "Resistance to change" is determined by the speed that each species responds to the others' changes in population through repopulation and starvation. "Current position" is the current population levels. The overall topography of the two-species system is static, with a single basin of attraction and animal populations falling off to zero outside of that basin (Figure 3.2b).

### *3.1.2 The Adaptive Cycle*

Within ecology, the systems approach has been used to describe the movement of natural systems through phases of conservation, exploitation, and adoption to stresses and shocks. The "adaptive cycle" is a tool used to focus attention on the cycle of destruction and reorganization within social and ecological systems. The model of the adaptive cycle systems, reviewed by Gunderson and Holling in *Panarchy* (2002), includes four phases of change: conservation, release, reorganization, and growth/exploitation.

Each phase is characterized by differing levels of potential, connectedness, diversity, and resilience. As systems become more productive and efficient they also become more interconnected. This progression leads to a reduction of diversity and an increase in the rigidity of the system. Rigidity reduces the system's ability to adapt to changes which reduces resilience and eventually leads to collapse and disorder. A state of high disorder has low potential productive capability but opens up opportunities for new arrangements of resource extraction and strategies of survival. Actors are able to exploit newly formed niches, increasing diversity and the resilience of the system as a whole (Gunderson and Holling 2002).

The process of creation and collapse described by the adaptive cycle allows for creative destruction and evolution within the system. Transitions between the cycle phases take place at different speeds and on many different levels at once. As a system moves through its cycles, micro-systems within it are adapting to the changing macro environment, in turn affecting their larger environment. In addition, interactions taking place at the species level affect the system as a whole, determining the stability of their

environment. The evolution of a system is both a function of micro-systems reacting to changes in their environment and the emergent macro-system itself reacting to feedback across levels.

The qualities of potential productive power, connectedness, diversity, and resilience described by the adaptive cycle provide a metric by which to begin thinking about the quality or health of a system as a whole. Rapport, Costanza, and McMichael (1998, 1) promote the use of three indicators to measure ecosystem health: vigor, organization, and resilience. "Vigor", or potential and productivity, is a measure of the number of interactions that are taking place within the system. Interactions are the mechanisms that transmit information through the system. "Organization" refers to the structure of the system, specifically the connectedness between components and scale levels and the diversity within the system. The extent to which the networks within the system are able to reorganize themselves determines how the system as a whole will be able to adapt to changes or shocks. If the change is large or the networks are highly entrenched, there will be a large collapse. If flexibility remains, the system will be able to absorb the shock by reorganizing. According to Rapport, Costanza, and McMichael (1998) the "resilience" of a system is determined by the persistence of relationships within a system. It is a measure of the ability of these systems to absorb changes in state variable, driving variables, and parameters, and still persist (Holling 1973).

### *3.1.3 Socio-Ecological Systems (SES) Models*

The socio-ecological systems (SES) approach applies the lessons learned by ecologists to systems composed of both human and ecological relationships.

Smallholders' household decisions take place within socio-ecological systems that can affect not only their economic situation but also the future quality of the households' assets and environment. For example, poor soil management can cause the degradation of a field, which can then impact species diversity within the environment. Farmers can impact variables such as the water table or the flora of an entire region. Collectively, societies impact the world climate, which in turn may influence every socio-ecological scale.

The Resilience Alliance, a multidisciplinary research group that explores the dynamics of complex adaptive systems, uses a foundation in ecological systems to formulate a model of SESs that mimics the cycles of stress and release that were first observed in ecological systems. The SES framework describes "an integrated system in which the dynamics of the social and ecosystem domains are strongly linked and of equal weight" (Resilience Alliance 2010) and "are composed of multiple subsystems and internal variables within these subsystems at multiple levels" (Ostrom 2009, 419). One significant difference between human and ecological systems is that individuals exist in communities governed by institutions. Individuals operate within a social system where their social capital depends on the institutions and resilience of the social unit or community (Adger 2000). A second difference between social and ecological systems is that actors in social systems have the ability to learn and exhibit agency and foresight. Learning provides a feedback loop that encourages adaptation. Through learning, agency, and foresight, humans can choose to act consciously to preserve the resilience of their SES (Norberg et al. 2008).

Within the social sciences, resilience has been defined as "the ability of human communities to withstand external shocks or perturbations to their infrastructure, such as environmental variability or social economic or political upheaval, and to recover from such perturbations" (Klein, Nicholls, and Thomalla 2003, 40). Walker et al. (2004) define the resilience of an entire SES as 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. This definition explicitly includes the concepts of change and reorganization within the system as factors of resilience. An actor's capacity to affect the structures and institutions that create its environment and to change within that environment, are also factors of resilience.

The SES perspective provides a vantage point by which to express the highly interrelated and complex systems that create a landscape. Its strength lies in its holistic approach to addressing the inherent complexity and adaptability of human and natural systems (Holling, Gunderson, and Perterson 2002). As many nested systems move through their individual phases and thresholds are approached, humans are able to manage aspects of the systems intentionally, both adapting to the environment and adapting it to their needs. As thresholds are crossed, intentionally or not, returning to earlier states may become very difficult or impossible. Human foresight, institutions, the adaptive cycle, and sensitivities to initial conditions create trajectories that do not necessarily converge on the same sets of attractors. Human-ecosystem landscapes diverge, in some countries creating booming economies and healthy ecosystems while a second very similar landscape may produce a stagnant economy with deteriorating ecosystems. The sustainable livelihoods framework, discussed in the following sections,

models actor behavior and decision making in their social and natural context. It contributes to the resilience framework by examining concepts such as capitals and capabilities, that link human agency to the SES. The sustainable livelihoods framework will be used to analyze households for drivers of livelihood strategies and individual impact on the SES.

## 3.2 The Sustainable Livelihoods Framework

The sustainable livelihoods (SL) framework is useful for assessing how and why individuals or household units make their decisions. It focuses on the household's ability to sustainably provide for itself within the complex system of its environment (Scoones 1998). Within this framework, household economics seeks to better understand how people make a living and how successful their chosen strategies are, given the capitals they access and control. The following sections will focus on the assumptions and implications of household economics, the livelihoods model, and how these theories contribute to the sustainable livelihoods approach that will be applied in this research.

### *3.2.1 Household Economics*

Household economics formed out of the need to model households with members that share resources and where time allocation includes labor markets and household activities (Becker 1962). Initially, the model included only physical factors of production; land, labor, and capital goods. The resources available to households has since been extended to include other tangible resources and intangible resources such as human and

cultural characteristics and categorized into a list of capitals (Winters 2002; Valdivia et al. 2003).

Formal use of household models originated with the work of Alexander Chayanov in the 1920s to describe an economy without labor markets. Chayanov characterized households by their access to land and labor. The model supports his theory that Soviet peasants with flexible access to land but without a labor market would not produce a surplus that could be used to feed Soviet non-agriculturalists (Sadoulet and De Janvry 1995). Chayanov (1926) observed:

> Since the labor family's basic stimulus to economic activity is the necessity to satisfy the demands of its consumers, and its work hands are the chief means for this, we ought first of all to expect the family's *volume of economic activity* to quantitatively correspond more or less to these basic elements in family composition. (Qtd. in Benjamin 1992, 288)

The consequence of imperfect labor markets is the violation of the neoclassical assumption of separability, where actors in the market make consumption and production decisions independently in order to maximize utility (Benjamin 1992; Sadoulet and de Janvry 1995). Where there are imperfect or missing markets, actors will make consumption and production simultaneously, a phenomenon known as nonseparability. The condition of nonseparability obscures the household's optimal production/consumption choices from the model but does show that the level of production is lower than it would be with functioning markets. For Chayanov's peasants, production is lower than that predicted by neo-classical economics because their incentives to produce fall when they have achieved their basic needs.

More recently, Ellis used household models extensively in order to describe the rural agriculture households in environments with missing or incomplete markets. Ellis uses the term 'peasants' to refer to rural agricultural households that are "only partially integrated into imperfect markets" (1993, 4). The rural households in this study experience various degrees of market integration and are consistent with Ellis's definition of the peasant household.

Theoretically, markets have the capacity to increase opportunities available to households, but many real life obstacles may reduce market benefits. These constraints include transaction costs, shallow markets, price risks, and risk-aversion (Ellis 1993; Sadoulet and de Janvry, 1995; Omamo 1998; Key, Sadoulet and de Janvry, 2000).

The definition of transaction costs varies considerably though the literature. In Coase's *The Problem of Social Cost* (1960), transaction costs are limited to the cost of market transactions. McCann et al. (2004) extend the definition to include the development of market-enabling institutions, changes in the institutional environmental and legal system, and the dimension of time. The broader definition of transaction costs allows for a more complete analysis of the effects of policy on market integration, but continues to run into costs that are difficult to categorize.

There are several ways of measuring transaction costs. Key, Sadoulet, and de Janvry, (2000) divided them into proportional and fixed. Proportional transaction costs raise the price paid by the buyer and reduce the revenue received by the seller. The differential creates a "price band within which some households find it unprofitable to either sell or buy" in the market (Key et al. 2000, 245). For small farmers, the key effects of proportional transaction costs are to reduce the capacity of farmers to participate in

markets. Omamo (1998) estimated fixed transaction costs by measuring the distance to market. They found that transaction costs reduced the incentives felt by the household to specialize in cash crops, which require that households act in the markets both to sell their products and to buy consumption products. Fixed transaction costs, such as the costs of price negotiation, affect the quantity of products that must be exchanged per transaction for the transaction to be valuable for both parties. Key et al. found that fixed transaction costs could produce "discontinuities in responding to market incentives" (2000, 258). The result is that both proportional and fixed transaction costs lower the profitability of market activities and reduce market participation.

Low levels of market participation may also be the product of households reducing their exposure to risk. Risk may motivate households without access to insurance mechanisms, to deviate from profit-maximizing behavior toward risk reduction strategies (Ellis 1993; Valdivia, Dunn, and Jetté 1996). They sacrifice the possibility of greater profit in order to gain income security. For example, households that are vulnerable to climate shocks and do not have access to credit may diversify investments in order to reduce the impact of poor weather on crop incomes, at the expense of profit maximizing investments (Morduch 1995). In an effect described by Lipton (1993 from Zimmerman and Carter 2003) as the "Micawber Threshold", households with low initial levels of assets may, through risk reducing behavior, reduce their stock of assets over time where households with greater initial levels, increase their stocks. Zimmerman and Carter, (2003) found that households with fewer assets pursue an assets smoothing strategy, resulting in lower-yielding income portfolios compared with those with greater initial assets. Diversification as a risk-reducing mechanism is further supported by a

study of different agro-ecological and economic regions of western Africa (Reardon, Delgado, and Matlon 1992). Likewise, livelihoods in the Altiplano take place in the context of a volatile climate, high risk factors, and poor access to credit (Valdivia and Quiroz 2001). In group meetings involving three Altiplano communities, "producers indicated the greatest threat to their well-being were weather-related risks" (Gilles and Valdivia 2008).

In shallow agricultural markets, producers and consumers are faced with prices that are correlated with their own supply and demand. For example, during drought years, the prices and demand of agricultural products are high while the supply is low. This correlation reduces the utility of markets for the peasant farmers, pushing households toward self-sufficiency (Sadoulet and de Janvry 1995).

### *3.2.2 Livelihoods Models*

Livelihoods models gained recognition in the 1990s as new theories based on food security information combined with the development theories of the 1980s concerning governance and policy (Ashley and Carney, 1999). Its application in household economics seeks to better understand how people make a living and the success of the strategies that they use, using the capitals framework. Chambers and Conway describe livelihoods as "[comprising] people, their capabilities and their means of living, including food, income and assets" (1991, 1). According to the livelihoods model, households exist in both natural and social environments, each with its own risks and uncertainties that "individuals, households and communities have to negotiate to reduce their vulnerability and improve their welfare" (Valdivia and Quiroz 2001, 3;

Valdivia 2004). Understanding how households successfully navigate these obstacles is important for those trying to alleviate food insecurity and poverty. For example, a study by Adato and Meinzen-Dick (2002) uses the sustainable livelihoods framework to assess the impact that agricultural research has had on poverty in order to better understand which types of research best contribute to the reduction of poverty.

Generally, livelihoods models include household resources (capitals), human capabilities (agency), and institutions. They investigate how capitals and agency are combined into activities that combine to create livelihood strategies within the natural and social structures in which the household exists. CARE, an international humanitarian organization, uses the livelihoods framework to address poverty by identifying and working with those that are the worst off (Carney et al. 1999). They use the concept of livelihood security to emphasize the "adequate and sustainable access to income and other resources to enable households to meet basic needs" (Frankenberger 1996). Security is measured by the household's risk of failure or vulnerability, which is often tied to its access to resources. CARE uses household economics to measure the household's access to assets, and the livelihood framework to assess opportunities for improved security by addressing the issues that make the household most vulnerable.

### *3.2.3 The Sustainable Livelihoods (SL) framework*

The sustainable livelihoods (SL) framework is an assets-centered approach used to understand livelihood strategies in a context of imperfect markets, culture, history, environmental systems, and institutions. This framework includes the aspects of the livelihood security that addresses basic needs, but it also emphasizes the social,

natural, and temporal context of the household. It "offers a way of thinking about livelihoods that helps order complexity and makes clear the many factors that affect livelihoods" (Department for International Development 1999, 2) including the need of households to maintain access to capitals over time and absorb shocks. The SL framework is used by many development organizations (e.g., DFID and Oxfam) and researchers that want to address development issues from the bottom up.

Early in its conception Chambers and Conway defined sustainable livelihoods as those that "can cope with and recover from stresses and shocks, maintain or enhance its capabilities, assets and entitlements, while not undermining the natural resource base" (1992, 6). At that early point, SL was concerned with addressing sustainability at the household level. Since that time, SL has expanded to include the social context of the household. In an article documenting the evolution of the livelihoods framework, Scoones (1998) discusses the aim of the SL framework:

> Given a particular ***context*** (of policy setting, politics, history, agroecology and socio-economic conditions), what combination of ***livelihood resources*** (different types of 'capital') result in the ability to follow what combination of ***livelihood strategies*** (agricultural intensification/extensification, livelihood diversification and migration) with what ***outcomes***? Of particular interest in this framework are the ***institutional processes*** (embedded in a matrix of formal and informal institutions and organizations) which mediate the ability to carry out such strategies and achieve (or not) such outcomes. (Scoones 1998, 3, italics in original)

The SL framework "seeks to analyze and understand the development and dynamics of livelihood strategies based on the assets and opportunities available within the context of the relevant external and institutional environment" (Parvez and Rasmussen 2004, 106). It is in exploring these different dimensions of context—such as

cultural, historical, institutional, and ecological—that the SL framework has really advanced our understanding of livelihoods. The household is both affected by and affects each of these dimensions over time, so that action in one time period defines the parameters of another.

Bebbington's capitals and capabilities framework (1999) further advanced the SL perspective by incorporating tight feedback loops between capitals, capability, and social capital while North, Ahn, and Ostrom (among many others) have championed the role of institutions as a method for describing the human environment. Bebbington's framework emphasizes that capitals "are not simply *resources* that people use in building livelihoods: they are the assets that give them the *capability* to be and to act" and affect their "perceptions of well-being" (Bebbington 1999, 2022). In Bebbington's model, social capital plays a large role in livelihoods because "relationships are a critical precursor to access being possible" (Ibid. 2039). For North (2005), social capital determines the rules by which human interests interact through institutions, while for Ahn and Ostrom it is the "set of prescriptions, values, and relationships created by individuals in the past that can be drawn on in the present and future to facilitate and overcome social dilemma" (2003, 73).

"Path dependence" is a term used to acknowledge that current conditions are the result of the past, and that culture plays a part in the opportunities that we perceive. Past knowledge and experiences are imbedded in our language, perceptions, institutions and technology. Culture provides the filter though which all learning and problem solving take place (North, 1994). It creates the incentive structures that guide individuals as they make decisions and determines the set of all possible actions.

Incomplete access to information and imperfect feedback loops create uncertainty in human systems. Institutions play a vital role in constructing the parameters of human interaction. They function to reduce uncertainty by reducing the possible outcomes of an interaction and "[structuring] human interaction by providing an incentive structure to guide human behavior" (North 2005, 66). Laws and cultural norms create the venue for transactions to take place, where actors know *ex ante* what the results of certain actions will be. Ahn and Ostrom note that institutions "may provide sufficient information and deterrents to greatly increase the likelihood that Trustees will behave in reciprocal ways even when they are faced with high material temptations to break the trust placed on them" (2008, 84). If all the actors share knowledge of the environment that they are acting in, law and norms increase the symmetry of information and the predictability of the transaction.

North agrees that the human perception of uncertainty "can be reduced by the accretion of knowledge" (North 2005, 73). Human knowledge is the mechanism by which uncertainty and unpredictability is transformed into probability distributions of possible future arrangements, or risk. Growth in the knowledge pool beyond the capacity of a single person necessitates specialization. Specialization requires "a vast range of institutions and organizations that enable specialized individuals to have access to the other consumer markets that they need in order to take advantage of the potential economies" (Ibid., 121).

At the household level, specialization allows producers to take advantage of economies of scale and use their own competitive advantage to increase productivity. While this division of labor has been instrumental in increasing productivity, it also

increases the potential for asymmetric information and transaction costs. Specialized production increases the number of required transactions by the specialist. If there are costs associated with transactions they will reduce the benefits generated through specialization. Institutions must then facilitate transactions in transportation, negotiation, measurement (collection of information), search, opportunity costs, and enforcement. However, the formation of the necessary institutions and infrastructure are not inevitable (North 1992). Where they do not exist, markets will not provide incentives for the division of labor and specialization. Thus, there are multiple thresholds in the development of societies and markets: some that do include high degrees of specialization and some that do not.

Furthermore, each individual within a society will relate to the institutions that exist in a different manner. Winters, Davis, and Corral (2001) found that social capital plays an important role in accessing infrastructure that is used to generate income. Social capital may provide unequal access to other institutions, such as insurance mechanisms that reduce perception of risk or cooperatives that reduce transaction costs, which produce different incentive structures associated with market participation and specialization.

Similar to the terminology used in the SES framework, institutions must be resilient to shock and flexible to changes in their environment. Because institutions exist in a complex environment without complete knowledge, they must be flexible and adaptable. In societies and economies, adaptive efficiency "entails a set of institutions that readily adapt to the shocks, disturbances, and ubiquitous uncertainty that characterize

every society over time" (North 2005, 78). In the next section, further linkages between the SES and SL frameworks will be explored.

## 3.3 Sustainable Livelihoods within Socio-Ecological Systems

Approaching the subject of livelihoods from a perspective of social-ecological systems creates the opportunity to analyze livelihoods strategies for their ability to succeed in a complex and dynamic environment. SESs describe a complex domain of interactions that includes both people and the environment that they inhabit. The language used by Chambers and Conway to describe sustainable livelihoods, which "cope with and recover from stresses and shocks" (1991, 6), is very similar to that of the SES's framework of resilience as "the capacity…to absorb disturbances and reorganize…so as to still retain essentially the same function" (Walker et al. 2004, 2). In the SES framework, institutions also must "maintain social flexibility for adaptive response" (Carpenter, Brock, and Ludwig 2002, 193). All three perspectives refer to a multiple thresholds model where variables interact across scales.

Including resiliency and adaptability in the SL framework places it into the context of a complex SES moving through a process of change. A combined model builds on SL by including not only shocks but also change and the need for adaptation. Livelihood resiliency is the level at which a livelihood is flexible and is able recover from, learn from, and adapt to stresses and shocks that they confront (Gunderson and Holling 2002). The resilience of the household is dependent not only on its own characteristics but also on the resilience of its larger social and natural systems. For example, peasant households are vulnerable to climate shocks because of their

dependence on natural systems and isolation from dominant institutions that moderate risk. In the case of ecological services, households can degrade an ecosystem's future ability to provide services by over-exploiting those systems at this time. Over-exploitation is often related to the fact that households must maintain a minimum of basic needs, forcing vulnerable populations to value short-term survival over long-term sustainability. If those systems are to be maintained, institutions are needed that reduce household vulnerability. If those systems are shared, institutions may be needed to reduce the incentive of each user to overuse (Ostrom 1990).

Returning to the lessons learned from the SES framework, the resilience of the ecosystem and the institutions that manage their use must also be maintained so that they do not become more vulnerable to shocks or stress. Likewise, those very institutions and the culture that contains them are also vulnerable to shocks and change. Carpenter, Brock and Ludwig find that an institution that "maintains social flexibility for adaptive response… [has] the potential to ameliorate the risk of collapse" (2002, 193). Each system must adapt and evolve according to the pressures applied to it by the SES in which it operates or risk collapse.

Here, the goal of SES analysis is not necessarily to learn how to avoid perturbations and uncertainty, but to accept that they are unavoidable and learn from strategies that have avoided undesirable outcomes. In their study of SES, Walker et. al. (2002) use a set of assumptions drawn from both systems theory and household livelihoods frameworks. They assume that:

- there are thresholds that are irreversible,
- the probability distributions of the outcomes of decisions are highly uncertain,

- actors do not have perfect knowledge,
- actors are not only motivated by profit,
- market imperfections are the norm,
- agents have preferences that cannot be described by a simple utility function, and
- for many goods and services, well-defined property rights do not exist.

These assumptions allow them to analyze natural resource management from a perspective that is able to include a number of scales and systems that is not possible from a neoclassical approach. Although it reduces the predictive power of the model, it may be more realistic to include uncertainty and the complex aspects of human behavior into the model. Instead of searching for steady state solutions, they search for solutions that would increase the ability of the SES to adapt by increasing organization and information flows between stake-holders and policy makers and managers.

The following research will apply the combined SL/SES framework to households in the Bolivian Altiplano. It will analyze rural livelihood strategies for their ability to provide for the basic needs of the household and contribute to the sustainability of their natural and social systems in an environment characterized by climate volatility and imperfect markets. The purpose is to understand in which ways current livelihood paths as well as access to capitals and capabilities lead to vulnerable or resilient systems.

# Chapter 4: Conceptual Framework and Empirical Model

## 4.1 Introduction

Households are members of a larger system of ecological and social interactions; although one of many, each household's actions impacts the entire socio-ecological system (SES). This research will use the sustainable livelihoods framework to investigate the relationships between different households and their SES. This chapter focuses on the development of a framework is informed by the sustainable livelihoods and resilience frameworks. The purpose is to derive an empirical model that includes the household access to assets, livelihood strategies, and impact on the SES.

The conceptual relationship between assets, strategies, and the SES is outlined in the first section of this chapter. The second section explores the empirical model, explaining the analytical methods that are used and how variables are chosen and constructed.

## 4.2 Conceptual Framework

This research draws on both the sustainable livelihoods framework and concepts from the socio-ecological systems (SES) perspective, in order to analyze household-level data to gain insights into resilience and adaptive capacity. The former provides the theoretical foundation for analysis at the household level, focusing on the recursive

relationship between access and control of assets, and how they are used to create well-being for the household members (Chambers and Conway 1991). Livelihood strategies describe the portfolio of activities that a household performs and the social context in which the household exists (Ellis 1998; Valdivia and Gilles 2001; Valdivia 2004). In this case, the household's context is composed of human (social and economic structures) and natural systems (agroecological systems of the Andes). The SESs perspective emphasizes the cross-scale and dynamic aspects of systems that are required to connect ecological, economic and social theories (Yorque et al. 2002). It provides the conceptual link between the household and its environment. In order to capture both specific household characteristics and the long-term impacts of household strategies on their environment, this research combines aspects of the sustainable livelihoods and SES frameworks. The model aims to determine which relationships between household characteristics and livelihood strategies produce positive or negative changes in the SES. The approach used in this research places household access to capitals and livelihood strategies in an explanatory role and their impact on the SES as the response (Figure 4.1).

$$[\text{Access to capitals}] + [\text{Livelihood Strategy}] \Longrightarrow \begin{bmatrix} \text{Socio} - \text{Ecological} \\ \text{Impact} \end{bmatrix}$$

Figure 4.1 The conceptual relationship between assets, strategy formation, and impact on the SES.

Access to capitals affects the type of livelihood strategies that households choose. The livelihoods approach is used in order focus analysis on individual households and

their production decisions. Within the livelihoods approach, access to capitals determines the resources that households use to create the products that they need and want. Capitals are often divided up into categories such as; natural, human, social and financial. Together they provide the household with both the "*means* through which to make a living" and "give *meaning* to the person's world" (Bebbington 1999, 2022, italics in original). Households choose their production and consumption portfolios through the lens of their culture, according to their control of assets and their capabilities and where they are in lifecycle (Valdivia et al. 2003; Valdivia 2004). The production methods that they choose determine both the output and thus consumption of the household and the capitals available for the next production decision.

The sustainable livelihoods model has grown to include social and historic factors through the examination of institutions, social capital and path dependency. Here, institutions and social capital refer to resources that can be drawn on from social networks and relationships within the community. Social capital and the relationships between individuals are central to understanding the issues of access and exchange that take place between people (Bebbington 1999). Those relationships form a framework by which the household perceives its opportunities and interactions (North 2005). To a great degree, they determine a household's access to resources and the incentive structure in which the household exists. Path dependency acknowledges that differences in historical conditions have produced different cultural environments that affect how people perceive the world and act (North 1994). These paradigms determine the way that people learn and the ends that they attempt to achieve.

A livelihood strategy is the combination of methods that are used to create a means of living. From the capitals perspective, each household will perform activities that combine its assets in order to produce the goods that it desires. Allowing for a more complex model, strategies are also a product of culture, path dependency, risk avoidance, institutions, and capabilities that a household draws on in order to take advantage of the opportunities that it perceives. This study uses the household as its unit of analysis and the sustainable livelihoods framework for six reasons.

1. Although all decisions within the survey households are not made as a unit, asset pooling does takes place within the household unit and the well-being of household members are correlated.
2. The households make consumption and production decisions simultaneously.
3. Most of the survey households derive the majority of their livelihoods from agricultural enterprises.
4. The survey households operate in an environment of incomplete and imperfect markets.
5. This research aims to better understand the impact of decisions that are made at the household level.
6. There is a history of different pressures and evidence of divergence between the two survey regions that require the use of a model that includes the concept of path dependency.

The result is a livelihood framework that places the household in a historic, social, and natural context (Figure 4.2).

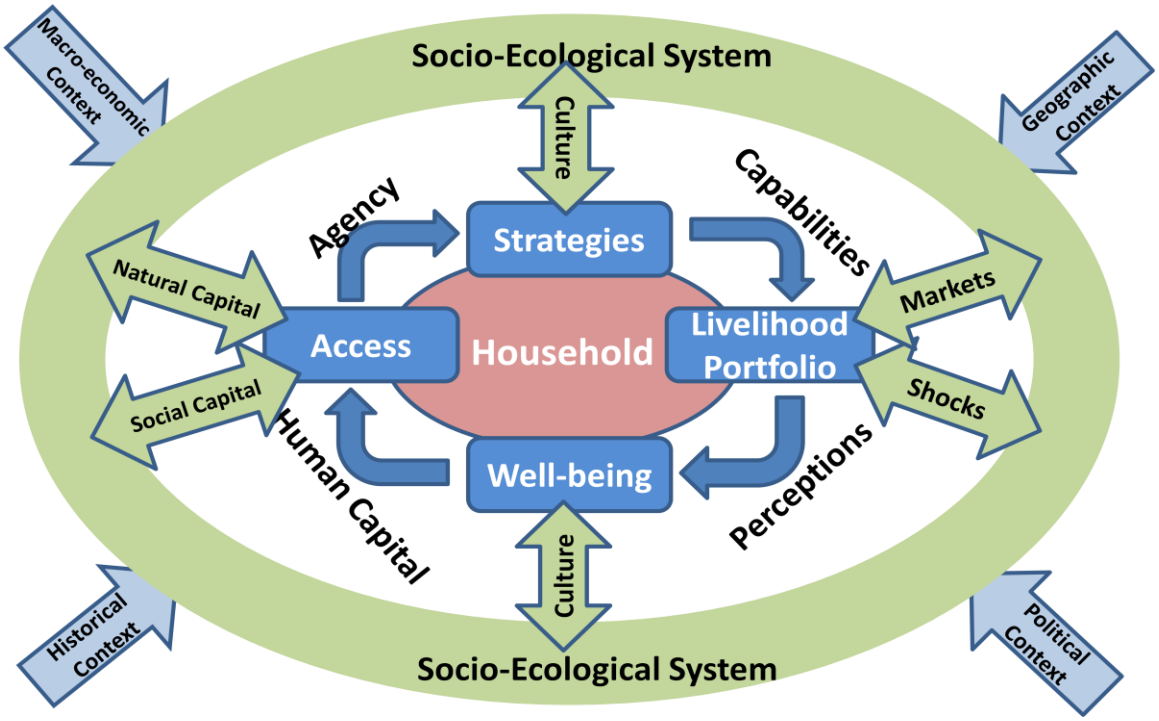


Figure 4.2 Integrating the sustainable livelihoods framework into the SES framework.

There are some drawbacks to using the livelihoods perspective. Because analysis takes place at the household level, the model is at a disadvantage when analyzing broader systems, such as society and impact on the ecosystem, which usually take place across a community or region. Institutions are able to model some aspects of livelihood factors that take place at a community or country level; for example, prices represent an agreement in exchange, but may inherently reflect the social relations or asymmetries in information and bargaining power. Policies, such as an import subsidy, are an expression of the government's position in terms of certain resource allocation and favoring certain players. A second weakness of focusing on the household is that the role of the household in creating and molding its social and natural environment in often deemphasized. The

SL framework addresses this issue in part, by endogenizing the feedback loops between the household and its natural capital, but still struggles to include the household's impact on the larger social and eco-sphere. This research draws on the SES framework in order to extend the model to include the household's impact on the larger landscape. Similar to the sustainable livelihoods expansion into the stock of available natural resources, the SES framework of resilience provides a foundation for analyzing the vulnerability and adaptability of not only the natural systems but also the human systems.

Landscapes are the product of many systems interacting to varying degrees across scales. Rural households in the Bolivian Altiplano rely heavily on social institutions such as reciprocity, collective action and local fairs (Mayer 2002) social networks (Valdivia et al. 2003) and their natural capital (Bebbington 2001; Mayer 2002; Valdivia 2004). This research includes factors at the household, community, and landscape levels, in order to capture relationships that exist across these various scales. It models the impact that the household has on its SES, and in turn on its own resilience, as a product of the relationship between household access to assets and livelihood strategies. This will inform on the combinations of access to assets and livelihood strategies, which produce more resilient or more vulnerable socio-economic systems.

*Hypothesis 1: Livelihoods associated with low access to all capitals are correlated with vulnerability and are unable to invest in maintaining a stable SES.* As an expression of both path dependence and multiple equilibria (Barrett and Swallow 2006), current poverty is often the result of a history with low access to assets and inability to invest in safety measures. Research in the study region has found that poverty increases the

household's vulnerability to shocks (Valdivia and Quiroz 2001). This research hypothesizes that households with overall low access to resources are unable to invest in maintaining or improving the resilience of their SES. The state of low access to resources and thus resilience is expected to reflect regional historic differences in land fragmentation and population growth, interacting with markets and transaction costs. Another factor that is expected to be significant is lifecycle. As households enter into the later portion of their lifecycle, they often bequeath their lands to the younger generation and reduce livestock holdings as their access to labor decreases (Coppock and Valdivia 2001). It is expected that these households will also express low adaptive capacity or ability to invest in resilience.

*Hypothesis 2: Households with low access to natural capital will invest in strengthening human systems but may overexploit their natural systems.* Households with low access to land will follow an income diversification strategy that substitutes other capitals for land (Scoones 1998). Those that have low access to land will depend more heavily on income from labor markets (Barrett, Reardon, and Webb 2001). If their strategies are successful, those households will continue strengthening their position in those markets by increasing their investment in human and social capital. If they are unsuccessful, those households may be forced to over-tax their natural capital in order to provide their basic needs.

*Hypothesis 3: Households that practice traditional livelihood strategies (crop diversification, pastoralist activities, and autarky) will be more likely to practice sustainable land-management.* Traditional livelihood strategies and land management practices have allowed the Aymara to succeed for over 2000 years on the Altiplano. Households that currently practice strategies that are similar to those the Aymara traditionally have practiced should continue to maintain a resilient SES. Production for own consumption, crop diversification, and livestock ownership are three traditional livelihood methods that have been used for income smoothing in the face of risk without insurance markets. For centuries diversification has been a strategy used by people in the Andes to deal with climate variability (Valdivia et al. 2003). Livestock holding has traditionally been used as both a tool for saving and an insurance mechanism (Valdivia 2004). Although there is evidence of markets during the Inca and pre-Inca time periods, households depended heavily on subsistence farming and exchange between households within *ayllus*[7](Buechler 1983; Good 2006; Mayer 2002). Production for own consumption and crop diversification has also been shown to reduce exposure to risk associated with markets and avoid transaction costs (Omamo 1998). Those livelihoods associated with more traditional practices are expected to express impacts that increase the resilience of the ecosystem.

[7] *Ayllus* are kinship groups that controlled land across ecological zones. Households within the *ayllus* often exchanged goods and labor reducing climate risk and seasonal labor cycles.

*Hypothesis 4: Households that practice a rural multifunctional strategy will be highly resilient.* Diversification is both an indicator of a broad range of opportunities and creates further opportunities. Uncorrelated income increases the household's ability to absorb shocks and adapt to changes in the environment. According to Wilson, multifunctionality also includes aspects of "local embeddedness", informal relationships, and "high environmental sustainability" (2008, 368). Livelihoods that are diversified and do not specialize in either the capitals that they access or the strategies that they follow will be more adaptable and less vulnerable to shocks.

## 4.3 Empirical Model

The empirical model measures the relationship between access to capitals and livelihood strategies with the household's effect on the SES. In order to analyze the household's role in SES resilience, variables are measured and analyzed at the household level. Those results are then interpreted according to information on the micro and macro scales. The explanatory variables are composed of nine measurements of access to capital and four indicators of livelihood strategies. The response variables measure the impact that is associated with a specific arrangement of access and strategies. They are divided into those impacts that directly affect the resilience of the ecosystem and those that directly affect the resilience of the household.

Primary data collected during June and July 2009 is used for the qualitative development of the model and to interpret the results and implications of the statistical analysis. Statistical analysis is performed on data collected through a household survey in the Bolivian Altiplano by SANREM CRSP in 2006. Canonical correlation analysis

(CCA) is used in order to explore the dominant relationships that exist between assets and strategies (explanatory variables), and impact on the SES (response variables). This section begins with a description of the explanatory and response variables. Following that explanation is a brief overview of CCA and how it will be used in this investigation.

### *4.3.1 Explanatory Variables*

The capitals model based on the sustainable livelihoods framework can be used to account for the resources available to a household. Households can be described by the access to quantities of capital such as human, natural, cultural, productive, and social. Although there is no consensus on how many capitals there are or what method of categorization is most useful, their use by researchers continues to produce insight into household economics and behavior. This model will use three categories of household capital: natural, human, and social. Within each category, several variables are identified that together approximate the household's access to that capital (Table 4.1).

Table 4.1 Explanatory Variables: Capitals and strategies

| | Variable Name | Description |
|---|---|---|
| **Natural Capital** | Crop Land | The total number of hectares used for crops by the household in the 2005 season. Does not include fallow or native pasture. |
| | TAU | Livestock holdings in tropical animal units (TAU). |
| **Human Capital** | AE | The amount of labor within the household in adult equivalents (AE) constructed using the metric used by Valdivia and Jetté (1996) in the region (AE=1 for age>17.5, AE=.5 for 17.5>age>12.5, AE=.3 for 12.5<age<5.5, AE=0 for age<5.5). |
| | Age HH | The age of the head of household. |
| | Ed HH | The education level of the head of household. |
| | Gender HH | Gender of the head of household (0=female). |
| **Social Capital** | Local Orgs. | The number of formal local organizations that household members participate in. |
| | Informal Social Capital | An index calculated by summing the number of informal social capital building activities that the household participates in. |
| **Strategies** | Crop Diversity | The inverse Simpson's index of crop species planted. |
| | Autarky | The natural log of the value of goods produced for own consumption. |
| | Agricultural Markets | The natural log of the cash income generated through the sale of products in agricultural markets. |
| | Labor Markets | The natural log of total income generated in off-farm income. |

Natural capital is the stock of natural resources and environmental services. This includes item such as amount of land and access to surface water. Natural capital may be used to transform other assets into goods or the household may directly consume services provided by the natural capital. Two variables, cropland and livestock, are used to approximate the natural resources that households have access to. *Crop Land* is the number of hectares that the household used for crop production during the 05-06 season.

The sum of tropical livestock units (*TLU*) owned by each household is calculated according to the Food and Agriculture Organization's (FOA) method, which uses metabolic weight to account for each animal by its energy requirements (Table 4.2).

Table 4.2 Weight, metabolic weight, and equivalent tropical livestock units (TLUs)

| Body Weight (kg) | Metabolic Body Weight (kg $^{0.75}$) | T L U | | Body Weight (kg) | Metabolic Body Weight (kg $^{0.75}$) | T L U |
|---|---|---|---|---|---|---|
| 5 | 3 | 0.05 | | 50 | 19 | 0.3 |
| 10 | 6 | 0.09 | | 60 | 22 | 0.34 |
| 15 | 8 | 0.12 | | 75 | 25 | 0.41 |
| 20 | 9 | 0.15 | | 100 | 32 | 0.5 |
| 25 | 11 | 0.18 | | 125 | 37 | 0.59 |
| 30 | 13 | 0.2 | | 150 | 43 | 0.68 |
| 35 | 14 | 0.23 | | 200 | 53 | 0.85 |
| 40 | 16 | 0.25 | | **250** | **63** | **1** |
| 45 | 17 | 0.28 | | 300 | 72 | 1.15 |

**Source:** Livestock, Environment and Development Initiative 1999

The metabolic weight is used to calculate the TLUs because energy use is more closely tied to tissue mass, not body weight which is a product of tissues and fats. According to the FAO's Livestock, Environment and Development (LEAD) Initiative, "Metabolic weight is therefore considered as the best unit for aggregation of animals from different species, whether this is for the total amount of feed consumed, manure produced, or product produced"( Livestock, Environment and Development Initiative 1999). Metabolic weight (MW) is estimated by raising weight to the 3/4ths power (MW= weight$^{0.75}$).

Animal weights and TLUs were determined using a variety of sources and estimates (Table 4.3). For some animals, consistent data on their weight in the Altiplano could not be located. In those cases, an estimation based on a variety of weights found in other similar locations is used.

Table 4.3 Tropical livestock units of the animals held by households in the survey communities

| **Animal** | **Weight (kg)** | **Metabolic Weight** | **TLU** | **Source** |
|---|---|---|---|---|
| Cattle (mejoradad) | 240 | 63 | 0.89 | Estimate of 1.5 times the body weight of criollas |
| Cattle (Criollas) | 160 | 44 | 0.7 | Jahnke 1982; LEAD 1999 |
| Alpaca/Llama | 65/75 | 22.9/25.5 | 0.38 | Coppock and Valdivia 2001,184, from Rodrigues 1985 and Alzerreca 1988; Hurtado 1993, 133, from Rodriguez and Cardozo 1989 |
| Donkey/Horse | 100/ 225 | (.5/.9) | 0.7 | Coppock and Valdivia 2001 |
| Pigs | 30 | 13 | 0.2 | Jahnke et al. 1988 |
| Sheep (mejoridad) | 35 | 14.4 | 0.23 | Estimated from Coppock and Valdivia 2001, 181, from Rodriquez 1985 and Cardozo 1970 |
| Sheep (Criollas) | 20 | 9.5 | 0.15 | Coppock and Valdivia 2001, 181 from Rodriquez 1985 and Cardozo 1970; LEAD 1999 |
| Birds | 1 | 1 | 0.01 | Jahnke et al. 1988 |
| Rabbit/ Guinea Pig | (2.5/.5) | 2/1 | 0.02 | FAO 2001 |

Human capital is the stock of labor hours, skills, knowledge, capacity, and agency within the household. It is both the resource that the households use to make their production decisions and one of the assets invested in those decisions. Some aspects of human capital, such as quantity of labor, describe a stock that may be easy to compute while others, such as capacity, are more difficult to account for. In those cases other characteristics that are often associated with the variable of interest are used as proxies. Here, education is used as a proxy for knowledge and age is used to estimate experience. Gender of the head of household is also included as a human capital. Often, when the head of household is reported to be female, the spouse is either working outside of the community or has deceased. The result is a household that is missing a key decision maker and laborer. There are also social and cultural aspects to the gender of the head of household which affect the social capital of the household.

Social capital is composed of the relationships, networks, and institutions that a household can draw on to better its situation. In environments that are characterized by incomplete markets such as the Altiplano, social capital can be especially important to households. It may provide access to resources for which there are no markets. Formal structures such as collectives may be able to overcome barriers to entry, increase negotiating power or reduce transportation costs. Informal relationships between friends, family, and neighbors also provide opportunities for exchanges and transactions with lower costs. The variable used as a measure of informal social capital includes use of informal networks for weather information, access to land and labor, the use of bartering, and gift giving. Each of these activities involves both the exchange of goods or services and participation in traditional practices. The second social capital variable is a measure of the total number of local organizations that the household participates in. It approximates the household's civic engagement.

Livelihood strategies reflect the production and consumption decisions that the household has made and the institutional environment that the household is in. These decisions are a product of both the household's access to assets and their perceptions of opportunity and risk. While some strategies may be dominated by production strategies associated with specific goods or markets, others may rely on a diverse set of activities. Four different measurements are used to capture the strategies that households use; crop diversity, production for consumption, participation in agricultural markets, and participation of labor markets. Crop diversity is calculated using the inverse Simpson's index to determine the diversity of species planted. Simpson's index is calculated using equation 4.1 where $n_i$=hectares planted with species $i$ and $N$=total number of hectares

planted. The index produces a value equal to the number of species planted by the household if the household plants equal areas for each species. It drops as either the number on species drops or as specialization in specific species increases.

(4.1) $$Inverse\ Simpson's\ Index = 1/\sum_{i=1}^{N}(n_i/N)^2$$

Production for consumption, participation in agricultural markets, and participation of labor markets are calculated by summing the total market value of the products applied to that strategy. Each strategy reflects a household's set of value judgments, constraints, and institutional environment. For example, self sufficiency or autarky, allows the household to avoid certain transaction costs associated with the markets but also may reduce the household's ability to take advantage of competitive advantages and portfolio diversification into uncorrelated activates such as non-agricultural labor (Ellis 1998). Changes in transaction costs will change the benefits of market participation and impact the strategies that the household pursues. In most cases, households follow a variety of strategies varying their activities in each according to their situation.

### *4.3.2 Response Variables*

The response variables are indicators of the household's effects on the vulnerability and adaptability of its own livelihood and the ecosystem that it depends on. The variables are organized into categories according to four attributes—vulnerability, sustainability, household, and ecosystem—according the sphere that they most directly

impact (Table 4.4). In reality these categories are artificial. All nine variables are interrelated and part of the larger SES but they are categorized so that the results of analysis can be grouped together.

Table 4.4 Response variables: Indicators of resilience and vulnerability

| | Vulnerability | Adaptability/Sustainability |
|---|---|---|
| **Household** | **Vulnerability**: This index addresses the ability of households to reduce exposure to, and capacity to moderate risk.<br><br>**Sickness:** The vulnerability of the household members to sickness and disease.<br><br>**Income per Person:** Income is used by households to create buffers against shocks. | **Productivity of Land**: High productivity indicates that the household's practices have not depleted the natural resources.<br><br>**Investment in Education:** The number of children in school as an investment in future human and social capital.<br><br>**Income Diversity:** Income diversity both acts to smooth income and provide the household with greater ability to diversify away from strategies that are not working well.<br><br>**Bridging Organizations:** Access to individuals and organizations outside of the community increases the household's pool of opportunity uncorrelated with farm activities. |
| **Ecosystem** | **Land-Use diversity:** Greater diversity increases interactions and redundancy within the ecosystem reducing its vulnerability to any one shock. | **Percent Nitrogen Fixing Crops:** Legumes increase the nitrogen content and thus the fertility of the soil.<br><br>**Soil Amendments:** The value of soil inputs in order to maintain the fertility of cropped soils.<br><br>**Erosion Control:** Households that maintain native pastures, fallow fields, and perennial alfalfa fields provide year-around erosion protect for those fields. |

Vulnerability refers to the system's "susceptibility to harm" (Adger 2006, 1) while adaptability is the ability of SES to adjust "in response to actual, perceived, or expected environmental changes and their impacts" (Janssen and Ostrom 2006, 276). In the human sphere both adaptability and vulnerability investigate the household's ability to create well being over time. Vulnerability emphasizes the ability to provide basic needs and well-being while sustainability and adaptability emphasizes the household's

impact which is in part a function of vulnerability. The distinction is made in order to emphasize the aspect of each variable that is most important to this analysis.

Household vulnerability refers to the risk of harm that shocks pose to households and the possibility that the household will not be able to provide for its needs (Adger 2001). It is a function of the relative success of current livelihood strategies and the risk of an event reducing the household's ability to provide for itself. Although vulnerability and poverty are not necessarily related, households in poverty are often highly vulnerable because they have not had resources to invest in risk reducing mechanisms or buffers (Moench and Dixit 2004).

This research uses three measures of household vulnerability. The first is calculated by dividing a household's perception of threat from a number of different shocks, by the household's sense of control over the impact of those shocks. High numbers equate high risk and little control and low numbers indicate low risk and high control. Shocks included those associated with climate, pests, illness, social upheaval, and sickness. The second variable is a count of the number of household members that were sick for more than one week in the last year. It measures the household's ability to maintain health, both a measure of well-being and a measure of the household's ability to maintain access to labor from within the household. The third variable is income per person following the literature on the correlation between poverty and vulnerability (Valdivia and Quiroz 2001).

Household actions can work towards increasing or decreasing the adaptability of their livelihood. In the terminology of resource economics, household resources have stocks and flows. If stock is reduced faster than it is regenerated through inflow, the stock

of that resource will fall. Households can affect their environment by changing their extraction levels or by impacting the flows into and out of that resource. Investing in their future, for example by sending children to school or joining organizations, may increase flows, stock, quality, or diversity of capital available in the future.

Household adaptability is measured using four variables; income diversity, investments in education, land productivity, and membership in organizations that create bridging capital. Income diversity into uncorrelated fields smoothes income when there are shocks to the household (Reardon, Delgado, and Malton 1992; Morduch 1995; Valdivia, Dunn, and Jette 1996). Although income smoothing though diversification is a mechanism for reducing vulnerability to individual shocks, it is also an indicator of the household's ability to diversify away from or adapt to stresses that are ongoing. Because adaptability is a both an important measure of resilience and a difficult characteristic to measure, this research uses it as a measure of resilience in the human system[8]. Income diversity is calculated using the inverse Simpson's index of the household's income in three uncorrelated fields; crops, livestock, and labor market. An index value of 1 indicates complete dependence on a single source while equal dependence on all three fields produces a value of 3.

High land-productivity increases the chances that the household is able to provide for its basic needs and indicates the use of agricultural practices that maintain soil fertility. For households that depend on agriculture, high productivity is a measure of

[8] The reader might note the diversity is used as a measure of vulnerability in the ecosystem and adaptability/sustainability in the household. The distinction originates in the parameters of function. It is the belief of the author that a household's 'basic function' is to provide for its members which allows for a wide degree of adaptation and change. The ecosystems 'basic function' falls much closer to maintaining current systems. In the second case, diversity as a mechanism that reduces vulnerability is emphasized.

success. Because the communities have existed for many years, it also indicates that the household's practices are not degrading the productivity of their fields.

The resilience of an ecosystem depends on its ability to undergo shocks and stress and still maintain its basic functions. Vulnerability is a facet of resilience, measuring the susceptibility of the ecosystem to harm from those shocks. Walker (1995) argues that systems with a wide range of interactions and relationships are able to better absorb shocks because each set of relationships will have its own set of strengths and weaknesses. Diversity buffers systems from the impact of shocks and improves the system's ability to provide those functions. The inverse Simpson's index is used to calculate the diversity of household land-use and a proxy for ecosystem diversity and thus vulnerability. Each species that is planted as well as those fields left to fallow provide a new measure of protection against a single event causing the ecosystem to collapse.

Sustainability of the ecosystem is the ability of the system to continue providing basic functions without reducing its ability to do so in the future. It is a measure of both the impact that providing services has on its resource base and the system's adaptability to change. Soil health contributes to productivity of the landscape, which is sometimes used as a proxy for system health. Motavalli (2010) asserts that there is no universal method for defining soil health because health is determined by function. The researcher must first define the function of the system and then judge its ability to perform that function. The matter of defining subjective functions extents to other portions of the ecosystem. In an example provided by Sutherland, Parker, and Stephens (1999), an ecosystem composed of a pine forest that is feeding a large population of pine parasites

may be healthy from the parasites' perspective but not from the tree's or that of the lumber company.

The idea of function is especially important when humans exist in the ecosystem. Humans often expect to extract a service or good from the landscape. This requires that concepts from human ethics and values are integrated into our perspective of the biophysical process (Rapport, Costanza, and McMichael 1998). From the human's perspective, the function of the ecosystem is dependent on what services it provides and how those services are valued. In multiple user scenarios, the function of the landscape may be difficult to define due to conflicting concepts of landscape function (Meinig 1979).

This research will measure the household's impact on its ecosystem by examining its land-use for activities that increase or decrease the fertility of soil. The first two variables measure the sustainability of agricultural practices by their impact on soil fertility. *Nitrogen Fixing Crops* measures the proportion of cropped land that is planted with species of legumes, such as beans and peas, which increase the available nitrogen in the soil. The second variable, *Soil Amendments,* is the total cost of soil inputs, both chemical and organic, which help replace the nutrient extracted though cropping. The final sustainability variable measures the sum of land that is in fallow, native pastures and alfalfa greater than a year old. All three land-uses provide year around erosion control and allow for the growth of deep-rooting plants over multiple years. For example, if allowed to establish itself over a few seasons, alfalfa will grow roots up to 4 meters long making it drought resistant. Its deep roots also provide habitat for nitrogen fixing bacteria and pull micronutrients up from the subsoil. Fallowing has been shown to increase plant

diversity and fertility (Fridely 2002), increase phytomass (Pestalozzi 2000), and reduce nutrient loss increasing productivity (Swinton and Quiorz 2003). In analysis of data from the Umala region in the Bolivian Altiplano; Motavalli et al. (2009) found that KMn04 active C and POM C increased with fallow. In Senegal, Pate et al. (2000) found that nematode diversity and quantity in the top 15cm of soil increased with fallow time.

Figure 4.3 illustrates the model that will be used to explore the relationships set out above. There are a total of eight capital variables, four livelihood strategies and nine indicators of SES resilience. The entire system takes place within a historic, geographic, cultural, and institutional context that is used to understand the results of empirical analysis.

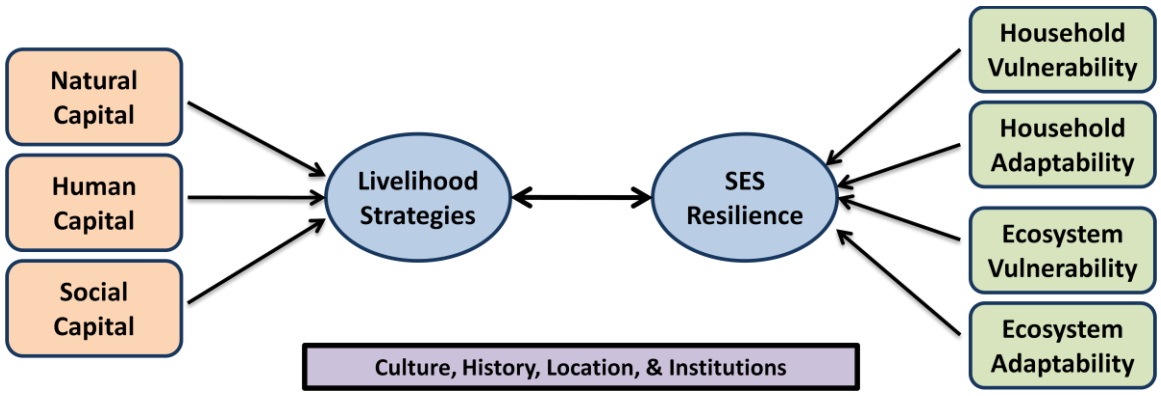


Figure 4.3 Household access to capitals, livelihood strategies, and impact on their SES.

Notes: Households use their access to capitals to construct livelihood strategies in the context of their culture, history, geography, and institutions. The strategies are implemented according to the household's capabilities, impacting the vulnerability, adaptability, and sustainability of the SES.

### *4.3.3 Canonical Correlation Analysis*

Canonical correlation analysis (CCA) was introduced by Hotelling in 1935 as a method for analyzing the relationship between two sets of variables. It is the most general member of the multivariate general linear hypothesis (MGLH) family, which includes Pearson's correlation and multiple regression analysis. Where Pearson's correlations compares variables at a one-to-one level and multiple regressions at a greater than one to one level, CCA compares two sets each with greater than one variable. Although it has some similarities in terminology and conceptually with factor and principal component analysis, it is not related to either (Clark 1975).

This research uses canonical correlation analysis in order capture the highly interrelated characteristics of complex systems. CCA analysis reveals the structure of relationships without necessitating that they are examined individually. In systems that are complex, such as SESs, the ability to analyze sets of variables maintains the connectedness that is integral to complexity. This research assumes that the sets of variables are interrelated and that their effects on each other cannot be captured by recording the relationship between variables in isolation. Because the terminology is new for many people and many of the terms are similar, a list of definitions has been included at the end of this chapter. The concepts in this section draw heavily on the lessons learned from Clark (1975), Garson (2008), and Tabachnick and Fidell (2007).

Equation (4.2) is one way to write the fundamental equation of canonical correlation. The canonical correlation matrix ($\sum$) has four parts; the inverse correlation matrix between the set of dependent variables ($\sum_{yy}^{-1}$), the set of independent variables ($\sum_{xx}^{-1}$), and the correlations between variable sets ($\sum_{xy}$) and ($\sum_{yx}$).

(4.2)[9] $$\sum = \sum_{yy}^{-1}\sum_{yx}\sum_{xx}^{-1}\sum_{xy} = \begin{bmatrix} \sum_{xx}^{-1} & \sum_{xy} \\ \sum_{yx} & \sum_{yy}^{-1} \end{bmatrix}$$

The objective is to construct a linear combination of each set of variables that maximizes the correlation between those linear combinations. This process depends on eigenvectors in order to redistribute the variance of each set (dependent and independent), consolidating it into a few variables from each set.

Assume a random sample of multidimensional observations $X=(x_1, \ldots, x_n)$ and $Y=(y_1, \ldots, y_n)$. CCA maximizes the correlation $r_{ci} = cor(\lambda_{xi}X, \lambda_{yi}Y)$ where $\lambda_{xi}$ and $\lambda_{yi}$ are eigenvalues computed by solving the eigenvalue equation (4.3). The canonical variables are constructed by multiplying the original set of variables by their eigenvalues (4.4).

(4.3) $$\hat{w}_x\lambda_{xi} = \hat{w}_x\sum_{xx}^{-1}\sum_{xy}\sum_{yy}^{-1}\sum_{yx}$$

$$\hat{w}_y\lambda_{yi} = \hat{w}_y\sum_{yy}^{-1}\sum_{yx}\sum_{xx}^{-1}\sum_{xy}$$

(4.4) $$C_{xi} = \lambda_{xi}X$$

$$C_{yi} = \lambda_{yi}Y$$

$C_{xi}$ and $C_{yi}$ are newly constructed latent variables or canonical variable (see figure 4.4). Each canonical variable is composed of a linear combination of the variables within a set (i.e. $x_1$, $x_2$, $x_3$ in figure 4.4) constructed under the parameter of maximizing the canonical correlation ($r_{ci}$). The canonical coefficients describe the relative importance

[9] Note that this equation is very similar to the equation for regression ($B_x=\sum_{xx}^{-1}\sum_{xy}$) where $B_i$ is the coefficient for predicting Y from X. Canonical correlation analysis uses the same relationship but includes the relationship in the opposite direction ($B_y=\sum_{yy}^{-1}\sum_{yx}$) in the analysis.

of each variable in constructing the canonical variable and can be interpreted similar to beta coefficients in multiple regression analysis. The correlations between original variables and their canonical variables are called loadings ($L_{x,y\ hi}$ in Figure 4.4).

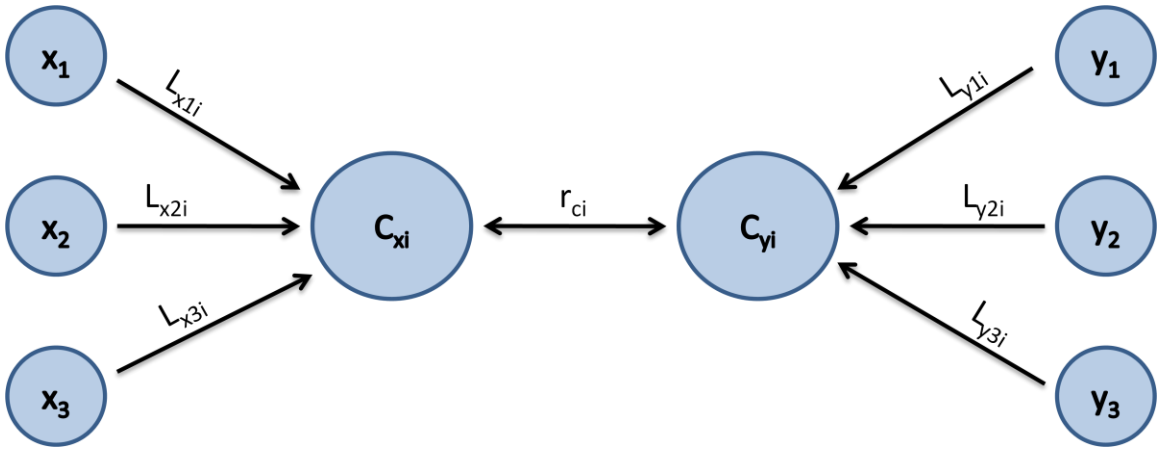


Figure 4.4 The canonical structure analyzed in canonical correlation analysis.

The residuals—components of the original variables not captured by the first covariate—of each set are then used to create a second round of eigenvectors and canonical variables, once again maximizing correlation between the new canonical variable pair. The second canonical variable is restricted to those dimensions orthogonal to previous canonical variable from the same set, that is, it cannot be correlated with the first canonical variable. A second round of canonical variables is associated with the new set of coefficients and loadings which can be interpreted as a secondary set of relationships between the variables or a second dimension. This process repeats until the number of canonical variable pairs equals the number of original variables in the smallest set.

#### *4.3.3.1 Analysis*

The goal of CCA is to describe the relationships between two sets of variables (Wuensch 2009). Because each canonical variable is orthogonal with the other canonical variables for that set, each canonical variable expresses a unique relationship structure. An F-test is used to determine how many pairs of canonical variables are significant. Once the number of significant canonical variables or dimensions is determined; loadings are used to determine the structure of the relationships described by the set of canonical variables. The set of loadings is called the canonical structure because it indicates which variables are most dominant in each dimension. It is generally accepted that variables with loadings greater than 0.3 can be used for interpretation (Tabachnick and Fidell 2007). The square of a variable's loading (e.g. $L_{xni}^{2}$ is the loading of the $n^{th}$ variable from the *x* set in the *i* dimension) is the variance of a variable captured by its canonical variable. The sum of squared loadings of a set is sometimes called the canonical community coefficient and is the percent of variance (*pv*) that the canonical variable extracted from the original variables in the set (4.5).

(4.5)
$$pv_x C_{xi} = \sum_1^{n_x} \frac{L_{xni}^2}{n_x}$$
$$pv_y C_{yi} = \sum_1^{n_y} \frac{L_{yni}^2}{n_y}$$

If the researcher is concerned with prediction, only the canonical coefficients of variables with loadings that have an absolute value greater than 0.3 should be used for interpretation. The canonical coefficient is similar to the beta coefficient in multiple

regression. Note that those coefficients are in relation to the canonical variable for that set. In order to determine the impact that a specific variable has on a variable in the other set, one must follow an indirect path; from variable ($x_i$) to its canonical variable ($C_{xi}$) though the loading ($L_{xki}$), through the correlation between the two canonical variables ($r_{ci}$), and then through the relationship between the second variables and its own canonical variable ($L_{yki}$).

Redundancy analysis tests the ability of one set of variables to predict the variables in the other set. The redundancy statistic measures the percent of variance in one set of variables that is explained by the other set's canonical variable. Figure 4.4 shows the amount of variance of the x-variables explained by $C_{yi}$. The redundancy statistic is created by navigating a portion of the path described earlier for predictive extrapolation. The sum of redundancy statistics is the total quantity of one set's variance contained within the other sets canonical variable.

#### *4.3.3.2 Assumptions and Conditions*

CCA makes many of the same assumptions that other members of the MGLH family assume. These include; linear relationships between variables, low multicollinearity, homoscedasticity, near normal distribution, and interval level data. CCA is also especially sensitive to outliers.

This research has addressed the assumptions of CCA in the construction of the empirical model, the methods used to create variables, and the level at which analysis takes place. In order to reduce heteroscedasticity in the data, this research uses the natural log of all of the variables that have a component of value calculated in Bolivianos. The

resulting data is much more homoscedastic. The procedure also has the benefit of reducing the impact of outliers in those variables and adjusting their distribution in the direction of normality. Although many of the variables are non-normally distributed across the dataset, analysis in this research takes place at the regional and community level, avoiding the bifurcation that exists in the data between regions and divergence between communities, decreasing the number of variables are fall outside normal distribution. The variables were constructed so as to be interval or near interval. Finally correlation matrices were used during the creation of the model to ensure that the variables used are not redundant or overly multicollinear.

### *4.3.4 Canonical Correlation Analysis of the Empirical Model*

The empirical model uses self-reported access to assets and measurements of livelihood strategies for explanatory variables and indicators of the household's impact on its SES as response variables. CCA is used to investigate the multiple relationship structures between the response and explanatory variables. Within each canonical dimension, the loadings of original variables on each set of canonical variables describe a set of relationships between an asset configuration and livelihood strategies with their impacts on the SES (Figure 4.5).

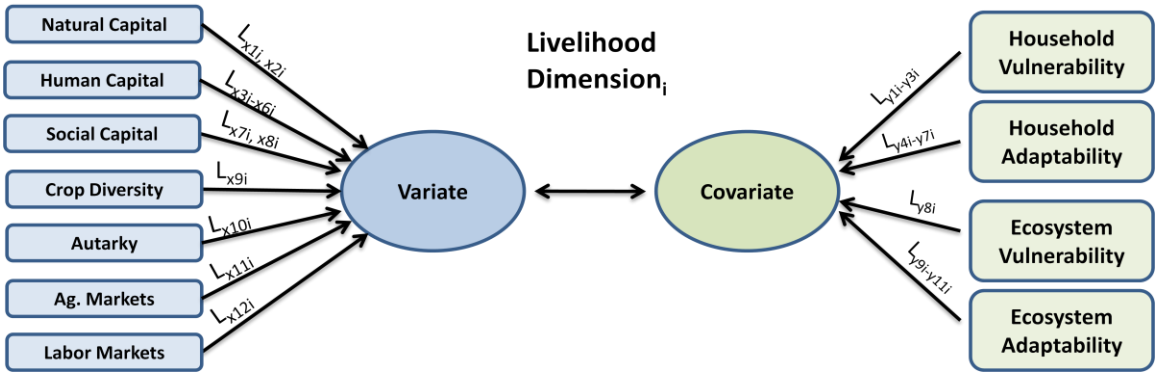


Figure 4.5 The empirical model, relating household characteristics and strategies to the SES

Notes: Each livelihood dimension expresses a unique set of relationships, each of which are analyzed for impact on the different facets of SES resilience.

The significant variables, those with loadings greater than 0.3, are interpreted through the cultural, historic, and demographic lens of the region or community in order to understand the underlying drivers and consequences of each dimension. The aim is to reveal constructs that are especially resiliency building or degrading and understand what drives those dimensions.

### *4.3.5 Definitions*

**Canonical Variable:** A linear combination of the set of original variables calculated to maximize correlation with a second canonical variable composed of a second set of variables. The canonical variable created from the independent variables is called the variate and for the dependent variables is called the covariate.

**Canonical Weights:** Similar to beta values in multiple regression analysis, the canonical weights describe the contribution of individual variables on the canonical variable.

These are often standardized so that so that the values are independent of measurement units and coefficient values can be compared.

**Loadings:** The correlation between individual variables and their canonical variable. These are sometime called structure variables because they express which relationships dominate the current pair of canonical variables. Variables with a standardized loading of greater than 0.3 are generally used for interpretation.

**Redundancy Coefficient:** The proportion of variance that one canonical variable is able to explain in the other set of original variables. This is generally used as a method for understanding the predictive power of the model. If there is assumed to be a direction of causality in the relationships, use the redundancy coefficient that describes the ability of the independent variables to predict the variance of the dependent variables.

**Square Multiple Correlations:** The squares of the correlation between each variable and the canonical variable for the other set. The value is the variance extracted from the variable by the opposite canonical variable. Square multiple correlations are used to indicate the predictive power of specific variables.

# Chapter 5: Analysis and Results

This chapter presents the results of canonical correlation analysis of household survey data from the Bolivian Altiplano. The analysis explores relationships between the capitals and strategies (independent variables), and SES resilience (dependent variables). The sustainable livelihoods (SL) framework provides a vantage point by which to model the household's incentive structure and activities. The first portion of this chapter is used to determine if the SL framework is a suitable framework for modeling household behavior in the Bolivian Altiplano and the scale of analysis that is most appropriate. After determining that the livelihoods model is appropriate for those households and that both region and community are important factors, the main section of analysis uses canonical correlation analysis to examine the relationships between the many dimensions of livelihoods and their impact on the SES at different scales.

## 5.1 Test of the Livelihoods Model and for Significance of Location

Agricultural households with little productive capital and poorly functioning markets, often rely on land and labor to create their livelihood. Income statistics and the context of the Altiplano indicate that the households are highly dependent on agriculture for their livelihoods. There should be a strong relationship between land, labor and income across the dataset. An ordinary least squares (OLS) regression is used to test for

that relationship. The dependent variable is total income, the sum of both cash and in-kind income. Across the entire dataset, access to crop land and labor are significant (*p=<.0001* and *p=0.0015* respectively) and able to account for the majority of variance in total income ($\bar{R}^2$=0.593; Table 5.1). Both relationships are in the direction predicted by the literature. The elasticity of income to land is 0.51 and income to adult equivalent is 0.22 indicating that land is the greater constraint to income generation.

Table 5.1 The relationship between land, labor, and income across the entire dataset

| N=330 | Mean | SD | Parameter Estimate | Standard Error | t-Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| **Independent Variables** | | | | | | |
| **Intercept** | - | - | 3592 | 934.4 | 3.84 | 0.0001 |
| **Crop Land** | 2.89 | 3.48 | 2275 | 127.4 | 11.8 | <.0001 |
| **Adult Equivalent** | 4.05 | 2.12 | 702.3 | 204.8 | 3.21 | 0.0015 |
| **Dependent Variable** | | | | | | |
| **Total Income*** | 13016.97 | 11426.89 | | | | |
| **Model** | F-value: 193.65 | | Pr>F: <.0001 | | **Adj R-Sq: 0.539** | |

**Data source:** SANREM CRSP 2006. *Total Income is that value of both cash and in-kind production.

Between the two regions, households have different access to land and labor (*Adult Equivalent*). In Umala, households are about 25% larger and have access to over eight times the amount of crop land than in Ancoraimes. They also have an average income that is nearly three times that of Ancoraimes. A second round of OLS regressions,

this time analyzing each region separately, is performed in order to determine if the model fits equally well in both environments[10].

The land, labor and income model remains significant at the regional level (Table 5.2). The relationship between land, labor and income is still very strong and in the expected direction. Adjusted R-Square values have fallen, which may be a result of reduced sample size. It is also becoming apparent that the differences in location extend beyond the access to capitals and into the relationships between variables. Absolute changes in access to land produce much greater changes in income for households in Ancoraimes than in Umala (probably pointing to a land constraint). The elasticity of income to land remains high and very similar in both regions ($\varepsilon$ =0.55) while the elasticity of income to labor has diverged somewhat ($\varepsilon_{Ancoraimes}$=0.22, $\varepsilon_{Umala}$=0.20) but is surprisingly similar. Notice that the average values of each variable in each region are different (Table 2.1 and 2.2).

[10] The regions are analyzed separately, as opposed to using a dummy variable, because there is evidence that the relationships between land, labor, and income are not identical in the two regions.

Table 5.2 The relationship between labor, land and income within Umala and Ancoraimes

| | Umala (N=181) | | Ancoraimes (N=141) | |
|---|---|---|---|---|
| | Parameter Estimate | Pr > \|t\| | Parameter Estimate | Pr > \|t\| |
| **Independent Variables** | | | | |
| **Intercept** | 4546.22 | 0.008 | 1678.13 | 0.060 |
| **Crop Land** | 2075.78 | <.0001 | 6695.08 | <.0001 |
| **Adult Equivalent** | 791.87 | 0.012 | 423.53 | 0.041 |
| **Dependent Variable** | | | | |
| **Total Income** | Mean: 18,092 | SD: 12,510 | Mean: 6851 | SD: 5490 |
| **Model** | **Adj R-Sq:0.424** | | **Adj R-Sq: 0.379** | |

**Data source:** SANREM CRSP 2006

The model has lost over 25% of it explanatory value when applied only to the region of Ancoraimes. It may be that there are communities within the regions that fit the model especially poorly or that the model needs to be adapted to fit their livelihoods. Community level analysis becomes difficult both because of the small sample sizes, which range between 15 and 97, and the finer resolution reducing the validity of generalizations. At fine resolutions and smaller sample sizes, unique characteristics of the household begin to overwhelm the general regional relationships.

For example, Karkapata is the smallest town and has a population of about 34 households, 15 of which were surveyed. Within those 15 participants are a high proportion of households that do not fit the model well. Of those 15, seven are outliers in the data; four receive 100% of their income from agriculture, and three of them fall within the top 95% for proportion of income coming from off-labor. Although the plot sizes are small in Karkapata, as is expected in Ancoraimes, all the households have

access to land even those that generate very little income from agriculture. The result is that access to land is no longer a significant predictor for income. Also, for those households that make the majority of their income from labor markets, the quantity of labor available within the household may not be as important as quality (reducing the significance of quantity of labor). Finally, a very low average income within the community creates the opportunity for a single employed individual to easily provide an entire household with an income similar to the average community income. The outcome is that neither land nor labor is predictors for income.

In order to use an analysis comparable to the above OLS regressions at the community level, a sampling technique based on the Bootstrap method is used to increase the sample size. A large sample (N=1000) for each community was collected by randomly resampling the original sample with replacement. This process creates a theoretically plausible population from the original sample that reflects the attributes of the original sample. From that, multiple (k=10) samples (n=100) are collected and each is analyzed using ordinary least square (OLS) regression analysis. The results of each OLS are used to calculate confidence intervals of the estimation statistics. These methods are used as an exploratory method in order to illuminate the relationship between variables, not to make predictions.[11]

[11] In the example of Karkapata, due to the small sample size (n=15) neither of the variables or the F-statistic is significant without resampling. Resampling allows for analysis of the relationships between variables within the dataset as a reflection of the relationships that exist in the population. Sampling errors, such as the use of samples that are not independent, reduce the similarity between the samples and the actual population. The effects of resampling are discussed further in the next section and in Appendix V.

Table 5.3 The relationships between labor, land and income within Karkapata

| k=10, n=100[1] | Mean | Standard Deviation | Parameter Estimate Lower Bound[2] | Upper Bound[2] | Average t-Value[2] | Pr > \|t\|[2] |
|---|---|---|---|---|---|---|
| **Independent Variables** | | | | | | |
| **Intercept** | - | - | 4430.2 | 5311.48 | 8.76±1.01 | <.0001 |
| **Crop Land** | 0.38 | 0.23 | -2435.1 | -1704.9 | -2.41±0.33 | 0.030±0.03 |
| **Adult Equivalent** | 3.83 | 1.55 | -198.35 | -62.01 | -1.11±0.46 | 0.328±0.26 |
| **Dependent Variable** | | | | | | |
| **Total Income** | 3550.95 | 2074.88 | | | | |
| **Model** | **F-value: 4.33 ± 1.35[2]** | | **Pr>F: 0.054 ± 0.07[2]** | | **Adj R-Sq: 0.110 ± 0.104[2]** | |

**Data source:** SANREM CRSP 2006. [1]k=10 samples of n=100 collected from N=1000. [2]Calculated at the 95$^{th}$ percentile from the OLS results.

After resampling, the 95% confidence interval of the adjusted R-square is 0.11±0.1, a very poor fit (Table 5.3). On average, crop land is significant ($\alpha$=0.05) but unexpectedly its coefficient has a negative sign. The expected relationship of increased access to land leading to increased income does not apply here. Access to labor is not significant. The deviation from expected sign in cropland, labor's lack of significance, and low explanatory value indicate that the current model is not a good fit for Karkapata.

The livelihoods in Karkapata express the importance of location and the differences that exist between communities in their use of resources and ability to create an income. Expanding the independent variables to include other assets and capitals increases the dimensions that the model measures, integrating livelihoods that do not rely as heavily on land or labor into the model. Characteristics, such as education and experience of the household's decision maker or head of household (HH), determine

which production methods or labor opportunities the household will use and impact its relative success. The gender of the HH may be an indicator of deeper differences. Within the Aymara culture, men and women have different roles and access to different resources. The gender of HH may also be an indicator of catastrophic loss. In 89.7% of households with male HH a spouse was reportedly living at the location, while only 44.1% of female HHs reported a spouse living at location. This could also be the result of men leaving their families for extended periods of time to work in the city, a fairly common practice in the rural Altiplano. In both cases, a female head of household is much less likely to have a spouse on the farm to help make decisions and to provide labor. Social capital is also important, in some communities more than others. In locations where resources are shared or households cooperate, participation in informal social relationships may increase access to resources. Membership in organizations is an indicator of access to networks that household may tap into for resources. If measures of both types of social capital and an expanded number of human and natural variables are included, the model is able to describe a wider variety of livelihood strategies.

Table 5.4 The relationships between natural, human, and social capitals with income in the community of Karkapata

| k=10, n=100[1] | Mean | SD | Parameter Estimate[2] Lower Bound | Upper Bound | Average t-Value[2] | Pr > \|t\|[2] |
|---|---|---|---|---|---|---|
| **Independent Variables** | | | | | | |
| **Intercept** | - | - | -1364.18 | 952.2631 | -0.09±0.71 | 0.48±0.18 |
| **Crop Land** | 0.38 | 0.23 | -7222.17 | -5524.50 | -5.60±0.71 | <.0001 |
| **AE** | 3.83 | 1.65 | -637.73 | -422.49 | -3.78±0.94 | 0.02±0.3 |
| **TLU** | 4.15 | 2.5 | 479.45 | 686.87 | 5.15±1.05 | <.0001 |
| **Age HH** | 47.62 | 14.4 | 53.12 | 91.25 | 2.65±0.55 | 0.03±0.02 |
| **Ed HH** | 5.45 | 5.09 | 385.71 | 531.69 | 5.13±0.57 | <.0001 |
| **Gender HH** | 0.6 | 0.51 | -1919.97 | -925.28 | -1.87±0.51 | 0.11±0.07 |
| **Local Organizations** | 0.74 | 0.59 | -1196.19 | -943.01 | 3.16±0.44 | 0.01±0.01 |
| **Informal Social Capital** | 1.56 | 1.06 | 846.09 | 1108.64 | 4.81±0.79 | <.0001 |
| **Dependent Variable** | | | | | | |
| **Total Income** | 3550.96 | 2074.88 | | | | |
| **Model** | **F-value:11.0±2.49[2]** | | **Pr>F: <.0001** | | **Adj R-Sq:0.44±0.06[2]** | |

**Data source:** SANREM CRSP 2006. [1]k=10 samples of n=100 collected from N=1000. [2]Calculated at the 95th percentile from the OLS results.

In Karkapata, the fit of the model increased dramatically (from adjusted $R^2$=0.110 ± 0.104 to adjusted $R^2$=0.44±0.06) with the addition of social capital and a greater variety of human and natural capital variables (Table 5.4.). The negative association between land and income remains. Increased access to labor and participation in local organizations are also associated with reduced income. Age, livestock ownership, education and use of informal social capital are associated with increased income. Households with the highest income have few people, little land, do not often participate in formal local organization but rely on informal networks, are older, educated, and own larger livestock herds. This indicates that income is generated by activities that value experience and skills gained over a lifetime and the capacities gained through education, all characteristics associated with labor markets. It may be that low access to land

provides a push factor that forces individuals into the labor markets, where over years of experience they are able to secure higher incomes.

This "assets and capitals" model of income generation accounts for between 33±5% and 69±4% of income generation within the communities (Table 5.5). The remaining unexplained income is due to a variety of factors. Location characteristics such as access to infrastructure and the development of institutions vary across space. As discussed for the community of Karkapata, income generated by individuals working off the farm is difficult to account for using the capitals that are most important for agricultural production. Remittances from individuals that are not included in the household's statistics are also a fair portion of some household's income. Finally, many other capital variables such as productive capital and unique household factors such as ingenuity are not included.

Table 5.5 The variance of income explained by the capitals and assets model in each community

| Community[1] | Lower F-value[2] | Upper F-value[2] | Pr>F | Adjusted-$\overline{R}^2$ |
|---|---|---|---|---|
| **Chinchaya** | 6.75 | 10.13 | <.0001 | 0.37 ± 0.05 |
| **Karkapata** | 10.04 | 14.6 | <.0001 | 0.46 ± 0.06 |
| **Chojñapata** | 8.73 | 13.31 | <.0001 | 0.44 ± 0.06 |
| **San José Llanga** | 11.11 | 17.17 | <.0001 | 0.50 ± 0.06 |
| **San Juan Circa** | 24.51 | 33.45 | <.0001 | 0.69 ± 0.04 |
| **Vinto Coopani** | 5.85 | 8.69 | <.0001 | 0.33 ± 0.05 |
| **Kellhuiri** | 15.08 | 24.4 | <.0001 | 0.59 ± 0.06 |
| **Calahuancani** | 6.89 | 10.73 | <.0001 | 0.38 ± 0.06 |
| **Cohani** | 15.11 | 24.37 | <.0001 | 0.59 ± 0.06 |

**Data source:** SANREM CRSP 2006. [1]k=10 samples of n=100 collected from N=1000 for each community. [2] Confidence intervals are calculated at the 95$^{th}$ percentile using the results of 10 regressions for each community.

A hierarchal model can be used to investigate the magnitude of the effects of region and community on the variables. The first level of analysis is region. An OLS

regression with income as the dependent variable and a dummy variable for region is used to analyze the component of income that can be attributed to regional differences. One the second level of analysis, community dummy variables are the independent variables and the income residuals from the first regression are the dependent variables. According to the first two levels of analysis, region accounts for 24% of the variance within income on households. Controlling for region, community is able to account for a further 15% (Table 5.6).

Table 5.6 The significance of region and community on income

| N=330 | Degrees of freedom | F-Value | Pr>F | Adj R-Square |
|---|---|---|---|---|
| **Region** | 1 | 103.8 | <.0001 | 0.2381 |
| **Community** | 8 | 8.26 | <.0001 | 0.1501 |
| **Total** | | | | **0.3882** |

**Data source:** SANREM CRSP 2006

The resulting residual of income after the above two-step regression is income controlled for region and community. It is then used as the dependent variable and the eight capitals variables are used as explanatory variables in a final regression (Table 5.7).

Table 5.7 The relationship between access to capitals and income controlled for location

| N=330 | Mean | SD | Parameter Estimate | Standard Error | t-Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| **Independent Variables** | | | | | | |
| **Intercept** | - | - | -3268.70 | 2336.58 | -1.40 | 0.163 |
| **Crop Land** | 0.38 | 0.23 | 909.17 | 154.83 | 5.87 | <.0001 |
| **AE** | 3.89 | 1.65 | 872.54 | 230.25 | 3.79 | 0.0002 |
| **TLU** | 4.26 | 2.5 | 58.91 | 73.08 | 0.81 | 0.4208 |
| **Age HH** | 48.07 | 14.4 | -115.91 | 35.39 | -3.27 | 0.0012 |
| **Ed HH** | 5.2 | 5.09 | -26.66 | 136.47 | -0.2 | 0.8453 |
| **Gender HH** | 0.6 | 0.51 | 1891.31 | 1242.51 | 1.52 | 0.1289 |
| **Local Organizations** | 0.73 | 0.59 | 834.75 | 822.87 | 1.01 | 0.3111 |
| **Informal Social Capital** | 1.53 | 1.06 | 487.61 | 397.29 | 1.23 | 0.2206 |
| **Dependent Variable** | | | | | | |
| **Total Income** | 3596.38 | 2074.88 | | | | |
| **Model** | F-Stat: 12.35 | | Pr>F: <.0001 | | **Adj R-Sq: 0.2163** | |

**Data source:** SANREM CRSP 2006

A reduction in adjusted R-square indicates that a portion of the explanatory power in the earlier models was due to correlation between variables and location. After controlling for the correlation between location and income, the capitals model is able to capture 21.6% of the variation in income. As predicted by the livelihoods model and our earlier analysis, land and labor are still the dominant variables followed by age, which is also significant. The other five capital variables are not significant indicating that they do not have a consistent relationship with income across the communities. Similar to the Karkapata's deviation from the expected relationship between land and income, specific capitals may have differing impacts in each community. The total variance explained by location in the model is 55.5%. Significance of both region and community indicate that livelihood studies should take place at the community level if possible. Community level

analysis will also provide insight into unique relationships between capitals and income that may be different in each community.

The above analysis of the data indicates that the livelihoods framework is an appropriate model for the survey households, but that any analysis must take location into account. This model will be extended to include livelihood strategies and other outputs in order to further explore the relationships between the assets that households have access to and their ability to generate a positive impact on their lives and environment.

## 5.2 Analysis of the Relationships between Livelihoods and SES Resilience

This section presents the findings of the canonical correlation analysis at the regional and community levels. The canonical correlation model consists of 12 independent variables and 11 dependent variables (Table 5.8). The analysis is first conducted at the regional level, and then at the community level. With each analysis an interpretation follows, which contextualizes the findings according to information specific to each location. Although differences associated with location are expected, the multi-level analysis will be justified by testing for the significance of location as the analysis progresses across the scales.

Table 5.8 Empirical explanatory and dependent variables in the canonical correlations analysis of socio-ecological systems for the Altiplano of Bolivia

| Independent Variables | |
|---|---|
| Natural Capital | Crop Land |
| | TLU |
| Human Capital | AE |
| | Age HH |
| | Ed HH |
| | Gender HH |
| Social Capital | Local Orgs. |
| | Informal bonding |
| Strategies | Crop Diversity |
| | Autarky |
| | Ag Markets |
| | Labor Markets |

| Dependent Variables | |
|---|---|
| Household Resilience | Vulnerability |
| | Land Productivity |
| | Sickness |
| | Education |
| | Diversity of Income |
| | Income per person |
| | Bridging Orgs. |
| Ecosystem Resilience | % Nitrogen fixing crops |
| | Soil Amendments |
| | Land-Use Diversity |
| | Erosion Control |

### *5.2.1 Regional Analysis*

The livelihoods analysis indicates that historical, climatic, and institutional differences between the regions are a significant factor for household livelihoods. Access to some capitals, such as land or markets may be a reflection of location rather than household characteristics. From the earlier discussion on history, land constraints and transportation; higher crop production, income and participation in agricultural markets is expected in Umala. One-way analysis of variance (ANOVA) was used to determine if region has a significant influence on the variables (Table 5.9). Because a preliminary distribution analysis of the data (not included) revealed that 21 of the 23 variables are not normally distributed, the Wilcoxon ranked-sum test is used as a secondary test. The Wilcoxon ranked-sum procedure (also known as the Mann-Whitney-Wilcoxon test) is a nonparametric method for determining if independent samples are from identical distributions.

Table 5.9 Regional significant differences Between Ancoraimes and Umala in Bolivia: Analysis of variance within the dataset

| | ANOVA | | | | Wilcoxon |
|---|---|---|---|---|---|
| Variable | **SS** | **F Value** | **Pr > F** | **$R^2$** | Approx. P-value |
| Crop Land | 1492.57 | 197.35 | <.0001 | 0.376 | <.0001 |
| TLU | 543.31 | 12.84 | .0004 | 0.038 | .001 |
| AE | 69.47 | 16.2 | <.0001 | 0.047 | <.0001 |
| Age HH | 369.94 | 1.62 | 0.203 | 0.005 | .175 |
| Ed HH | 67.38 | 3.69 | 0.056 | 0.011 | .033 |
| Gender | 0.1 | 0.6 | 0.441 | 0.002 | 0.441 |
| Local Orgs | 27.68 | 108.11 | <.0001 | 0.248 | <.0001 |
| Informal Social Capital | 133.4 | 121.94 | <.0001 | 0.271 | <.0001 |
| Crop Diversity | 122.32 | 100.53 | <.0001 | 0.101 | <.0001 |
| Autarky | 211.03 | 404.26 | <.0001 | 0.552 | <.0001 |
| Ag Markets | 122.27 | 39.37 | <.0001 | 0.107 | <.0001 |
| Labor Markets | 41.28 | 3.23 | 0.073 | 0.010 | .065 |
| Vulnerability | 8.39 | 0.09 | 0.765 | 0.001 | .880 |
| Land Productivity | 24.07 | 81.08 | <.0001 | 0.198 | <.0001 |
| Sickness | 4.57 | 39.95 | <.0001 | 0.109 | <.0001 |
| Education | 1.63 | 0.9 | 0.342 | 0.003 | .664 |
| Income Diversity | 0.008 | 0.03 | 0.8636 | 0.001 | .945 |
| Income per person | 101.85 | 136.05 | <.0001 | 0.293 | <.0001 |
| Bridging Orgs. | 103.21 | 160.89 | <.0001 | 0.329 | <.0001 |
| % Nitrogen Crops | 0.606 | 17.09 | <.0001 | 0.049 | <.0001 |
| Soil Amendments | 76.66 | 19.55 | <.0001 | 0.056 | .005 |
| Land-Use Diversity | 0.67 | 0.32 | 0.57 | 0.001 | .865 |
| Erosion Control | 2843.87 | 129.45 | <.0001 | 0.283 | <.0001 |

**Data source:** SANREM CRSP 2006

According to the ANOVA test, region is significant ($\alpha \leq 0.10$) in 17 of the 23 variables. The Wilcoxon test confirms the ANOVA results. The age and gender of the head of household are not significantly different, nor are their perceptions of vulnerability, propensity to send children to school, income diversity, and diversity of land-use. Perhaps the most unexpected similarities are in education, indicating that both regions have very similar access to and perceptions of education, which is public, and land-use diversity, which does not seem to be affected by the large differences in field size between the regions.

Table 5.10 Descriptive statistics of the two regions: Umala and Ancoraimes, Bolivia

| | Umala (n=181) | | | Ancoraimes (n=149) | |
|---|---|---|---|---|---|
| **Variable** | **Mean** | **Std Dev** | **Difference** | **Mean** | **Std Dev** |
| **Crop Land** | 4.82 | 3.69 | 4.27* | 0.55 | 0.49 |
| **TLU** | 9.57 | 6.54 | 2.58* | 6.99 | 6.46 |
| **AE** | 4.47 | 2.31 | 0.93* | 3.54 | 1.73 |
| **Age HH** | 49.81 | 15.74 | 2.13 | 47.68 | 14.27 |
| **Ed HH** | 7.02 | 4.16 | 0.91* | 6.11 | 4.41 |
| **Gender HH** | 0.81 | 0.4 | 0.04 | 0.77 | 0.42 |
| **Local Orgs.** | 0.12 | 0.35 | 0.58* | 0.7 | 0.64 |
| **Informal Social Capital** | 0.73 | 0.86 | 1.28* | 2.01 | 1.23 |
| **Crop Diversity** | 2.99 | 1 | 1.23* | 4.22 | 1.22 |
| **Autarky**[#] | 8.68 | 0.78 | 1.61* | 7.07 | 0.65 |
| **Ag Markets**[#] | 8.3 | 1.73 | 1.22* | 7.08 | 1.8 |
| **Labor Markets**[#] | 4.49 | 3.65 | 0.71* | 5.2 | 3.48 |
| **Vulnerability** | 35.02 | 10.19 | 0.32 | 34.7 | 9.06 |
| **Land Productivity**[#] | 7.88 | 0.48 | 0.55* | 8.43 | 0.62 |
| **Sickness** | 0.24 | 0.28 | 0.24* | 0.48 | 0.4 |
| **Education** | 1.15 | 1.44 | 0.04 | 1.01 | 1.21 |
| **Income Diversity** | 1.8 | 0.52 | 0.01 | 1.79 | 0.52 |
| **Income per person**[#] | 8.34 | 0.79 | 1.12* | 7.22 | 0.95 |
| **Bridging Orgs.** | 1.39 | 1 | 1.12* | 0.27 | 0.44 |
| **% Nitrogen crops** | 0.31 | 0.19 | 0.09* | 0.22 | 0.19 |
| **Soil Amendments**[#] | 5.39 | 2.55 | 0.97* | 6.36 | 0.88 |
| **Land-Use Diversity** | 3.58 | 1.31 | 0.09 | 3.67 | 1.58 |
| **Erosion Control** | 6.9 | 6.13 | 5.9* | 1 | 1.72 |

**[#]Natural Log**
***Significantly Different at $\alpha$=0.1**

**Data source:** SANREM CRSP 2006

Human characteristics and demographic patterns such as gender and age are fairly similar across both regions, while access issues such as control of natural capital and access to social networks vary more widely (Table 5.10). The table also expresses interesting differences in the details of livelihoods in each of the regions. In Ancoraimes, a high level of soil amendment application may be an indicator of strong input markets in the region or a consequence of high livestock holdings in the region. Lower access to

land also provides households with incentive to invest in factors that increase productivity.

Differences between regions expressed in the livelihoods analysis, hierarchy analysis, ANOVA analysis, and the theoretical importance of location and history, all indicate that region must be included in analysis. There are two commonly used methods for including location into analysis. The first is to include a dummy variable for region and the second is to analyze the datasets separately. The first has the advantage of maintaining the full sample size (N=330) and absorbing the significant differences between regions into the model. ANOVA indicated that region is a significant factor in many of the variables. One difficulty with using a dummy variable for location is that a large portion of the significance and information provided by analysis will be concerned with the regional variable. Analysis has already determined that region is significant in many of the variables. In Umala households have greater access to land, livestock, labor, education, less social capital or crop diversity, and greater participation in agricultural markets. The results of a canonical analysis at this level will be dominated by those differences. This research is more interested in investigating relationships that exist within the data in each region and not regional differences.

A second disadvantage of using a regional dummy variable is that it assumes that the relationships between the variables are similar across both regions. Because the objective of this research is to investigate for multiple relationships that may be different in each region, the use of a dummy variable for location reduces the information gained from the analysis. Therefore, each region will be analyzed separately. For those interested

in further investigating the differences between these two methods, the canonical analysis of the data using a dummy variable for region is included in Appendix IV.

#### *5.2.1.1 Umala*

Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root are four tests that are often used to test the significance of a canonical model. According to all four tests, the model is significant ($\alpha \leq 0.01$; See Appendix VI, Table VI.1). Within the canonical structure, the first seven out of eleven possible orthogonal canonical dimensions are significant ($\alpha \leq 0.01$; Table 5.11). The canonical correlation, which is the correlation between the canonical variables representing each set of variables, is 0.83 in the first dimension and decreases as the strongest relationships are accounted for.

Table 5.11 Umala: Test for the number of significant canonical dimensions

| | Canonical Correlation | Adjusted Canonical Correlation | Approximate Standard Error | Squared Canonical Correlation | Test of H0: The canonical correlations in the current row and all that follow are zero | | |
|---|---|---|---|---|---|---|---|
| | | | | | Approximate F Value | Num DF | Pr > F |
| **1** | 0.83383 | 0.806136 | 0.022713 | 0.695272 | 6.05 | 132 | <.0001 |
| **2** | 0.783571 | 0.759326 | 0.028772 | 0.613984 | 4.76 | 110 | <.0001 |
| **3** | 0.648634 | 0.591644 | 0.043176 | 0.420727 | 3.59 | 90 | <.0001 |
| **4** | 0.590781 | 0.551221 | 0.048521 | 0.349022 | 3.01 | 72 | <.0001 |
| **5** | 0.484497 | 0.416543 | 0.057039 | 0.234737 | 2.44 | 56 | <.0001 |
| **6** | 0.404 | . | 0.06237 | 0.163216 | 2.1 | 42 | <.0001 |
| **7*** | **0.386532** | **.** | **0.063399** | **0.149407** | **1.9** | **30** | **0.0028** |
| **8** | 0.272358 | . | 0.069007 | 0.074179 | 1.45 | 20 | 0.0935 |
| **9** | 0.25266 | . | 0.069777 | 0.063837 | 1.32 | 12 | 0.2019 |
| **10** | 0.148837 | . | 0.072884 | 0.022152 | 0.78 | 6 | 0.5842 |
| **11** | 0.074158 | . | 0.074126 | 0.005499 | 0.46 | 2 | 0.6292 |

*The first seven canonical dimensions are significant at $\alpha=0.05$.

Canonical correlation analysis produces a correlation coefficient and a canonical coefficient for each variable in each canonical dimension. Canonical coefficients for original variables that are correlated with their canonical variable to a degree greater than

r=0.3 are used by researchers for predictive purposes. Table 5.12 shows the standardized canonical coefficients for the first seven canonical dimensions. The first seven dimensions represent seven significant orthogonal, dominant relationships that exist within the dataset. For the sake of interpretation within the sphere of this research, each dimension represents a different combination of assets and livelihood strategies which can be thought of as a livelihood dimension. Each livelihood dimension produces unique social and natural outcomes.

Table 5.12 Umala: Standardized canonical coefficients of the first seven livelihood dimensions (LD)

| | LD* 1 | LD* 2 | LD* 3 | LD* 4 | LD* 5 | LD* 6 | LD* 7 |
|---|---|---|---|---|---|---|---|
| **Crop Land** | 0.441 | 0.774 | | | | | |
| **AE** | 0.117 | | | -0.632 | | 0.221 | |
| **TLU** | -0.069 | | | | | 0.334 | |
| **Age HH** | | 0.604 | | | 0.371 | 0.468 | |
| **Ed HH** | 0.195 | 0.005 | | | | | |
| **Gender HH** | -0.055 | -0.334 | | | | | |
| **Local Orgs** | | | | | | 0.451 | 0.391 |
| **Informal Social Capital** | | | -0.255 | 0.319 | -0.442 | | 0.260 |
| **Crop Diversity** | | | | | 0.720 | -0.349 | 0.274 |
| **Autarky** | 0.565 | | | 1.059 | | | |
| **Ag Markets** | 0.033 | | | | | -0.545 | 0.833 |
| **Labor Markets** | | | 0.720 | -0.254 | | | |
| **Vulnerability** | | 0.533 | | 0.391 | | 0.633 | 0.323 |
| **Land Productivity** | | -0.536 | 0.133 | 0.642 | | | |
| **Sickness** | | 0.216 | | | | -0.469 | |
| **Education** | 0.176 | -0.206 | | | -0.416 | | 0.378 |
| **Income Diversity** | -0.100 | | 0.566 | -0.357 | | | |
| **Income per person** | 0.308 | 0.503 | 0.688 | | | | |
| **Bridging Orgs.** | 0.263 | | | | -0.772 | | |
| **% Nitrogen Crops** | | | | -0.363 | | -0.507 | |
| **Soil Amendments** | | -0.102 | 0.269 | | | | |
| **Land-Use Diversity** | 0.621 | | | | 0.675 | | 0.461 |
| **Erosion Control** | 0.427 | | | -0.214 | | | -0.500 |

*LD stands for livelihood dimension. Notes: Only canonical coefficients for variables that are significantly correlated to their canonical variable ($r \geq 0.3$) are included in the interpretation of that dimension.

Interpretation of the standardized canonical coefficients is similar to that of standardized regression coefficients. For example, in the first livelihood dimension an increase of one standard deviation in *Crop Land*, increases the score of the first canonical variate for the first set of variables by 0.44 standard deviations. The relationship between a set of variates, the canonical correlation, expresses the relationship between the two canonical variates. In this case the canonical correlation is 0.83; thus, when access to crop land is increased by one standard deviation, the canonical co-variate increases by 0.37 (1*0.44*0.83=0.37) standard deviations and *Income per Person* increases by 0.11 (1*0.44*0.83*0.31=0.11) standard deviations. The purpose of this explanation of canonical coefficients is to provide the reader with a better understanding of how canonical correlation works. This research focuses on the canonical structure, which is best illustrated in the correlation between the variables and their variates.

Redundancy analysis calculates how much variance in the variables is accounted for by the canonical variables. Each canonical variable accounts for a percentage of the variance of its own set of original variables and the opposite set of original variables. It is a measure of the model's ability to account for variance in the dependent variables, similar to the purpose of the coefficient of determination ($R^2$) in regression models. In Umala, the canonical variables associated with the explanatory variables are able to account for 28.3% of the variance in the response variables (Table 5.13). This indicates a fairly low level of predictability within the model which, is expected because we are testing for relationships across a wide variety of variables on both sides of the model. The

objective of this analysis is to determine trends in dominant relationships, not predictive power.

Table 5.13 Umala: Redundancy analysis testing the variance captured by each sets own canonical variable and the variance captured in the opposite variables

| | **Their Own Canonical Variables** | **The Opposite Canonical Variables** |
|---|---|---|
| **Cumulative Standardized Variance of the Dependent Variables Explained by** | **0.650** | **0.291** |
| **Cumulative Standardized Variance of the Independent Variables Explained by** | **0.712** | **0.283** |

The canonical structure provides a picture of the dominant relationships in each livelihood. It is composed of the loadings, or weight and direction, of the correlation between variables and their canonical variable. Figure 5.1 illustrates the relationships between explanatory and response variables. Because this study is more interested in groups of relationships than the ability to predict the impact of change within a single variable, most of the interpretation is derived from the canonical structure. The relationships included in interpretation are those that are significantly correlated with their canonical variable ($r \geq 0.3$). In the figure, the dependent variables (assets and strategies) are on the top half and the dependent variables (SES indicators) are in the bottom portion. Only the first three canonical dimensions are shown in order to focus on the strongest relationships. The values shown are the correlation between each variable and their canonical variable. Variables with no value lack a consistent and significant tendency within that dimension.

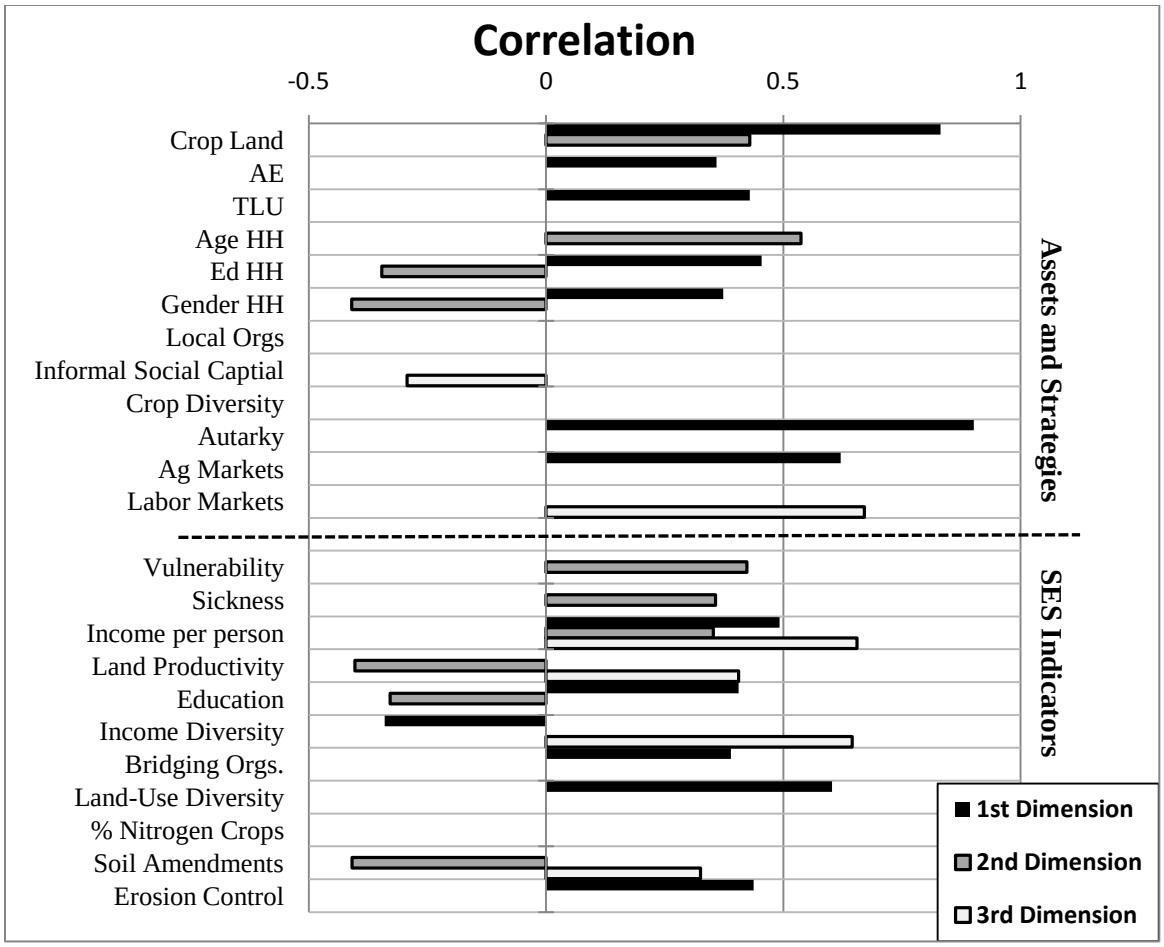


Figure 5.1 Umala: Correlations between variables and their canonical variable in the first three canonical dimensions

The reader should keep in mind that each dimension is describing a unique set of relationships but that multiple relationships are extracted from each household. Each individual household practices a livelihood that is characterized by differing levels of activity in multiple dimensions. At times, the terms livelihoods and dimension are used interchangeably in order to focus on the implications of investing in a specific dimension. Also, the signs of the correlations are a construct of the model and are relative to each other. This analysis will generally follow the direction of the signs provided by the output

of analysis but it is important to know that all the relationships can also be interpreted in the reverse direction. For example, if increased access to land is positively correlated with reduced vulnerability, lower access to land increases vulnerability.

***1st Livelihood Dimension****:* The first livelihood dimension is dominated by the relationships associated with agriculture predicted by the sustainable livelihoods framework. In it, access to land, labor, livestock, education of the HH, and gender of the head of household are all relevant and correlated in the same direction as income per person. Both autarky and participation in agricultural markets are also positively correlated with this agricultural livelihood. The financial impact of increased investment in this strategy is successfully generating a high level of income through agricultural activities, but not a high degree of diversity in income. This is consistent with theory, as households have more land they require more labor, which reduces labor available to generate income in non-cropping activities. Increases in access to capital are associated with increases in investment in human capital through child education, and social capital through the participation in organizations outside the community. Increased access also reduces the vulnerability of the natural systems through increased diversification of land-use and greater erosion control.

***2nd Livelihood Dimension:*** The second livelihood dimension expresses many of the characteristics generated by the lifecycle of the household. As age increases the head of household is more likely to be a female and less educated. Although there is a positive correlation with access to land, there is a negative correlation with productivity,

indicating a lack of labor. Drawing on Chayanov's household model, in environments with imperfect markets, production corresponds to household makeup. Thus, increased access to land that is not accompanied by increased access to labor results in reduced productivity of land to maintain constant output. This livelihood dimension is positively correlated with sickness and vulnerability. Although older households generate a greater level of income per person, they also reduce investment in the future through child education or maintaining land productivity. Lower child education may be the result of the natural family cycle or that households with greater access to land rely on their children's labor. Within this dimension, younger households have less access to land, are more educated, are less vulnerable, and have greater resilience, and lower income per person.

***3rd Livelihood Dimension:*** This dimension is associated with the effects of activity within the labor markets. Labor markets include any off-farm income generated by the household. Increases in labor activities reduce involvement in informal social relations, which may be a result of formalizing those relationships in the labor market or that working outside of the community reduces the individual's opportunities to engage with community members. Within this dimension, increases in labor activities generate higher income per person and diversifies the income portfolio. Activity in the labor market is also associated with increases in land productivity and investment in maintaining productivity through inputs, which may be the result of increased cash from off-farm employment.

***Conclusions:*** The first three canonical dimensions express three dominant livelihood dimensions; agriculturalist (Bebbington 1999; Valdivia and Quiroz 2001), life cycle (Chayanov in Ellis 1993; Valdivia, Dunn, and Jetté 1996) and diversification into off-farm income (Barrett, Reardon, and Webb 2001; Ellis 1998; Reardon, Delgado, and Malton 1992; Valdivia, Dunn, and Jetté 1996). Each dimension impacts its surroundings differently. Although each household's livelihood strategy within the population is composed of unique combinations of many different dimensions, these three dimensions (along with 4 others) are statistically significant across the population. Their impact on the resilience of households and the ecosystem has been divided into two groups, vulnerability and sustainability (Table 5.14) according to the parameters in Table 4.4.

Table 5.14 Vulnerability and sustainability of dominant livelihood dimensions in Umala

| | | 1st Dimension | 2nd Dimension | 3rd Dimension |
|---|---|---|---|---|
| Household | Vulnerability[1] | ↓ | ↑ | ↓ |
| | Sustainability[2] | ↑ | ↓↓ | ↑↑ |
| Ecosystem | Vulnerability[3] | ↓ | | |
| | Sustainability[4] | ↑ | ↓ | ↑ |

[1]Household Vulnerability: *Vulnerability, Sickness, Income per person.* [2]Household Sustainability: *land productivity, Education, Income diversity, Bridging organizations.* [3]Ecosystem Vulnerability: *Land-use diversity.* [4]Ecosystem Sustainability: *Percent nitrogen crops, Soil amendments, Erosion control*

The agricultural dimension is correlated with increasing SES in all four categories. In Umala, increased participation in this livelihood dimension successfully generates income and is positively correlated with investment in the future of their livelihoods through child education and land-management methods with positive outcomes. A potential weakness of this strategy lies in an economic portfolio that is not diversified into uncorrelated sectors such as off-farm labor or livestock. Households that

generate the majority of their income from cropping activities are vulnerable to natural shocks. These households appear to have built a network of relationships with organizations from outside of the community, which may be used to access resources if a natural shock should place them at risk.

The lifecycle dimension expresses that households later in their cycle are more vulnerable and less sustainable. It may be that the observed increase in income, as age increases, is in part due to remittances from younger family members or generally smaller households. With age comes a reduction in field productivity and lower investments in inputs indicating a loss of sustainability in their agricultural practices. As is common for many older households, age increases vulnerability to both natural and social shocks, and households seem unable to invest in increasing their future resilience or that of the ecosystem.

The third livelihood captures participation in labor markets. The household's resilience to both natural and social shocks increases with activities in the labor market. Participation in the labor market is also positively correlated with land-use/management methods that increase the sustainability of the natural systems. Diversifying into off-farm labor markets appears to have benefits in both the natural and ecological systems. Because the labor market does not appear to discriminate according to age, this may be a rout for older households to reduce the negative impacts associated with lifecycle. In Umala, diversification in the labor markets increases resilience in the SES.

### *5.2.1.2 Ancoraimes*

In Ancoraimes the Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root found the model is significant ($\alpha \leq 0.01$; See Appendix VI, Table VI.2). The first seven canonical dimensions are significant ($\alpha \leq 0.01$; Table 5.15).

Table 5.15 Ancoraimes: Test for the number of significant canonical dimensions

| | Canonical Correlation | Adjusted Canonical Correlation | Approximate Standard Error | Squared Canonical Correlation | Test of H0: The canonical correlations in the current row and all that follow are zero | | |
|---|---|---|---|---|---|---|---|
| | | | | | Approximate F Value | Num DF | Pr > F |
| **1** | 0.88 | 0.86 | 0.02 | 0.77 | 5.86 | 132.00 | <.0001 |
| **2** | 0.76 | 0.71 | 0.03 | 0.58 | 4.40 | 110.00 | <.0001 |
| **3** | 0.72 | 0.68 | 0.04 | 0.51 | 3.70 | 90.00 | <.0001 |
| **4** | 0.59 | 0.51 | 0.05 | 0.35 | 2.98 | 72.00 | <.0001 |
| **5** | 0.55 | 0.51 | 0.06 | 0.30 | 2.63 | 56.00 | <.0001 |
| **6** | 0.45 | . | 0.07 | 0.20 | 2.23 | 42.00 | <.0001 |
| **7*** | **0.44** | **.** | **0.07** | **0.20** | **2.02** | **30.00** | **0.00** |
| **8** | 0.34 | 0.33 | 0.07 | 0.12 | 1.47 | 20.00 | 0.09 |
| **9** | 0.22 | . | 0.08 | 0.05 | 0.98 | 12.00 | 0.47 |
| **10** | 0.19 | . | 0.08 | 0.04 | 0.89 | 6.00 | 0.51 |
| **11** | 0.04 | -0.01 | 0.08 | 0.00 | 0.14 | 2.00 | 0.87 |

*The first seven canonical dimensions are significant at $\alpha$=0.05.

Redundancy analysis shows that the model is a slightly better fit in Ancoraimes than for Umala. The seven significant canonical dimensions are able to capture a greater portion of the variance (32.8%) in their own variable set and the opposite variable set (Table 5.16).

Table 5.16 Ancoraimes: Redundancy analysis testing the variance captured by each set's own canonical variable and the variance captured in the opposite variables

| | Their Own Canonical Variables | The Opposite Canonical Variables |
|---|---|---|
| **Cumulative Standardized Variance of the Independent Variables Explained by** | **0.671** | **0.330** |
| **Cumulative Standardized Variance of the Dependent Variables Explained by** | **0.746** | **0.3281** |

Similar to the analysis for Umala, the first three canonical dimensions are examined in detail. Only those variables that are correlated at r≥0.3 are used for interpretation (Figure 5.2).

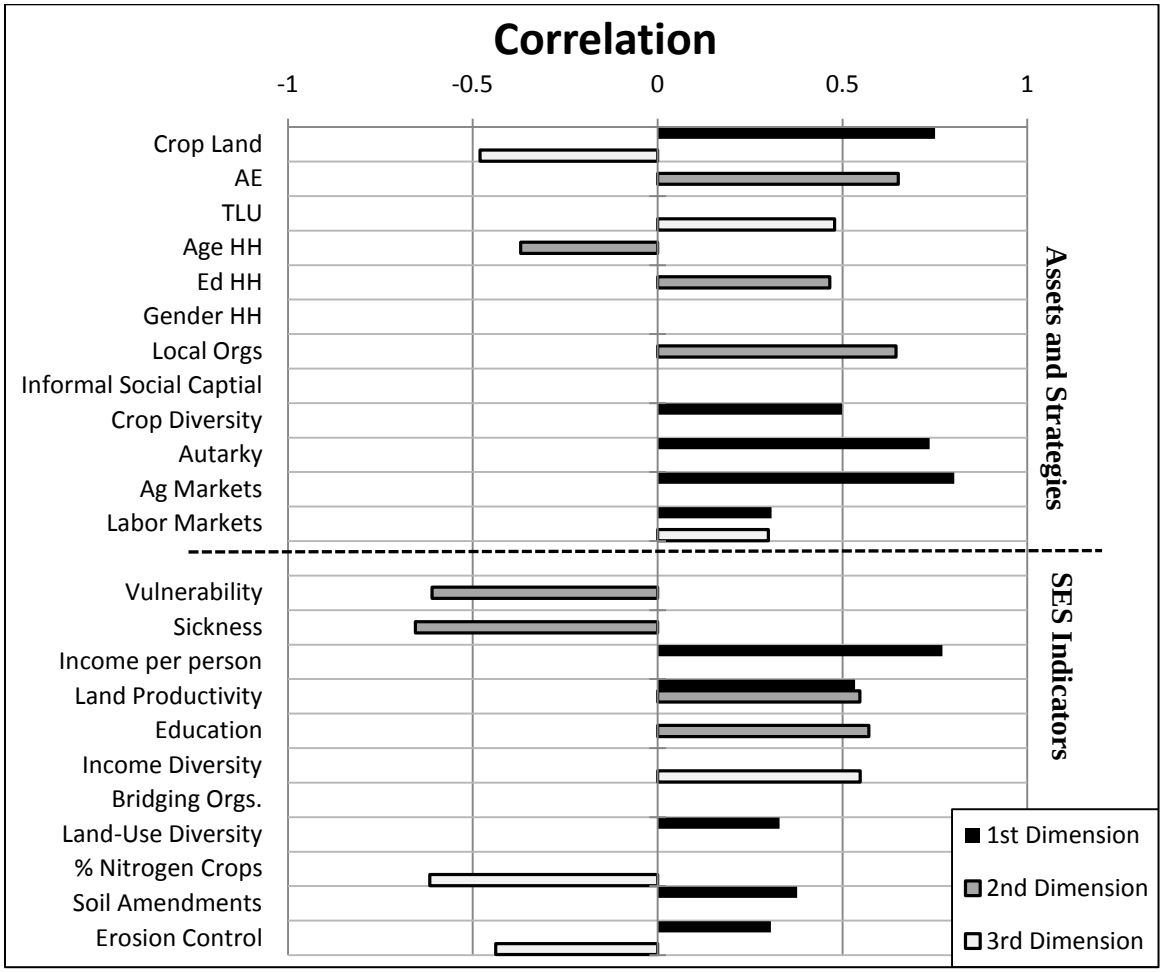


Figure 5.2 Ancoraimes: Correlations between variables and their canonical variable in the first three canonical dimensions

***1st Livelihood Dimension:*** The most dominant livelihood dimension in Ancoraimes is correlated with access to only one asset, land. Access to land is positively correlated with

increased crop diversity, autarky, agricultural markets, and labor markets. Investment in this livelihood is correlated with sustainable and diverse land-management practices through increased use of inputs maintaining erosion reducing techniques. It is interesting to note that this livelihood shares many of the characteristics of the agricultural dimension in Umala but differs in its independence to livestock, labor and HH characteristics. This is a reflection of the relatively high degree of cropland constraint in Ancoraimes whereas in Umala there are a greater number of important constraints indicating that no one constraint is key in that region.

***2nd Livelihood Dimension:*** Household lifecycle drives the second livelihood dimension in Ancoraimes, as it did in Umala. Households that are earlier in their lifecycle are larger and are more likely to have a younger, educated head of household. Within Ancoraimes, lifecycle is correlated with participation in local organizations, with younger households participating to a greater degree. Younger families also more heavily invest in future human capital, their land is more productive, they feel less vulnerable, and suffer from less sickness.

***Livelihood 3:*** The third livelihood dimension in Ancoraimes is similar to Umala in its association with activity diversification but differs in including diversification into livestock. Here households diversify away from cropping, into pastoralist activities and labor markets. It may be that households with little access to cropland are pushed into these other activities or that livestock and labor are better fitted to other household factors such as climate or access to markets. For example, in the northern portions of

Ancoraimes where Chojñapata is located, small plots and climate reduce the benefits of cropping. Households have adapted by keeping large herds of llama and alpaca (Table 2.2). Although this analysis does not express it, many of the households in Chojñapata, which on average generate 60% of their income from livestock and livestock byproducts, contribute to the significance of this livelihood. As households have less access to cropland, they increase their livestock holdings and their activities in the labor markets. The result is a diversified income spread across livestock, labor, and crops. They also under-invested in maintaining their natural systems, planting less nitrogen fixing crops and maintaining less erosion control on their lands.

***Conclusions:*** Investment in the first livelihood dimension is correlated with both reducing the household's vulnerability to shock and maintaining resilience (Table 5.17). Unlike the agricultural dimension in Umala, this strategy is not negatively correlated with income diversity nor is it correlated with other assets. This is an expression of land fragmentation and accessibility across the region, and differences within the region that reduce the impact of land on other assets. Beyond that difference, the two livelihoods are very similar even though the absolute access to land is very different.

The second dimension associates younger households with sustainability and reduced vulnerability, but only at the human level. The model provides little information about the impact on natural resilience which indicates that there is no general correlation between lifecycle and impact on the ecosystem. This is different than in Umala where activities by older households work towards reducing the resilience of the ecosystem.

The third pastoralist strategy is associated with reduced vulnerability but invests little in maintaining the natural system. These households have chosen a livelihood in order to adapt to a harsh climate. It may be that this livelihood relies on income diversity and little investment in any one specific piece of land, or that the model does not capture the pastoralist livelihood well. Further investigation into the data reveals some insight. In Chojñapata, where the households are pastoralist to a greater degree than in any of the other communities, there are few reports of owning native pastures. During a personal interview in Chojñapata, Jensen talked to a household about its grazing practices. The head of household reported that most households allow their livestock to graze freely in open pastures located in the mountains during the summer. This community also continues to practice the traditional method of community owned fields or *aynocas*. The survey does not account for access to either of these commonly owned resources which may be unique to the one community. It may be that their grazing practices are highly sustainable or vulnerable but not captured here. The following community level analysis will return to this issue in hopes of gaining more insight into the unique characteristic of communities.

Table 5.17 Vulnerability and sustainability of dominant livelihood dimensions in Ancoraimes

| | | 1st Dimension | 2nd Dimension | 3rd Dimension |
|---|---|---|---|---|
| Household | Vulnerability | ↓ | ↓↓ | |
| | Sustainable | ↑ | ↑↑ | ↑ |
| Ecosystem | Vulnerability | ↓ | | |
| | Sustainable | ↑↑ | | ↓↓ |

#### *5.2.1.3 Regional Summary*

The first dimension in both regions expresses that low access to assets can constrain a household's ability to buffer itself from shocks and reduces its ability to work towards increasing the resilience of its SES. In Umala it seems that households are constrained by human and natural capital whereas livelihoods in Ancoraimes are dominated by a land constraint. Lifecycle dominates the second dimension in both locations. Younger families generally are less vulnerable and are able to practice more sustainable activities. In Umala, older households are able to generate a high level of income per person but that income is not able to reduce their vulnerability to sickness or perceptions of vulnerability to weather/climate related risk. The third dimension is a measure of the household's diversification away from cropping. In Ancoraimes we see that a push factor, lower access to land, increases investment in livestock and the labor market. Within Umala there is no push from a lack of land, and investment in land is not correlated with low capital except for informal social capital, which may be a product of participating in the labor markets. In both regions, diversification increases household resilience. In Ancoraimes reduced access to labor on the farm decreases the likelihood of sustainable agricultural practices while in Umala, increased activity in the labor market has only positive impacts.

### *5.2.2 Community Level Analysis*

Each community has its own unique characteristics and environment in which households function. The households in Chojñapata have adopted a higher level of pastoralism in order to reduce dependence on crops that are vulnerable to the elements at

higher elevations. In Karkapata, the households have bifurcated incomes with some households generating the majority of their income from a few individuals working in the labor markets while others depend completely on agricultural production. Canonical correlation at the community level will illuminate unique community characteristics. Random sample with replacement is used in order to increase the sample size and stabilize the results. The resulting sample reflects that attributes of the original survey results but is not the only set of data that could do so. Here it is used only as a means to explore the sets of relationships that exist within the data, not investigate specific variables for significant predictive power. The original sample for each community has been resampled to produce a sample of n=1000 in each community[12].

The objective of analysis at the community level is twofold. The first is to see at what level the dimensions of livelihoods that were found at the regional level are followed at the community level. The second is to investigate those dimensions that do not follow the general regional trends, searching for those that are unique or especially resilience increasing or decreasing. The communities are grouped together by region during the discussion of results. This is in order to maintain the regional context that has been developed over the previous analysis. The descriptive statistics of the variables at the community level are included in Appendix VI: Tables VI.3 and VI.5.

The results of canonical analysis are reported using arrows to express the direction of correlation (Tables 5.18 and 5.19). For ease of analysis, one positive correlation is able to offset one negative correlation in the SES categories (See Appendix

[12] See Appendix V for a side-by-side comparison of original and resampled data used in a canonical analysis.

VI: Tables VI.4 and VI.6 for the full numeric results). Also, remember that it is the relationships between directions that are important, the absolute direction of the signs are relative. Once again, only the absolute correlations greater than 0.3 are reported.

#### *5.2.2.1 Communities within Umala*

In Umala we expect to see differences between the communities on the lowlands (San José Llanga and San Juan Circa) and those in the hills (Vinto Coopani and Kellhuiri). The two zones have distinct differences in access to land, livestock, and income. They are similar distances to the market town and county seat of Patacamaya but the households in the lower regions report greater access to transportation. There are also infrastructural differences such as access to milk depots and geographic differences such as topography of the land.

Table 5.18 Umala: Community level livelihood dimensions

| | | San José Llanga | | | San Juan Circa | | | Vinto Coopani | | | Kellhuiri | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L1 | L2 | L3 | L1 | L2 | L3 | L1 | L2 | L3 | L1 | L2 | L3 |
| **Crop Land** | | | ↑ | | ↑ | ↑ | | ↑ | ↑ | ↑ | ↑ | | |
| **AE** | | | ↑ | ↓ | ↑ | ↑ | | | ↑ | | ↑ | | |
| **TLU** | | | ↑ | ↓ | | ↑ | | | | ↑ | ↑ | | |
| **Age HH** | | ↓ | | ↑ | ↑ | ↓ | | | | | ↓ | | |
| **Ed HH** | | ↑ | ↑ | | | ↑ | | | | ↓ | ↑ | | |
| **Gender HH** | | ↑ | ↑ | | | ↑ | | | | | ↑ | | |
| **Local Orgs.** | | | | ↑ | | ↑ | ↓ | ↓ | ↑ | | ↑ | ↓ | |
| **Informal Social Capital** | | | | | ↓ | ↓ | | | | | | | |
| **Crop Diversity** | | ↑ | | | ↑ | | | ↑ | ↓ | | | ↑ | |
| **Autarky** | | ↑ | ↑ | | | ↑ | | ↑ | ↑ | | ↑ | ↑ | |
| **Ag Markets** | | ↑ | ↑ | | | ↑ | ↑ | ↑ | ↑ | | ↑ | | ↑ |
| **Labor Markets** | | | ↑ | | ↓ | | ↑ | | | | ↓ | ↑ | |
| | | | | | | | | | | | | | |
| **Human System** | **Vulnerability** | | ↓ | | | ↓↓↓ | ↓ | ↓↓ | ↓ | | | ↓↓ | ↑ |
| | **Sustainability** | ↑ | ↑ | ↓ | ↓↓ | ↑↑ | | ↑ | ↑↑ | ↓↓ | ↑ | | ↑↑ |
| | | | | | | | | | | | | | |
| **Eco-system** | **Vulnerability** | ↓ | | | ↓ | ↓ | | ↓ | | | | | |
| | **Sustainability** | ↓ | ↑↑↑ | | | | ↓ | ↑↑ | ↑ | ↑ | ↑ | ↓ | ↓ |

In all four communities there are agriculturalist dimensions that are correlated to cropland access. In most cases increased access to land it is associated with increased access to other capitals and generally positive impacts on SES resilience. In only two cases the majority of impacts associated with land are negative; one in San Juan Circa and one in Vinto Coopani. In both cases there is negative impact on the sustainability of the household but not the ecosystem.

In San Juan Circa, the first dimension associated with increased access to land is correlated with age and many of the negative effects associated with life cycle that was evident in the regional analysis. Here age brings reduced household sustainability and increased ecosystem vulnerability. The households have low participation in organizations that can help build bridging capital, have low land productivity but high land-use diversity. It is interesting to note that these households still maintain a high degree of access to labor. At the regional level, age and labor are either uncorrelated or negatively correlated. This dimension is also negatively correlated with activities in the labor market. It may be that these households maintain their labor levels by focusing on agriculture.

In Vinto Coopani, the third dimension is positively associated with land but contrary to the expected correlation between access to land and improved resilience, increased access to land generally produces poor results. These households hold greater livestock herds and the education of the head of household decreases while land access increases. They have low land productivity and low investments in child education but do plant a higher proportion of nitrogen fixing crops. In all likelihood the households with

greater land are keeping their children at home as a sources of labor. There is an explanation for this in the geography and history of Vinto Coopani. Until recently, Vinto Coopani was two communities; Vinto was down next to the road and Coopani was a separate community further up in the hills. The two towns joined in order to become recognized as an official community and gain access to federal funds. Those funds were used to build the school that now lies in what was once Vinto. Some of the households from Coopani are very isolated, far from roads and without transportation. For those households the opportunity costs of school are much higher than for the families from the Vinto. For those households that are isolated, relying on traditional insurance methods, such as livestock herds, may be more beneficial than increasing crop production, which is more vulnerable to climatic shocks.

There are no dimensions in any of the livelihoods where increases in age are correlated with a net positive effect across the human and ecological systems. This supports the earlier analysis of life cycle. There does not appear to be a strategy or safety net that is able to completely off-set the difficulties that affect households later in their lifecycle. It would have been fortunate to find a strategy in one of the communities that was able to reduce the vulnerabilities that seem to nearly always be associated with age, without negatively impacting the other systems.

The third strategy that appears at the regional level was a rural strategy of diversifying into labor markets away from agriculture. In all the communities except Vinto Coopani there are dimensions correlated with the labor market. Vinto Coopani receives the highest proportion of income from off-farm labor and remittances (23%); it may be that nearly all the households are pursuing this strategy to similarly high degrees.

Of those dimensions that are correlated with participation in the labor markets, increased participation increases resilience except for Kellhuiri. There is a tradeoff in Kellhuiri between increased access to natural, human, and social capital and increased participation in labor markets. In that dimension, increased access to capital is associated with greater resilience, while reduced access to capital pushes individuals into the labor market and reduces overall resilience. Kellhuiri's second dimension illustrates the impact of participation in labor markets that is not caused by low access to capital. In this dimension, activities in the labor market reduce the household's vulnerability but continue to reduce the likelihood that the household will practice sustainable land-management.

#### *5.2.2.2 Communities within Ancoraimes*

There are five communities within Ancoraimes. Analysis of the communities will follow the methods used for Umala, examining peculiarities within communities that do not fit the findings of the regional model well.

Table 5.19 Ancoraimes: Community level livelihood dimensions

| | | Chinchaya | | | Karkapata | | | Chojñapata | | | Calahuancani | | | Cohani | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L1 | L2 | L3 | L1 | L2 | L3 | L1 | L2 | L3 | L1 | L2 | L3 | L1 | L2 | L3 |
| Crop Land | | ↑ | ↑ | ↑ | ↓ | | ↑ | ↑ | | | | | ↑ | ↑ | | |
| AE | | | ↓ | | | | | | | ↑ | | ↑ | ↑ | | | ↑ |
| TLU | | | | ↑ | | | ↑ | | | ↓ | | | ↑ | ↑ | | ↑ |
| Age HH | | | | | | | | ↑ | | | | | | | ↓ | ↓ |
| Ed HH | | | | | | | | ↓ | | | | ↑ | | | | |
| Gender HH | | | | | | | ↓ | | ↑ | | | ↑ | ↑ | | | ↓ |
| Local Orgs. | | | ↓ | | | | | ↓ | | ↑ | | | | | ↑ | |
| Informal Social Capital | | | | | ↑ | ↓ | | ↑ | | | | | | | | |
| Crop Diversity | | | | | | | ↑ | | ↑ | | | ↓ | ↑ | | ↑ | |
| Autarky | | ↑ | | ↑ | | | ↑ | ↑ | | ↑ | | ↑ | ↑ | ↑ | ↑ | ↑ |
| Ag Markets | | ↑ | | ↑ | | ↑ | | ↑ | | | | ↑ | ↑ | ↑ | ↑ | |
| Labor Markets | | ↑ | ↑ | ↓ | | | | ↓ | | | ↑ | | | ↑ | | |
| | | | | | | | | | | | | | | | | |
| Human | Vulnerability | ↓ | ↑ | ↑ | ↓↓ | | ↑ | | | ↓ | ↓ | ↓↓ | ↑ | | | ↑ |
| Systems | Sustainability | ↑ | | ↓ | | ↑ | ↑ | ↓ | ↓ | | ↑ | ↑↑ | ↑↑↑ | ↑ | ↑ | ↑ |
| | | | | | | | | | | | | | | | | |
| Eco- | Vulnerability | | ↓ | | ↑ | | | | ↓ | ↓ | | | ↓ | | ↓ | |
| system | Sustainability | | ↑ | ↑ | | ↑ | | ↑ | ↑ | ↓ | | ↑ | ↑ | ↑ | | ↑ |

In each community, the first livelihood dimension is correlated with land except for Calahuancani, where only the third dimension is positively correlated with land. At the regional level, the agricultural dimension was associated with positive impacts across the entire SES. That is not necessarily the case at the community level. In Chinchaya, Karkapata, Chojñapata, and Calahuancani there is evidence of households negatively impacting at least one dimension of the SES as their access to land increases. Further examination of the data reveals that the damages associated with increased access to land never take place within ecosystem sustainability. The same rule holds in the communities of Umala. That is, increased access to land is most often correlated with ecosystem sustainability and is never correlated with reducing ecosystem sustainability.

The consistency of this relationship indicates that low access to land is a consistent cause of damages to the resilience of ecosystems.

There is evidence of the impact of lifecycle in only two of the communities, Chojñapata and Cohani. In Cohani, two of the dimensions are correlated with age of the head of household. Both express negative impacts in both sustainability and vulnerability associated with older age. Both Chojñapata and Cohani have the least educated head of household, invest least in child education, and have the lowest crop diversity. For Cohani, the list goes on; it also has the lowest access to land, fewest livestock, and lowest amount of social capital. The outcome is that the households in Cohani have the lowest total income and have not been able to successfully tap into labor or agricultural markets relative to the other four communities. The community as a whole has the lowest score in six of the nine indicators of SES resilience. For both Chojñapata and Cohani, it may be that poor results of their efforts have left the population very vulnerable, increasing the impacts of those variables that are highly significant such as land, lifecycle, and participation in the labor markets. Another perspective is that higher degrees of education and crop diversification have reduced the impact of lifecycle on the households in Chinchaya, Karkapata, and Calahuancani.

In Calahuancani the first dimension is associated only with labor markets on the explanatory side. This dimension leads directly to greater resilience in the human system through both greater income per person and higher land productivity. The correlation between activity in the labor market and increased resilience in the human system is generally consistent in all the communities. The one exception is the second of three dimensions in Chinchaya correlated with labor. Within that dimension, households have

greater access to land but lower labor and participation in local organizations. The result is insufficient labor to both work off the farm and reduce vulnerability in a sustainable way. The dimension is associated with increases in perceived vulnerability and sickness, even while generating a greater income per household member (Table VI.6). It is also correlated with all four human sustainability variables which have off-set each other in Table 5.11. Their strengths lie in building bridging capital and income diversity while their weaknesses are low land productivity and low access to labor, resulting in households keeping children at the farm.

There is evidence of the impact of livestock ownership in all five communities. In every community there is a positive association between increases in livestock and vulnerability in the household system. In Chinchaya, Karkapata, Chojñapata, and Calahuancani, livestock is correlated with the household's own perceptions of vulnerability. In Cohani, livestock is correlated with sickness in both cases and increased income generation when it is coupled with activity in the labor market. This implies that investment in livestock is either a mechanism by which households with high vulnerability buffer themselves from shocks or that increases in livestock holdings create increases in vulnerability. There is significant evidence that households on the Altiplano use livestock as a saving and insurance mechanism, buffering them against shocks (Moser and Antezena 2001; Valdivia 2004).

There are a few other trends in the data that are worth noting. Education is only correlated with two of twelve possible dimensions. Where it is significant, education is always correlated with higher sustainability in the human system, in Chojñapata through increased income diversity and in Calahuancani through increased investment in

the education of children and participation in bridging organizations. The social capital variables are not consistently correlated with any of the outcomes or other inputs. It may be the structure of costs and benefits associated with social capital are unique to each household, producing no recognizable association in this analysis. Households must be investing in the factors of social capital for a diverse set of reasons, perhaps because the outcomes of investment are very inconsistent. It may also be that the variables used in this research are not appropriate measures or that their impacts differ widely between communities. Although the average community values for *Local Organizations* and *Informal Social Capital* are similar across the communities, the meaning and benefits of participation is different in each.

Finally, Calahuancani has the two most resilience improving livelihood dimensions. They also have the greatest average participation in local organizations, smallest families, and highest participation in the labor markets. Their livelihoods produce households that, on average, invest the most in child education and practice the most highly diversified land-use while participating in formal bridging organizations less than any other community. Although they do not have the highest income they do produce the greatest quantity of potatoes and income from livestock. An interesting note is that Calahuancani generates a significantly larger portion of its income from livestock sales than any of the other communities but produces very little milk. They appear to be following a non-dairy livestock path that has less negative factors associated with it than the dairy livestock path. Their livelihood strategies build especially strong human systems without eroding sustainability of their natural systems.

Examining the difference in the first, second and third dimensions within Calahuancani reveal subtle relationships similar to what we have seen on the regional level and within other communities. The first dimension expresses the relationships associated with the labor markets; increase resilience of the human system. The second and third express the trade-offs that take place on the farm; both are positively correlated with labor. With increased access to land and livestock comes the ability to diversify crops and reduce vulnerability of the ecosphere, at the cost of higher household vulnerability. The second dimension is a very similar scenario except the head of household is more educated and uncorrelated with land and livestock. Investment in this second dimension no longer reduces ecosystem vulnerability but drastically reduces household vulnerability.

### *5.2.3 Summary*

Many of the same livelihood dimensions exist at the community and regional levels. Households with high access to land and labor are able to both decrease vulnerability and increase sustainability, often improving the resilience of their SES. There is evidence that the influence of life cycle plays a large part in some communities, while others are able to mitigate its effects. In both Chojñapata and San Juan Circa, increased access to land is associated with increased ecosystem resilience even as age increases. In Ancoraimes, communities that do not have a livelihood dimension associated with lifecycle have, on average, the most highly educated heads of household. It may be that these households are able to better plan for their old age or that at an older age they are more likely to continue using the same practices that they used earlier in

their lifecycle. In both cases, education seems to reduce the impacts of lifecycle within the household.

Many of the livelihood dimensions express that the household's decision of where to invest its labor is a very important decision. Households with greater access to land are often able to generate more income, but at the expense of investing their labor elsewhere. In San Juan Circa, Kellhuiri, Chinchaya, and Chojñapata increases in access to land is negatively correlated with participation in the labor market and loss of the advantages that come with it. There is also evidence that increased access to land reduces investments in child education in Chinchaya and Vinto Coopani.

Investing labor in off-farm activities is often correlated with increased SES resilience. According to the literature, households that diversify their income experience reduced vulnerability. The two methods of diversification measured in this research are off-farm labor and livestock. Dimensions that are correlated with participation in the labor markets nearly always express a positive relationship between market participation and increasing the resilience of the household. The result of livestock holdings is more mixed. In those dimensions that are also correlated with land and labor (the Umala agriculturalists), investments in livestock complement an already resilient livelihood. In Ancoraimes, there is evidence that household's livestock holdings are correlated with vulnerability. These vulnerable households are most likely keeping livestock as a form of saving and insurance. Finally, information from Calahuancani indicates that some of the negative factors associated with livestock may be more closely related to intensified dairying than the agro-pastoralist livelihood.

# Chapter 6: Conclusions, Limitations, and Further Research

This chapter is divided into four sections. It begins by examining the conclusions that can be drawn from analysis of the survey data. Specifically, it addresses the results of analysis in light of the four hypotheses stated in the conceptual framework. That examination leads to a discussion of what was revealed regarding the relationships between households in the Bolivian Altiplano and their social-ecological system, and the limitations of this research. The final section is composed of suggestions for further research that would continue to inform on the relationships between livelihoods and SES resilience.

## 6.1 Conclusions

This section will use the hypotheses formed from the conceptual model in order to direct a discussion on the results of the analysis. In most cases there is no single conclusion; rather, individual communities relate to the hypothesis in different manners. Often, some communities support the hypotheses and others contradict them, while in a third group they are irrelevant. Rather than analyze each communities' relationship to the hypotheses, this analysis will emphasize those that seem to be especially supportive or contradictory.

*Hypothesis 1: Livelihoods associated with low access to all capitals are correlated with vulnerability and are unable to invest in maintaining a stable SES.*

Initial analysis of the sustainable livelihoods model provided significant evidence of a strong positive correlation between access to capitals and income. According to poverty theories and multiple studies on vulnerability, low income is often associated with high vulnerability and the inability to invest in maintaining long-term, sustainable, risk-reducing livelihoods. The canonical correlation analysis supports the preliminary livelihoods analyses. Dominant livelihood dimensions at the regional and community levels most often show positive correlation between access to capitals and increased SES resilience. Nearly all the exceptions to that relationship involve access to social capital and livestock. After controlling for location, access to livestock and social capital are not significant predictors of income (Table 5.7) but there is evidence that they are important in some communities. This finding indicates that the role of social capital and livestock production varies across communities.

Traditionally, Bolivian farmers use livestock as saving and insurance mechanisms (Moser and Antezena 2001). Valdivia (2004) found that households use sheep to buffer themselves against economic shocks. A second study found that perceptions of risk decreased as sheep and dairy holdings increased (Rees 2009). The positive correlation between livestock and vulnerability reflects the use of livestock by vulnerable households to buffer themselves from shocks. The correlation between households with low livestock holdings and low perception of vulnerability may be the result of an association between higher income levels and access to forms of insurance beyond livestock holdings.

Household levels of livestock ownership are influenced by geography and policy. Households far up the Ancoraimes watershed in the community of Chojñapata are more vulnerable to certain climatic shocks such as frost or drought. They are also furthest from certain types of formal infrastructure like paved roads, urban markets, or public transportation and they feature highly pastoral livelihoods. Their relationship to livestock is very different than that of the lowland households of Umala. National policies, such as those that are meant to foster the development of dairy, may inadvertently discriminate along geographic and social lines. For example, the towns of San José Llanga and San Juan Circa have dairy collection points that provide a reliable demand and price for dairy farmers in the region. Geographically distant communities must either depend on daily consumer markets or preserve milk in the form of yogurt or cheese.

Access to social capital has an inconsistent influence within the model. Social capital is created and destroyed depending on the amount of time that people have to invest in it, reflecting the importance of relationships in people's livelihoods. Other social factors such as migration and religion may change the nature of networks, too. In this model, the use of informal networks is often positively associated with age, and thus the many detrimental relationships to the SES that come with the end of the lifecycle. If older heads of household are more likely to use informal networks, it also means that younger heads of household are less likely to depend on informal networks.

In Ancoraimes, participation in formal organizations is always correlated with increased resilience in the human systems. In Umala, the relationship is inconsistent, producing detrimental consequences in San José Llanga, beneficial results in Kellhuiri, and mixed results in Vinto Coopani and San Juan Circa. These findings point to benefits

associated with participating in organizations in the most vulnerable communities but not so for the wealthier communities.

*Hypothesis 2: Households with low access to natural capital will invest in strengthening human systems but may overexploit their natural systems.*

In many of the individual communities and across the Umala dataset there is evidence that households with less access to land increase their investments in human capital. In specific circumstances—especially in communities with low absolute levels of land—reduced access to land is correlated with reduced ecosystem resilience, even where it is correlated with increased household resilience.

At the regional level in Umala, the second livelihood dimension shows a distinct relationship between increased access to land and reduced investment in education. Although the characteristics of that dimension are partially attributed to the lifecycle of the household, the dimension does not include changes in adult equivalents. Younger households have less land but are more likely to invest in their children's education. Younger households also have reduced perceived vulnerability, increased household resilience, and are contributing positively to their natural systems though soil inputs.

At the community level, in five villages[13] there is evidence of livelihood dimensions that have a net positive impact on their human systems as access to land decreases. These households maintain or increase their resilience by investing in human systems such as labor markets, social capital outlets, or education. In four of those five communities, households increase participation in the labor markets or social capital as

[13] San Juan Circa, Vinto Coopani, Chinchaya, Karkapata, and Chojñapata.

access to land decreases. In Vinto Coopani and Chinchaya, households are investing in their children's education, ensuring strong human capital in the future.

Within the five communities where reduced access to land leads to stronger human systems, two are in Umala and also increase the resilience of their natural systems while the three in Ancoraimes reduce the resilience of the natural system. Households in Umala with relatively low levels of land for their region maintain much larger plots than those in Ancoraimes. In Ancoraimes, population growth had led to land fragmentation, and households do not have the resources to intensify production without threatening the environment. It may be that these households in Ancoraimes have crossed a threshold where they cannot increase resilience in one system without overexploiting the other. For example, in Chinchaya the second dimension shows that lower access to land is associated with reduction in household vulnerability but increased ecosystem vulnerability and decreased sustainability. Households can either reduce their vulnerability by overexploiting their ecosystem, or they invest in ecosystem resilience at the expense of their own current security.

Finally, there is evidence that households substitute social capital for natural capital if they have low access to cropland. In San Juan Circa, Vinto Coopani, Chinchaya, Karkapata, and Chojñapata there are dimensions where social capital and land are negatively correlated. Although all three of the variables are on the explanatory side of the equation, it is not unexpected that households with low access to one capital will compensate by increasing use of other capitals.

*Hypothesis 3: Households that practice traditional livelihood strategies (specifically crop diversification, pastoralist activities, and autarky) will be more likely to practice sustainable land management.*

At the regional level in Ancoraimes, crop diversity is positively correlated with ecosystem resilience. In Chojñapata, Cohani, and Calahuancani there is also positive correlation between crop diversity and net ecosystem resilience, but the relationship does not hold in the other two communities. In Chinchaya, where onion sales dominate income (48% of total income), and Karkapata, where nearly half of the households' income is generated off the farm, there is no correlation between crop diversity and ecosystem resilience. The implication is that high labor market participation or crop specialization is not necessarily associated with reduced sustainability. At the community level in Umala, increases in crop diversity are most often correlated with reduced ecosystem vulnerability but the relationship is inconsistent. In Kellhuiri, crop diversification is associated with reduced ecosystem sustainability. In Vinto Coopani there is one dimension where it increases ecosystem sustainability and another where sustainability is reduced. The opposing factors associated with crop diversity in Vinto Coopani may be a result of the geography and history of the community, which as discussed in Chapter 5 is composed of what were once two distinct communities and remain geographically separate.

Ownership of livestock is positively correlated with ecosystem resilience in seven of the nine communities. In Karkapata, there is no relationship between number of livestock and ecosystem resilience. The households in Karkapata score relatively high on all the ecosystem resilience indicators (Figure VI.2), but they produce a low proportion of income from livestock, which results in low overall impact factors associated with

livestock ownership on the ecosystem. In Chojñapata, the results of livestock ownership are mixed. Increases in livestock leads to greater ecosystem vulnerability because land use diversity decreases, but also results in more sustainable practices; households invest more land in practices that reduce erosion. This conflict illustrates a very common theme: the tradeoff between vulnerability and sustainability. In this case, if households convert large portions of their fields into fallow or pasture, they lose land use diversity but may be protecting and restoring land to health.

Production for consumption is correlated with more livelihood dimensions than any other strategy or asset. Generally, the more traditional, subsistence agro-pastoralist livelihoods are correlated with increased ecosystem resilience, although movement towards non-traditional livelihoods is not necessarily associated with a loss in ecosystem resilience. In all but one community, an increase in the degree of household autarky is correlated with increased ecosystem resilience. In Karkapata however, where the main economic activity is off-farm labor, autarky is not correlated with any of the ecosystem indicators. This finding indicates disconnect between the households in Karkapata and the agricultural livelihood. Differences between regions, communities, and in all probability households, are a very significant factor in determining the impact of specific livelihoods. In communities where the ecosystem services are less relevant for food security, livelihood strategies tend to have less impact on the ecosystem altogether.

*Hypothesis 4: Households that practice a rural multifunctional strategy will be highly resilient.*

A multifunctional strategy results in a diverse portfolio of activities within a household, which is correlated with increased resilience in a rural household's SES. Diversification into the labor market is one of the strongest livelihood strategies examined in the analysis, although it may produce detrimental results if the household does not have access to enough labor. Increased livestock ownership also has beneficial impacts on the SES in seven of the nine communities.

At a regional level, increases in the level of autarky, participation in agricultural markets, and activity in labor markets in Umala all have a net positive effect on SES resilience. In Ancoraimes, the first livelihood dimension is associated with increased activity in all three strategies and benefits both the natural and human systems. The third dimension is associated with increases in labor markets, producing a positive impact on the household but reducing ecosystem sustainability. Within the individual communities of Ancoraimes, in six of seven dimensions related to labor markets, increased activity is associated with increased household sustainability. Increased participation in the agriculture markets increases ecosystem sustainability six out of eight times, while increased production for consumption has a positive impact on SES resilience in seven of ten dimensions. Chinchaya's three livelihood dimensions are responsible for the majority of those points that do not fit the multifunctionality model, which is a result of specialization in onion production in the community. Omitting Chinchaya, there is a 76% probability that increases in any of the three strategies will be associated with increased SES resilience.

Returning to Wilson's (2008) multifunctionality concept and its theoretical link to local embeddedness, this analysis did not find a consistent relationship between informal relationships and environmental sustainability, but the findings do support a general positive correlation between multifunctionality and SES resilience.

## 6.2 Discussion and Policy Implications

Analysis of the survey data has revealed sets of relationships between household livelihood strategies and the resilience of the SES, some are evident across the dataset but many are unique to the characteristics of each region or individual communities. The analysis gives us a better understanding of how households respond to their unique constraints and how regions and communities in general must adapt to characteristics of their location. For example, the role of social capital has been highly dependent on local characteristics throughout this analysis. In Umala and Ancoraimes, both social capital variables are significantly correlated with vulnerability ($\alpha \leq 0.1$) but in opposite directions. In Umala, participation in organizations and informal relationships are associated with increased vulnerability while in Ancoraimes the opposite is true. In order to understand this divergence, the regional and community context must be understood. On average, the households in Umala have greater access to both natural and human capital, are much more integrated into agricultural markets, have greater access to transportation, and have higher income. They follow an agricultural path. In Ancoraimes, land fragmentation and population pressures have pushed households into the labor markets where social capital becomes more important.

Within the communities, there is evidence from Chinchaya, Karkpata, San Juan Circa, and Vinto Coopani that households with relatively less land seem to increasingly participate in social capital-growing activities. For the two communities in Ancoraimes, social capital offsets the negative impact of low land access on the SES, while in Umala that is not the case. It may be that low overall participation in Umala reduces the size of networks and effectiveness of social capital for those that do participate.

In a different study of the same dataset, researchers found that some capitals that are not significant predictors of income work toward building other capitals that do build income (Jensen and Valdivia 2010). Social capital may be used in some communities to access (Bebbington 1999) or build up many of the other capitals, generating affects that this research did not expose. Different types of social capital are beneficial in different situations. For those households specializing in selling agricultural products, a seller's cooperative provides increased negotiating power, while herders may find that more informal agreements benefit them. For example, in the second livelihood dimension in Chinchaya, lower access to land and less participation in the labor market is associated with increased participation in local organizations greater access to labor and loss of household vulnerability. Here the benefits of local embeddedness are greater than the benefits of increased participation in labor markets and greater land. In this case, one aspect of social capital is membership in an onion sellers' organization which provides members with greater negotiating power in the markets. Chinchaya also has much larger plots than any of the communities in Ancoraimes. It may be that all the households in

Chinchaya are beyond the threshold of plot size where a household can sustainably work and participate in the labor market.

In all nine communities, there are dimensions where households working towards increasing resilience in one sphere decrease it in another. Those dimensions that reduce household vulnerability while damaging other portions of the SES pose a great threat to both household and ecosystem. In some cases, households may not know that they are depleting their resources as they work toward reducing exposure to vulnerability. In other cases, households may have no choice. Poverty and basic needs are immediate while sustainability often requires that the household has discretionary assets that it can invest in the future. For example, in San Juan Circa, the third livelihood dimension expresses that households can reduce their vulnerability by increasing activity in the labor and agricultural markets. Although those activities are associated with greater income per person and income diversity, it is also associated with reduced investment in child education and soil amendments. Following this path may lead to degradation of natural and human capital reducing the household's total access to capital and decreasing future opportunities.

The system of constraints and relationships that create these highly detrimental dimensions where ecosystem resilience is sacrificed to reduce household vulnerability appear to be location-specific. At the regional level, no dimensions result in that effect. At the community level, seven of the 27 possible dimensions reduce household vulnerability but also reduce ecosystem sustainability. Two of those dimensions are in Umala (San Juan Circa and Kellhuiri), but this result did not show up in the regional analysis. In both cases, households that work towards reducing their vulnerability by

participating in the labor markets do so at the expense of sustainable agricultural practices. Both dimensions are negatively correlated with participation in local organizations but neither is correlated with access to labor. This finding points to an effect where vulnerability pushes some households to increase participation in the labor market and reduce involvement in local organizations to the detriment of their ecosystems.

In Ancoraimes, 5 of 15 dimensions put household vulnerability and ecosystem sustainability at odds. In all but one, increased household vulnerability is associated with higher livestock holdings and increased ecosystem resilience. This may be a result of vulnerable households using livestock as a means of saving and to buffer themselves from shocks. Apparently, as households sell livestock or as they become less vulnerable, they move away from the sustainable practices that are associated with pastoralism.

Overall, this analysis does not reveal a universal path to SES resilience. Instead, it shows that more often than not, livelihoods have both beneficial and detrimental impacts on the SES. How exactly that system of relationships functions is unique in each location, but there are some general trends that have been revealed. The following are three policy implications that are supported by my analysis:

1. Limited access to land is often a constraint that in many cases, if reduced would lead to greater SES resilience. Programs that worked towards increasing productivity or reducing loss could benefit households in every community. As the climate continues to change, households will need to learn about and adapt to new weather related threats, pests and disease. Programs that facilitate the transfer

of knowledge on these issues and increase access to markets for products and technologies that increase the final yield may have tremendous impacts. Where access to land is especially low, investment in social and human capital may be able to open doors into labor markets, reduce marketing costs, and increase household resilience. Groups such as parent-teachers associations that both work towards increasing the quality of education and create social capital can mediate the negative effects of limited land. Seller's associations increase negotiating power and reduce marketing costs. Education and social networks increase opportunity in labor markets. Supporting existing local organizations and aiding in the formation of new organizations can increase household resilience. It should be noted that for many households, increased participation in the labor markets will result in a reduction of sustainable agricultural practices.

2. Livestock ownership is often correlated with the very vulnerable and increased ecosystem sustainability. Services, such as increased access to veterinary services that benefit livestock owners may be a method for targeting and aiding vulnerable populations and encouraging sustainable land use. Livestock owners also will increasingly feel the effects of climate change. As extreme temperature events increase, shelters become more important while changes in average temperature and precipitation will bring with it new pests and disease. Other programs that confront those changes and their impact on pastoralist activities will become necessary if that lifestyle is to continue.
3. Increasing public services that reduce the negative impacts of certain household lifecycles will benefit populations in many communities. Older households are

very likely to suffer from more sickness and feel more vulnerable. Increased access to health services and safety nets may decrease their vulnerability. Households later in their lifecycle also tend to practice less sustainable land management as they lose access to labor. Programs that provide transfer payment for sustainable practices, similar to the Conservation Reserve Program in the United States, could reduce household vulnerability and increase ecosystem at the same time. For example, payments to households past a certain age for fallowing portions of their lands.

## 6.3 Limitations

Cross-sectional data is used to investigate dominant relationships that exist between variables on the community and regional level. The complex nature of the data makes it difficult to determine the effects of change, causal relationships, or temporal sequences. Because the data does not include a time component, the relationships are analyzed as though they are static. In all likelihood, the relationships described in this research are built through an iterative process of feedback loops between activities and their outcomes. Without access to panel data, it is very difficult to distinguish how characteristics are changing, and in what direction. Ideally, vector or panel data would be used to describe how household access, strategies, and impacts are changing. In this case, the data can only be used to investigate the data for current correlations. Although this research draws heavily on theory and my colleagues' knowledge of the location, the research struggles to move beyond cross sectional relationships and tentative conclusions.

Small community size (seven of the nine communities have populations of less than 50 households) lead to small samples, reducing the strength of statistical analysis. It may be that for small communities other more qualitative methods, such as case studies, might be more appropriate or be useful as a second level of analysis.

A third limitation originates in the assumptions and generalities required to apply a single model to all the households. The level of statistical generalization between communities is reduced by analyzing them separately, but a single model is applied to each community. Although the capitals model used in this research is able to provide a substantial amount of explanatory power over the entire dataset, it falls short in describing the situation of some households. Ideally, a single model could fully describe each individual household. The limitation of this model is due, in part to the nature of individual variance, but it is also a manifestation of a model constructed on the general features of the region, not the unique attributes of the communities. The outcome is that the model does not fit some communities as well as others. This variation in fit limits to what extent analysis at the community level can be compared.

Finally, the concepts of vulnerability and resilience are not only complex but subjective and extremely sensitive. By placing very different variables on similar scales, the author is making ethical judgments, such as placing vulnerability to sickness on the same scale as the use of manure for field fertilization. This parallel is difficult to accept as valid, especially outside of the academic environment. Further, this research aggregates several very different indicators into a single "household vulnerability" or "ecosystem resilience" variable, which assumes an equivalence that may be tenuous. The objective of this study is to explore the structure of dominant relationships between

livelihoods and the SES. Determining how to best value the facets of the SES and household well being are outside the scope of this research, but would have helped in analyzing the livelihood dimensions.

## 6.4 Further Research

This research investigated the relationships between households and their social and ecological systems. Greater knowledge of the values held by households and the incentive structures they perceive would be a tremendous resource. Canonical correlation analysis produced sets of statistically significant relationships, but it is important to know as much as possible about households' perceptions of those relationships. The personal experiences within the Altiplano of the author and other researchers have been used to try to understand the causality and chain of decisions that lead to the outcomes measured here. Introducing these results to households in the Altiplano and hearing their thoughts and explanations would provide insight and possibly validation, and could contribute to the welfare of the households.

Reevaluation of the independent social capital variables and the inclusion of indicators on community resilience as dependent variables would move this analysis further into the SES framework. The current social capital variables are often significant but they lack consistency in direction. Other social capital measurements may produce more consistent results. Early on in this project, the objective was to also have indicators of community resilience as dependent variables. Data constraints and a general deficiency in literature on a solid theoretical framework for constructing indicators of community resilience made this impracticable.

As mentioned earlier, research based on panel data would provide a much more stable set of conclusions in this area. Currently, this research is unable to determine whether households were acting out of character during the survey year, or if they were in the middle of changing behavior. With a time dimension, analysis of adaptation and response to shocks would provide a much greater understanding of household decisions and the impact of those discussions. The SANREM CRSP project in Bolivia has recently performed a second survey of the households, and that data will soon be available. Including that second dataset in the analysis will provide a much more robust set of results and provide insight in to the results of specific strategies revealed in this research.

Finally, in this research, canonical correlation analysis is used explore large sets of complex relationships. Other statistical methods may provide insight into specific relationships within the larger SES and further refine the variables that are used. The explanatory variables that were used in this research are based on the SL framework, which provided a method for determining which variables were most relevant. The ecosystem response variables had no such model by which to test their relevance. Further empirical research on the impact of specific human actions on ecosystem resilience and methods for operationalizing the theories put forth by resilience literature would inform this field of research tremendously.

# Appendix I: Data Collection

This thesis analyzes data collected through a household survey performed in 2006, and primary data collected by Nathan Jensen collected during June and July in 2009. Three methods were used for primary data collection; key informant interviews, focus groups, and community and market observations. This appendix will summarize the methods used for the survey and provide a brief overview of my primary data collection.

## I.1 Household Survey

*Methods*

The survey, "Cuestionario de Estrategias de Vida, Capitales, y Prácticas Ciclo 2005-2006" was performed by project LTRA-4 through the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP), which is funded by the United States Agency for International Development (USAID). It was performed by students and employees of the Universidad Mayor de San Andres (UMSA), Universidad de la Cordillera, and Promoción e Investigación de Productos Andinos (PROINP).

Survey regions were selections in order to provide a wide sample of climate and economic conditions on the Altiplano. Both regions are populated by Aymara, the majority of which make portions of their livelihoods in agriculture. Within those regions, communities were selected in order to further the diversity of the sample. In Ancoraimes, the communities express a continuum, beginning at the lower, warmer shore of Lake Titicaca, up into communities that are characterized by their higher altitude agro-pastoral livelihoods. In Umala, community differences also have their origins in differences in landscape. The communities of Vinto Coopani and Kellhuiri are in a hilly rough area. Erosion has created gullies that interrupt fields and transportation routes.

Households within the communities were chosen by random selection with replacement. Table I.1 shows the community size and percentage of each community that participated in the survey. Surveys were performed by individual interview.

Table I.1Survey participants in each community

| Total number of households and number of households surveyed | | | | |
|---|---|---|---|---|
| **Region** | **Community** | **Households Surveyed** | **Households in the Community** | **% of Households Surveyed** |
| **Umala** | | 181 | 219 | 0.83 |
| | **San José Llanga** | 96 | 123 | 0.78 |
| | **San Juan Circa** | 31 | 38 | 0.82 |
| | **Vinto Coopani** | 29 | 29 | 1.00 |
| | **Kellhuiri** | 25 | 29 | 0.86 |
| | | | | |
| **Ancoraimes** | | 149 | 227 | 0.66 |
| | **Calahuancani** | 23 | 37 | 0.62 |
| | **Cohani** | 27 | 34 | 0.79 |
| | **Chinchaya** | 57 | 80 | 0.71 |
| | **Karkapata** | 15 | 34 | 0.44 |
| | **Chojñapata** | 27 | 42 | 0.64 |

**Data Source:** SANREM CRSP 2006

*Results*

The survey included 330 households across two regions and nine communities. Each household answered more than 100 questions about their activities and livelihoods. According to the SANREM CRSP 2007 annual report, the survey data "informs initial conditions regarding practices, networks of information, and risk perceptions, as well as the type of soils, soil amendments practices, crop varieties, problems with pests and diseases, and land-use patterns" (2008, 106). Data from the survey has been used to research a diverse array of topics including; climate change, risk perceptions, livelihood strategies, indigenous knowledge, networks, agricultural methods, and adaptation to name a few.

## I.2 Key Informant Interviews

*Methods*

Jensen performed a series of interviews in order to obtain a fuller understanding of the livelihood decisions of survey households, beyond what the survey 2006 SANREM survey data was able to express. Specifically, he investigated how households chose their level of market integration, and what advantages and constraints drove those decisions. We choose to interview a small sample of key informants to

greater depth than attempting to interview all the participants during a very limited time-frame.

From July 12 through July 24th the students from La Universidad de Cordillera conducted a follow-up survey to the 2006 SANREM survey in the Umala region. Jensen accompanied one student, Olga Yana on her survey interviews so that he could hear the complete answers to survey questions and to avoid returning to a household that had been surveyed by the same organization recently. As the survey was conducted he learned about the background information to the survey data and when it was completed was able to ask for clarification or more detail on topics relevant to this research. After the formal interviews were completed, he was also able ask follow-up questions. While staying in the community, he also conducted informal interviews with community members. Jensen spent seven days in the Umala communities, conducting formal and informal interviews.

In Ancoraimes, Jensen traveled with Miguel Cabrera to the four different communities in Ancoraimes in order become more familiar with communities and invite participants to the focus group. During those visits he conducted informal interviews of community members. Interviewees were chosen by Miguel Cabrera, an extension agent with extensive experience in the area, according to those that would be both informative and willing. Jensen also conducted several informal interviews in the region.

*Results*

The research resulted in a fuller understanding of the barriers and constraints that rural households faced as well as their production and marketing options. In general, it seemed as though the primary constraints to market participation is a poor position in the market by producers and low production levels. Barriers to market, such as transportation factors and difficulties associated with selling good in the larger cities, reduce opportunities to seek higher prices. Other producers described situations in which they were unable to produce enough to make using markets worthwhile.

### I.3 Focus Groups

Two focus groups were held, one in the Ancoraimes (July 29) region and one in Umala (July 24). Although the objective in both was to investigate how households chose their level of agricultural market participation, the emphasis in each region was very different. In the Umala region nearly all agricultural goods are sold and bought in Patacamaya, a regional market. Here, the barriers to market participation and gaining a better understanding of differences in access to transportation were emphasized. In the

Ancoraimes region, a greater percentage of income is generated in agricultural markets and participants reported using a variety of markets Here the advantages and disadvantages of specific markets and buyers were emphasized.

*Participant Selection*

Umala: Participants from each community were chosen so as to represent both highland and lowland communities and a wide range of market participation and gender. Within each community households that were diverse in frequency of market use and most important product were invited. The survey team, Miguel Alejandro Romero and Olga Yana, selected individuals that both fit the above parameters and: A) had not requested to be left out of future PROINPA activities and B) assured that those that had requested further participation in PROINPA activities were included. Between July 18$^{th}$ and July21, 16 participants were invited from the communities.

Ancoraimes: Participants were chosen according to the suggestion of Miguel Cabrera, a researcher and "extension agent" that has worked in the region for many years. Cabrera and Jensen invited four individuals from each of the four survey communities. From each community, two individuals from households that were known to be more active in the markets and two that were less involved with markets were invited. The aim was to have a diverse group economically and an equal number of men and women.

*Implementation*

Umala: The focus group was held in Patacamaya, at the PROINPA office. There were a total of 11 participants (8 male, 3 female) from four communities (Table I.2). The participants divided into two groups. One group was composed of participants from Vinto Coopani, and Kellhuiri (upper region) and the second from San José Llanga and San Juan Circa (lower region). The two regions are near each other but have many differences. The lower region has larger fields, more access to transportation, higher income, and is much more integrated into agricultural markets. The communities in the upper region are less that 15km further from the main market than the lower region but they have much less access to public transportation and there are fewer privately owned vehicles in the area.

Each group drew maps of their regions including their fields, transportation routes, modes of transportation, cost, frequency, and duration. During this time they

discussed the advantages and disadvantages of Patacamaya verses other markets and who they sold to in the market.

Ancoraimes: The focus group was held in Calahuancani on July 29. The participants consisted of 7 women and 8 men, each of the four communities was represented (Table I.2). Each person was given a group number according to degree of market use. Group one was composed of individuals from each community that sold more often and group two were those that sold less often.

The focus group began with a discussion on the markets, identifying and ranking them. Then, in pairs or individually, the participants filled out a sequence of worksheets on their market use, transaction costs, advantages and disadvantages of each market and type of buyer, and perceptions of their relationship with the markets. For more details contact the author.

Table I.2 Focus group participants

**Grupos Focales: Municipio de Umala**
**24 de Julio de 2009**

| Comunidad | Group | Number | Gender |
|---|---|---|---|
| **San José Llanga** | Lower | 1 | Male |
| **San Juan Circa** | Lower | 1 | Male |
| | Upper | 4 | Male |
| **Vinto Coopani** | Upper | 3 | Female |
| | Upper | 2 | Male |
| **Kellhuiri** | Upper | 1 | Female |

**Grupos Focales: Municipio de Ancoraimes**
**29 de Julio de 2009**

| Comunidad | Group | Number | Gender |
|---|---|---|---|
| **Chinchaya** | | | |
| | Sells less | 1 | Male |
| | Sells more | 1 | Male |
| **Calahuancani** | | | |
| | Sells more | 2/1 | Male/Female |
| | Sells less | 4/1 | Male/Female |
| **Cohani** | Sells more | 1 | Female |
| | Sells less | 1 | Female |
| **Chojñapata** | Sells less | 1 | Female |
| | Sells more | 1 | Female |

*Facilitators*

Umala: Olga Yana, Alejandro Romero, Bernardo Baltasar López, Gerson Alejo Aruni with help from Claudia Jarandilla Rodríguez, Virginia Quispe Herrera, Angelica Quenta, and Nathan Jensen

Ancoraimes: Edwin Yucra, Miguel Cabrera, Olga Yana, and Nathan Jensen

*Data Collected*

Umala: Each producer constructed a story, beginning with the barriers community members meet as they move their product from their field to their homes and then to market if they choose to sell their products. For those that do sell, the story extends into the market and describes the situation that they face when they arrive at market with products to sell. For those that do not sell, the participants describe how and why they made the decision not to market their goods. The dominant reason for not participating in markets was inability to produce enough and the high cost associated with using markets. See Appendix II for an in-depth description of the focus groups and a summary of the findings.

Ancoraimes: The participants filled out matrices that provide information on transportation costs, calendar of commercialization, advantages and disadvantages of specific markets and types of buyers and the participants' perceptions on their own strengths, weaknesses, threats, and opportunities. While determining the characteristics of the different markets and creating maps, participants discussed the differences between the different communities represented. See Appendix II for an in-depth description of the focus groups and a summary of the findings.

## I.4 Community and Market Observations

*Methods*

From July 12 through August 12, Jensen traveled between communities markets using the transportation options that were available in the survey communities in order to better understand the transportation and market options available to the survey participants. Jensen recorded routes, transportation types, costs, frequencies, and duration. In the markets venders were interviewed concerning competition, prices, their marketing options, and where they came from.

*Results*

A detailed account of access and frequency of transportation data of the routes that households use, and description of the market characteristics that households within the communities use, provided a more realistic view of transportation costs than relying only on distance, and market data that can be used to differentiate between markets by their characteristics of depth and breadth. Finally, GSP points for the markets so that they can be could include them in spatial analysis of the survey regions.

# Appendix II: Focus Groups

The following is a summary of the methods and findings of two focus groups conducted in July, 2009. The objective is to provide further context and a brief glance into the stories behind the differences that are evident in the statistics of each community. It is meant to provide the reader with interesting pieces of information that illustrate some of the concepts in this research, not provide a complete background.

## II.1 Umala Focus Group

**Objectives**

To investigate the aspects of location (geography, economy, institutions, and social) that affect transaction costs and how those costs influence the extent of market integration into livelihood strategies in the region of Umala.

**Participants**

11 participants (8 male 3 female) from four communities participated in the focus group. The participants divided into two groups. One group was composed of participants from Vinto, Coopani, and Kellhuiri (upper region) and the second from San José Llanga and San Juan Circa (lower region). The two regions are near each other but have many differences. The lower region has larger fields, more access to transportation, higher income, and uses the markets more often. The communities in the upper region are only about 10km further from the main market, Patacamaya, than the lower region but are economically much more isolated.

The purpose of dividing the participants was:

a) create two groups each with generally different access to transportation
b) create two groups each with generally different agricultural environments
c) create groups with participant in similar transportation and agricultural situations to investigate other factors of market integration
d) create smaller group sizes while maintaining a larger sample

**Program**

1. **Maps-**Each group drew maps of the region, including towns, markets, roads, their own households, and fields. As each individual drew in their fields and houses they drew the routes that they used to transport their products from field to house

and then to market. They included data such as time required for transportation, costs, and barriers. During this time they also discussed which, if any, products they sold, where, and when.

2. **Markets-**During the mapping, the participants discussed their market use habits. All the participants primarily use Patacamaya. The discussion touched on the advantages and disadvantages of Patacamaya verses other markets and the differences between buyers (e.g. consumers, whole-sale). Also, the sale of products to buyers that come into the community specifically to buy at lower prices, their interactions with buyers that have organized to control prices, and producers that have organized as a response.

3. **Chuño and Papas report-**PROINPA presented the results from a study on the chuño and papas marketing chain in the region to the whole group.

4. **Closing Remarks-**Alejandro Romero made the closing remarks and lunch followed.

**Findings**

*Gender*

Both the upper and lower communities agree that women are better negotiators. It is usually the case that both the buyers and sellers of crops are women. The women both negotiate and handle the money, giving the men money if they need it. The men say that the bundles are heavy so they carry them, but that the women are more vicious negotiators and must do that part.

*San Juan Circa*

Participants reported that they most often sold their goods to middlemen or rescatistas in Patacamaya. Public transportation to Patacamaya is not regular or useful.

> *Micro 26 comes but it is expensive and only takes small loads. It arrives in the plaza and will not come to pick our goods up. We have to transport them to the square ourselves. Also it will not wait. Now our friends and neighbors come to our houses and pick our goods up.* (Focus group participant, July 24, 2009)

Five to seven families own transportation in the community. Many of the other households depend on those families to provide transport, both to pick up goods from their fields and to take them to market. Because both the public transportation and the

cars cannot take much cargo, households bring smaller quantities of goods to market each time they go. Participant reported that they are able to bring small quantities of quinoa (which sells for a much higher price than other goods) on the bus or in cars without being charged for cargo, which may be a factor in the community's high investment in quinoa.

*San José Llanga*

The households in San José Llanga cooperate in the potato market, their largest crop, to give them increased negotiating power. Because the community produces large amounts of potatoes, middlemen are known to drive trucks out to the community and buy large quantities of potatoes at whole-sale prices. The households are able to secure higher prices negotiating as a group. Participant reported that last year, the six boroughs of San José Llanga pre-set a price floor for potatoes. No one was allowed to sell below that price.

Some of the producers in San José Llanga have a contract with QUINUABOL, PROMEBOLIVIA for a price of 730bs/qq. The contract created price security that would not have existed, reducing risk in the quinoa market.

San José Llanga was the only community to emphasize the costs of production. They reported renting tractors, hiring laborers, and purchasing inputs for a total cost of 2,270 Bs/h for their potato fields. Many of the production costs the they reported in San José Llanga are for intensification techniques that are not used heavily in the other three communities.

*Vinto Coopani and Kellhuiri*

In this group the conversation emphasized the difficulties associated with selling goods. First, with the time spent moving products from the fields to the house, then to the road, and then to the market. Many of the fields are more than 1.5 hours away from the households. Transporting products from the field to the household takes days of work. Transportation to Patacamaya is much less frequent here than in the lower regions and there is far less access to privately own transportation. Producers must wait at the road for trucks that drive buy on market days.

Many of the individuals participate very little or not at all in selling goods. They report that for all their effort and the cost of selling goods, there is no benefit and that they need their products for own-consumption. Lower prices and reduced productivity of his fields has reduced the benefit of vending in the markets. The participants report that they used to sell more in the markets but low access to land and reduced productivity of the fields have reduced the benefits. Many expressed an interest in selling more goods but cannot produce enough to make selling worthwhile

> *To return to selling I think that the intermediaries would have to disappear, the product would have to be more profitable and we would sell to the consumer. If you produced 10 or 15 quintales* (1quintale=100kg) *you could go to La Paz. That would cover the cost of transpiration, but you would have to know the price in the agencies. It is easier to just sell in Patacamaya. I produce potatoes only for consumption because transportation is difficult.*" (Focus group participant from Vinto Coopani, July 24).

*Patacamaya*

According to the participants, the wholesalers in Patacamaya are part of a syndicate. They set a low price and will not buy above it. If a wholesaler is found to have purchased above the low price they are fined. In general it is the intermediaries, not the producers, which set the price. When producers were asked what people did if they could not sell the products that they had brought to markets, they responded that they had no option but to reduce the price so that they would not need to pay for transportation of the goods home. The only product that they might return home with is quinoa.

## II.2 Ancoraimes Focus Group

### Objective

The objective in Ancoraimes was to investigate the differences between those that heavily used markets and those that used them less often. This includes, exploring the barriers to markets and the methods that individuals use to circumvent them, perceptions of the individual markets including who they sold to, and the personal differences.

### Participants

Participants were chosen according to the suggestion of Miguel Cabrera, a researcher and "extension agent" that has worked in the region for many years. Miguel and Jensen invited four persons from each of the five different communities. Within each community, two individuals that were known to be more active in the markets and two that were less involved with markets were invited. They also aimed for a diverse group economically and an equal number of men and women.

The result was a total of 7 women and 8 men with at least one participant from each community. The participants were divided into two groups. Group 1was

composed of those from each community that sold more often and group 2, those that sold less often.

Creating two groups creates an additional general categorical characteristic that can be distinguished between participants and is used to create a new group for analysis. The groups also sat together so that the individuals within a group were discussing issues with participants from the surrounding communities that theoretically had similar relationships with the market.

**Program**

1. **Market Identification-**As a group, the participants identified the local, inter-provincial, and urban markets. Each market was ranked according to importance within the category.

2. **Maps-**The participants each drew a map that contained their community and the markets that they used. Edwin Yucra then led a discussion on the marketing chain. The participants then indicated on their maps who they sold to, in the markets that they used.

3. **Advantages and Disadvantages**: The participants recorded the advantages and disadvantages of each of the markets that they used and the same for each type of buyer that they sold to in those markets.

4. **Calendar of Commercialization:** Each participant recorded the three products that they sold the most of. For each product then began by indicating month by month, if they sold "none", "a little", or "a lot" of that product. They then estimated the price that they received for their product on that month and an approximate amount of product sold. In this way, each individual created a calendar for three of their products containing month by month prices and quantities sold.

5. **Transaction Costs:** For the same three products listed in the Calendar, participants filled out a transaction costs matrix. For each product, the participants recorded the four markets that they most often sold in and the; transportation type, cost of transporting goods, cost of passage, how long transportation takes, how often they sell, who sells, the price in the market for their product, the time it takes to sell, who defines the price, and what they do if their good do not sell at the market.

6. **Strengths, Weaknesses, Obstacles, and Opportunities (FODA):** The participants recorded their own strengths and weakness in the markets. Then they recorded the obstacles that they confronted and the opportunities that they saw.

**Findings**

The majority of vending by individuals in Group 1 takes place in urban markets. In both groups, those that do sell in the urban markets have a specific strategy or advantage that reduces barriers in those markets. Some of the larger venders are able to negotiate low transportation prices because of their high volume. Others have family in the city that act either as venders, storage, or a temporary residence while selling goods.

The need to quickly sell or store unsold goods when in the city markets is a concern for those in the community that do not have the benefit of family in the city. Many households use agencies in the market of Chijini, which provide storage and a location to sell from for a low price. There is only one vender that sells in urban markets and does not sell in Chijini, indicating that the agencies' services are important. The one vender that does not use an agency and sells in the city, has a family house in La Paz that he can store his goods in.

Some venders are able to sell in local markets without incurring transportation costs beyond the opportunity cost of their own time. This circumvents one barrier of market use, personal transportation costs. Personal transportation costs are fixed costs which create a minimum amount of product that needs to be sold in order to make a trip profitable. Small producers that do not sell in great enough quantity so that their profits cover the fixed cost, will not sell in the market. If a producer does not have access to a strong labor market and cannot increase production with his/her own labor, the opportunity cost of time becomes very low. It appears as though that is the case for some households in Ancoraimes. Many of the venders, especially those that are in Group 2 and do not sell in great quantities, take advantage of their ability to reduce fixed transportation costs by walking to market, so that they can sell small quantities and still be profitable.

Chejepampa is a local market, less than 15 km from the furthest survey household. Its proximity to the households was the most often sighted strength of the Chejepampa market. Many of the households take advantage of that proximity by walking to market, avoiding transportation costs. The majority of demand in Chejepampa is driven by middle-men that come to rural areas to buy agricultural products and resell it in the urban areas. Although producers often receive better prices selling directly to consumers at the market, consumer demand is so low that most eventually sell to the middlemen.

Morocollo is the second local market. All of the participants from Group 2 sell in Morocollo, some of them bringing their goods to market by donkey, a trip that can take more than 3 hours.

A quirk of Bolivian public transportation is that the cost of personal passage includes a small amount of baggage. 5 out of 7 members in Group 2 and one from Group 1 report that they often bring small amounts products (often high priced and nonperishable such as *caya, quinoa, arveja*) that they are not required to pay transportation for, to market every time they go. The nonperishable nature of those goods allows producers to smooth their income over the year and transporting small amount over many different trips reduces cargo costs.

In income cycles of the two groups are roughly similar but Group 1 is able to maintain higher off-season sales, while Group 1's sales drop of rapidly after potato harvest (Figure II.1).

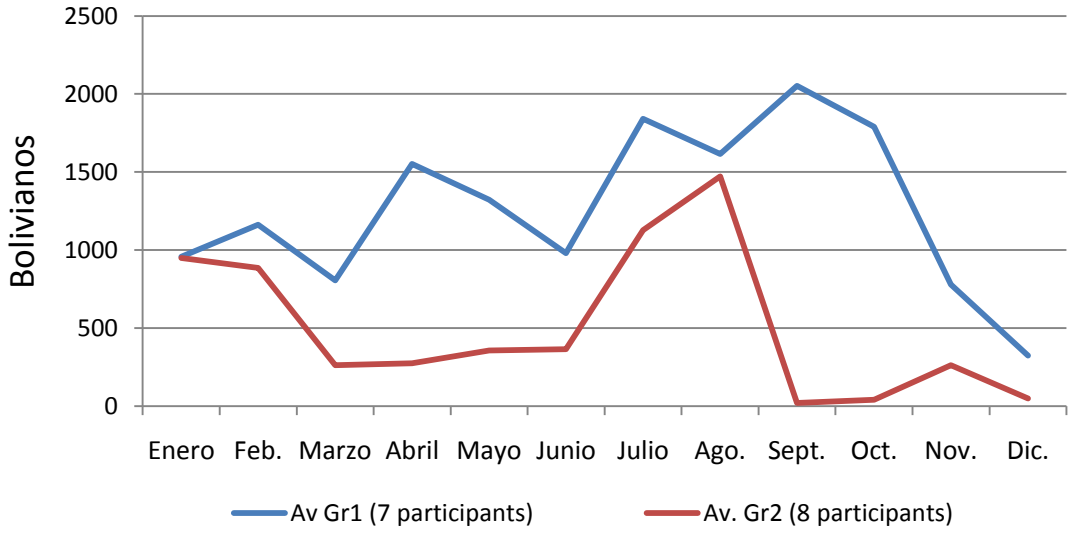


Figure II.1 The average income of each group generated by selling crops, created from the "Commercialization Calendar".

The potato harvest in August dominates Group 2's income from crop sales. Beyond potatoes, these households also rely on quinoa and *caya* (dried tubers) sales. Group 1 also generates the majority of its crop income from potato sales, but is able to sell potatoes year around, taking advantage of higher off-season prices. They also report high sales of onions and peas spread throughout the year.

Group 1 is able to generate a steady income from maintaining sales in the off-season. They often have advantages that allow then to reduce transportation and

marketing costs, which they are able to exploit to sell in the larger urban markets. They see procuring product to sell as the largest constraint to increasing sales. Group 2 relies more heavily on local markets. In those markets, they often sell small quantities directly to consumers. They report that low prices and low demand are the barriers that they confront in those markets. Of those that either do sell or would like to sell in urban markets, social barriers (discrimination, safety, and lack of networks) and locating a place to sell and store goods are the most significant barriers.

## Appendix III: Income composition in Umala and Ancoraimes, Bolivia

Income composition is a reflection of the push and pull factors and the incentive structures that are present in the communities. Low access to land has pushed many of the households in Ancoraimes into off-farm labor while greater access to global markets, through PIL Andean milk drop-off points for example, may provide a consistent demand that pulls households to invest more heavily in that good (Table III.1).

Table III.1 Income composition in the nine survey communities in the Bolivian Altiplano

| Region | Community | Remittances | Off-farm Labor | Livestock | Milk & Cheese | Crops | *Total Income* |
|---|---|---|---|---|---|---|---|
| **Umala** | San José Llanga (n=96) | 176 | 1694 | 3359 | 6422 | 11745 | 21936 |
| | San Juan Circa (n=31) | 68 | 795 | 2285 | 4318 | 11949 | 18479 |
| | Vinto Coopani (n=29) | 176 | 2184 | 1827 | 2716 | 3225 | 9192 |
| | Kellhuiri (n=25) | 387 | 1984 | 3516 | 4100 | 4466 | 13180 |
| | Region (N=181) | 187 | 1659 | 2951 | 5147 | 9409 | 18092 |
| **Ancoraimes** | Calahuancani (n=23) | 311 | 3249 | 1385 | 1431 | 1767 | 7260 |
| | Cohani (n=27) | 53 | 1554 | 309 | 310 | 650 | 2816 |
| | Chinchaya (n=57) | 190 | 1977 | 669 | 1042 | 6477 | 10092 |
| | Karkapata (n=15) | 149 | 1730 | 338 | 529 | 1052 | 3596 |
| | Chojñapata (n=27) | 453 | 632 | 1858 | 2185 | 1592 | 5506 |
| | Region (N=149) | 227 | 1828 | 897 | 1125 | 3263 | 6851 |

**Data Source:** SANREM CRSP 2006

All four communities in Umala maintain fairly similar economic portfolios, producing staple crops, preserving some through the process of freeze drying, and holding livestock. The difference in income is due mainly to greater production of milk barley and potatoes in the lower regions (Table III.2).

Table III.2 On-farm income of households in four communities in the municipality of Umala

| | San José Llanga | San Juan Circa | Vinto Coopani | Kellhuiri |
|---|---|---|---|---|
| **Milk** | 3099.30 | 2753.19 | 876.83 | 592.01 |
| **Chuño** | 1294.97 | 908.31 | 563.38 | 1739.64 |
| **Oats** | 179.17 | 0 | 0 | 104.00 |
| **Beans** | 23.44 | 0 | 3.10 | 48.00 |
| **Barley** | 4002.50 | 4856.77 | 1670.34 | 1730.40 |
| **Wheat** | 13.95 | 15.81 | 6.03 | 54.60 |
| **Isaño (tuber)** | 0 | 0 | 1.45 | 2.4 |
| **Oca (tuber)** | 0 | 0 | 2.17 | 0 |
| **Papalisa (tuber)** | 0 | 0 | 0.69 | 0 |
| **Turnip** | 0 | 0 | 0 | 0 |
| **Pea** | 0 | 0 | 0 | 0 |
| **Quinoa** | 266.57 | 2612.50 | 27.16 | 53.20 |
| **Onion** | 0 | 0 | 0 | 0 |
| **Papa** | 7259.02 | 4463.53 | 1513.63 | 2472.92 |
| **Cattle** | 2423.95 | 1364.48 | 841.38 | 2055.96 |
| **Camelids** | 0 | 0 | 0 | 48 |
| **Birds** | 0.26 | 0 | 0 | 0 |
| **Donkey/horses** | 0.63 | 0 | 6.21 | 0 |
| **Guinea Pigs** | 0 | 0 | 0 | 0 |
| **Pigs** | 3.13 | 0 | 0 | 0 |
| **Sheep** | 556.21 | 507.74 | 520.81 | 784.43 |
| **Total On-Farm Income** | 19123.09 | 17482.34 | 6033.18 | 9685.57 |

**Data Source:** SANREM CRSP 2006

The households in Ancoraimes grow a greater diversity of crops and exhibit greater diversity between communities in on-farm economic activities than in Umala (Table III.3). Many of the households in Chinchaya have been able to take advantage of their location on the shores of Lake Titicaca. Their fields are flat and the water table is high, making it ideal for irrigation. Access to irrigation and climate has pulled many of the households to specialize in onion production. Cohani generates the least amount of every farm product except for peas and barley (of which it does not grow much) reflecting their general lack of natural capital and low participation in the agricultural livelihood.

Table III.3 On-farm income of households in four communities in the municipality of Ancoraimes

| | Chinchaya | Karkapata | Chojñapata | Calahuancani | Cohani |
|---|---|---|---|---|---|
| **Milk** | 386.59 | 186.96 | 206.90 | 50.23 | 0.97 |
| **Chuño** | 216.24 | 134.30 | 232.33 | 203.61 | 112.88 |
| **Oats** | 169.48 | 18.04 | 349.91 | 44.97 | 0 |
| **Beans** | 235.39 | 7.06 | 8.89 | 17.27 | 6.37 |
| **Barley** | 268.79 | 155.07 | 66 | 179.82 | 81.11 |
| **Wheat** | 35.31 | 0 | 0 | 0 | 0 |
| **Isaño (tuber)** | 0 | 0 | 3.11 | 1.30 | 0 |
| **Oca (tuber)** | 72.46 | 202.30 | 423.44 | 348.25 | 131.37 |
| **Papalisa (tuber)** | 0 | 12.95 | 22.22 | 35.34 | 0 |
| **Turnip** | 0 | 0 | 17.78 | 0 | 0 |
| **Pea** | 164.07 | 179.69 | 12.07 | 68.90 | 198.35 |
| **Quinoa** | 40.80 | 0 | 5.56 | 31.63 | 0.90 |
| **Onion** | 4882.16 | 0 | 103.70 | 21.30 | 0 |
| **Papa** | 608.72 | 476.71 | 579.19 | 1017.90 | 231.99 |
| **Cattle** | 432.46 | 80 | 340.74 | 678.26 | 59.26 |
| **Camelids** | 0 | 0 | 932.15 | 383.04 | 16.67 |
| **Birds** | 0 | 0 | 0 | 0 | 0 |
| **Donkey/horses** | 0 | 0 | 0 | 0 | 0 |
| **Guinea Pigs** | 3.86 | 0 | 0 | 0 | 0 |
| **Pigs** | 63.68 | 84 | 33.33 | 16.96 | 17.04 |
| **Sheep** | 81.32 | 142.33 | 277.81 | 177.39 | 97.41 |
| **Total On-Farm Income** | 7661.34 | 1679.41 | 3615.13 | 3276.19 | 954.32 |

**Data Source:** SANREM CRSP 2006

# Appendix IV: Canonical Correlation Analysis using a Dummy Variable for Region

This research analyzes each region separately and then each community individually. A different option is to use dummy variables for region and community, and analyze them at the same time. This research analyzes them separately in order to extract a greater amount of information concerning the relationships between variables even though it reduced the sample sizes and the variance explained by the model. The following is a replication of the regional analysis using a dummy variable for region so that the reader may compare it to the separate analysis in chapter 5.

Table IV.1 Canonical correlation analysis of the entire dataset using a dummy variable for region

| | Canonical Correlation | Adjusted Canonical Correlation | Approximate Standard Error | Squared Canonical Correlation | Test of H0: The canonical correlations in the current row and all that follow are zero | | |
|---|---|---|---|---|---|---|---|
| | | | | | Approximate F Value | Num DF | Pr > F |
| 1 | 0.907068 | 0.900204 | 0.009771 | 0.822773 | 12.6 | 143 | <.0001 |
| 2 | 0.747861 | 0.722947 | 0.024297 | 0.559296 | 8.37 | 120 | <.0001 |
| 3 | 0.695608 | 0.675843 | 0.028455 | 0.48387 | 6.8 | 99 | <.0001 |
| 4 | 0.617447 | 0.596192 | 0.034113 | 0.381241 | 5.29 | 80 | <.0001 |
| 5 | 0.48943 | 0.448624 | 0.041925 | 0.239541 | 3.99 | 63 | <.0001 |
| 6 | 0.422379 | 0.388889 | 0.045296 | 0.178404 | 3.28 | 48 | <.0001 |
| 7 | 0.352004 | 0.315144 | 0.048301 | 0.123907 | 2.62 | 35 | <.0001 |
| **8** | **0.306614** | **0.30557** | **0.049949** | **0.094012** | **2.02** | **24** | **0.0025** |
| 9 | 0.194635 | 0.165342 | 0.053043 | 0.037883 | 1.12 | 15 | 0.3339 |
| 10 | 0.104684 | . | 0.054528 | 0.010959 | 0.57 | 8 | 0.8065 |
| 11 | 0.05731 | . | 0.054951 | 0.003284 | 0.35 | 3 | 0.7913 |

**Data source:** SANREM CRSP 2006

At $\alpha$=0.05, the combined analysis has eight significant dimension (Table IV.1), one more than either Umala or Ancoraimes did separately (Chapter 5). The explanatory side of the first livelihood dimension is dominated by: *Region, Land, Livestock, Local Orgs, Crop Diversity, Autarky, and Ag Markets* (Table IV.2). The analysis of means and variances in Chapter 5 concluded that the means and variances of each of those variables (*Region, Land, Livestock, Local Orgs, Crop Diversity, Autarky, and Ag Markets)* are significantly different between regions. The result is that the first livelihood dimension is a reflection of those differences associated with location.

There is some interesting information generated by this analysis though. First note: the region variable equals one in Ancoraimes and zero in Umala. As expected, a lower region value is associated with increased access to land and livestock and lower

participation in social capital building activities or crop diversity. These aspects are correlated with less vulnerability and more resilience (with the exception of land productivity).

Table IV.2 Correlation between variables and their canonical variables

| (N=330) | Livelihood Dimension 1 | Livelihood Dimension 2 | Livelihood Dimension 3 |
|---|---|---|---|
| **Region (0=Umala)** | -0.8916 | | |
| **Crop Land** | 0.8635 | | |
| **AE** | | 0.3068 | -0.3583 |
| **TLU** | 0.3059 | | |
| **Age HH** | | -0.3149 | 0.3407 |
| **Ed HH** | | 0.4756 | |
| **Gender HH** | | 0.4231 | |
| **Local Orgs** | -0.5101 | | -0.3353 |
| **Informal Social Capital** | -0.4407 | | |
| **Crop Diversity** | -0.4005 | 0.4674 | |
| **Autarky** | 0.8676 | 0.3127 | |
| **Ag Markets** | 0.5282 | 0.5965 | |
| **Labor Markets** | | | 0.4801 |
| | | | |
| **Vulnerability** | | -0.4464 | |
| **Land Productivity** | -0.3677 | 0.7305 | |
| **Sickness** | -0.3188 | | 0.3877 |
| **Education** | | 0.4709 | -0.4009 |
| **Income Diversity** | | | 0.4886 |
| **Income/Person** | 0.7522 | | 0.4741 |
| **Bridging Orgs** | 0.6669 | | |
| **% Nitrogen Crops** | | | |
| **Soil Amendments** | | 0.3648 | |
| **Land-Use Diversity** | | 0.4731 | |
| **Erosion Control** | 0.7085 | | |

**Data source:** SANREM CRSP 2006

The information from Livelihood dimensions 2 and 3 are independent of region. Dimension 2 is characterized by lifecycle of the household just as it is in the regional analysis (Chapter 5). Younger households succeed in reducing their vulnerability in a way that is sustainable within human and eco-systems. In the third dimension; age and labor markets work towards increasing income and income diversity, possibly through remittances from children. Older households are currently succeeding on the human level, but are unable to invest in their future resilience.

As expected, the redundancy analysis shows higher predictability within this model than analyzing the regions separately (Table IV.3). The region variable is able to capture much of the variance within the dataset and a larger sample size helps to reduce the impact of outliers and thus variance.

Table IV.3 Redundancy analysis of a model that uses a dummy variable for region

| | Their Own Canonical Variables (8) | The Opposite Canonical Variables (8) |
|---|---|---|
| Cumulative Standardized Variance of the Independent Variables Explained by | 0.7007 | 0.3650 |
| Cumulative Standardized Variance of the Dependent Variables Explained by | 0.7639 | 0.3361 |

**Data source:** SANREM CRSP 2006

Analysis of the entire dataset reveals three general relationships between access to capital, life cycle, and diversification into labor markets, and SES resilience. These relationships are further disaggregated when the regions are addressed separately.

Table IV.4 Redundancy analysis of the model that uses a dummy variable for region and each community

| | Their Own Canonical Variables | The Opposite Canonical Variables |
|---|---|---|
| Cumulative Standardized Variance of the Independent Variables Explained by | 0.682 | 0.345 |
| Cumulative Standardized Variance of the Dependent Variables Explained by | 1 | 0.434 |

**Data source:** SANREM CRSP 2006

Similar to the hierarchal model in Chapter 5, the analysis can be controlled for both region and community. The resulting canonical correlation analysis has greater predictive power (Table IV.4) but only one set of dimension that are responsible for explaining all the different relationships within each community (Table IV.5).

Table IV.5 Correlations between the variables and their canonical variables

| N=330 | 1st Dimension | 2nd Dimension | 3rd Dimension | 4th Dimension | 5th Dimension | 6th Dimension |
|---|---|---|---|---|---|---|
| **Region** | 0.87 | | | | | |
| **Chinchaya** | 0.43 | | 0.38 | | | -0.38 |
| **Karkapata** | | | | | | |
| **Chojñapata** | 0.31 | | | 0.31 | | |
| **San José Llanga** | -0.58 | 0.41 | | | | |
| **San Juan Circa** | -0.59 | -0.68 | | | | |
| **Vinto Coopani** | | | -0.37 | | | |
| **Calahuancani** | | | | | | 0.34 |
| **Crop Land** | -0.85 | | | | | |
| **AE** | | | | -0.34 | -0.39 | |
| **TLU** | | | | | | |
| **Age HH** | | | -0.41 | | 0.37 | |
| **Ed HH** | | | 0.43 | | -0.32 | |
| **Gender HH** | | | 0.36 | | | |
| **Local Orgs** | 0.49 | | 0.35 | | | |
| **Informal Social Capital** | 0.44 | | | | | |
| **Crop Diversity** | 0.44 | | 0.45 | | | 0.34 |
| **Autarky** | -0.78 | 0.43 | | | | |
| **Ag Markets** | -0.44 | 0.41 | 0.44 | | | |
| **Labor Markets** | | | | 0.35 | -0.34 | 0.32 |
| | | | | | | |
| **Vulnerability** | | | -0.43 | | 0.34 | |
| **Land Productivity** | 0.45 | | 0.54 | 0.38 | | -0.33 |
| **Sickness** | | | | 0.39 | 0.43 | |
| **Education** | | | 0.46 | -0.35 | -0.36 | |
| **Income Diversity** | | | -0.33 | 0.32 | -0.48 | 0.53 |
| **Income Per Person** | -0.68 | 0.46 | | 0.51 | | |
| **Bridging Orgs** | -0.58 | 0.32 | | | | -0.44 |
| **% Nitrogen Crops** | | | | | | |
| **Soil Amendments** | 0.53 | 0.79 | | | | |
| **Land-Use Diversity** | | | 0.52 | | 0.42 | 0.41 |
| **Erosion Control** | -0.69 | | | | | |

**Data source:** SANREM CRSP 2006. Note: Kellhuiri and Cohani are the suppressed categories

This analysis reveals in which communities, households are most likely to be following certain paths. The first dimension expresses the agricultural path. Umala's two lower communities, San José Llanga and San Juan Circa, are most likely to have greater portions of land and benefit from the resilience building factors that are often associated with increased land access.

The second dimension is specifically associated with differences that exist between San José Llanga and San Juan Circa, but must also exist between households within the other

communities. It addresses production for consumption and participation in agricultural markets; increased activity in both strategies, increases SES resilience.

The only livelihood dimension that is independent of location is the fifth, which is associated with lifecycle. This indicates that the impacts of lifecycle are not significantly more or less relevant in any of the communities or in one of the regions.

# Appendix V: The Impact of Resampling on Canonical Correlation Analysis.

In order to better understand the impact of resampling on the canonical analysis the following appendix contains analysis of the resampled and original data side-by-side. This example uses data from Ancoraimes to illustrate the impact of resampling.

Table V.1 contains the descriptive statistics for the original data and the resampled data. The data from Ancoraimes was randomly sampled with replacement 1,000 times. Theoretically, resampling reduces the variance and in canonical correlation will reduce the influence of outliers. In cases where there are too few observations for canonical correlation analysis, resampling provides an opportunity to investigate possible associations using canonical correlation. The resampled data represents a statistically plausible population with similar characteristic to the original sample.

Table V.1Ancoraimes: Descriptive statistics for original and resampled data

| | Original Data (N=149) | | Resampled Data (N=1000) | |
|---|---|---|---|---|
| **Variable** | **Mean** | **Std Dev** | **Mean** | **Std Dev** |
| **Crop Land** | 0.55 | 0.49 | 0.55 | 0.49 |
| **AE** | 3.54 | 1.73 | 3.53 | 1.68 |
| **TLU** | 6.99 | 6.46 | 6.97 | 6.18 |
| **Age HH** | 47.68 | 14.27 | 48.18 | 14.30 |
| **Ed HH** | 6.11 | 4.41 | 5.98 | 4.32 |
| **Gender HH** | 0.77 | 0.42 | 0.78 | 0.42 |
| **Local Orgs** | 0.7 | 0.64 | 0.70 | 0.66 |
| **Informal Social Capital** | 2.01 | 1.23 | 2.03 | 1.27 |
| **Crop Diversity** | 4.22 | 1.22 | 4.22 | 1.19 |
| **Autarky** | 7.07 | 0.65 | 7.09 | 0.63 |
| **Ag Markets** | 7.08 | 1.8 | 7.09 | 1.87 |
| **Labor Markets** | 5.2 | 3.48 | 5.18 | 3.47 |
| **Vulnerability** | 34.7 | 9.06 | 34.50 | 8.96 |
| **Land Productivity** | 8.43 | 0.62 | 8.47 | 0.63 |
| **Sickness** | 0.48 | 0.4 | 0.48 | 0.39 |
| **Education** | 1.01 | 1.21 | 1.01 | 1.19 |
| **Income Diversity** | 1.79 | 0.52 | 1.80 | 0.52 |
| **Income Per Person** | 7.22 | 0.95 | 7.22 | 0.93 |
| **Bridging Orgs** | 0.27 | 0.44 | 0.27 | 0.44 |
| **% Nitrogen Crops** | 0.22 | 0.19 | 0.22 | 0.19 |
| **Soil Amendments** | 6.36 | 0.88 | 6.36 | 0.87 |
| **Land-Use Diversity** | 3.67 | 1.58 | 3.72 | 1.56 |
| **Erosion Control** | 1 | 1.72 | 0.97 | 1.71 |

**Data source:** SANREM CRSP 2006

Canonical correlation analysis requires a sample size greater than the total number of variables included in the model. Our model contains 12 explanatory variables and 11 response variables, for a total of 23. In the case of Karkapata, the analysis with original data and this model cannot take place. In samples that are larger than, but not very much larger than, the number of variables, the results of analysis become very sensitive to each data point. Low degrees of freedom reduce the model's ability to extract significant variance and thus reduce the number of significant dimensions (Table V.2).

Table V.2 Resampling's impact on the number of significant canonical variables

| | Original (N=149) | | Resampled (N=1000) | |
|---|---|---|---|---|
| **Dimensions** | **Approx. F Value** | **Pr>F** | **Approx. F Value** | **Pr>F** |
| **1** | 5.86 | <.0001 | 45.96 | <.0001 |
| **2** | 4.4 | <.0001 | 34.55 | <.0001 |
| **3** | 3.7 | <.0001 | 29.56 | <.0001 |
| **4** | 2.98 | <.0001 | 24.07 | <.0001 |
| **5** | 2.63 | <.0001 | 20.38 | <.0001 |
| **6** | 2.23 | <.0001 | 18.02 | <.0001 |
| **7** | 2.02 | 0.0013 | 15.03 | <.0001 |
| **8** | 1.47 | 0.0885 | 10.38 | <.0001 |
| **9** | 0.98 | 0.4655 | 7.26 | <.0001 |
| **10** | 0.89 | 0.5054 | 5.65 | <.0001 |
| **11** | 0.14 | 0.8727 | 0.82 | 0.4396 |

Analysis of the correlation between the variables and the first two canonical variables shows how resampling affects the relationships between variables (Figure V.1). The results are very similar. Correlations in the original data that are the product of outliers will be under represented in the resampled data and correlations that are supported by greater numbers of households are emphasized.

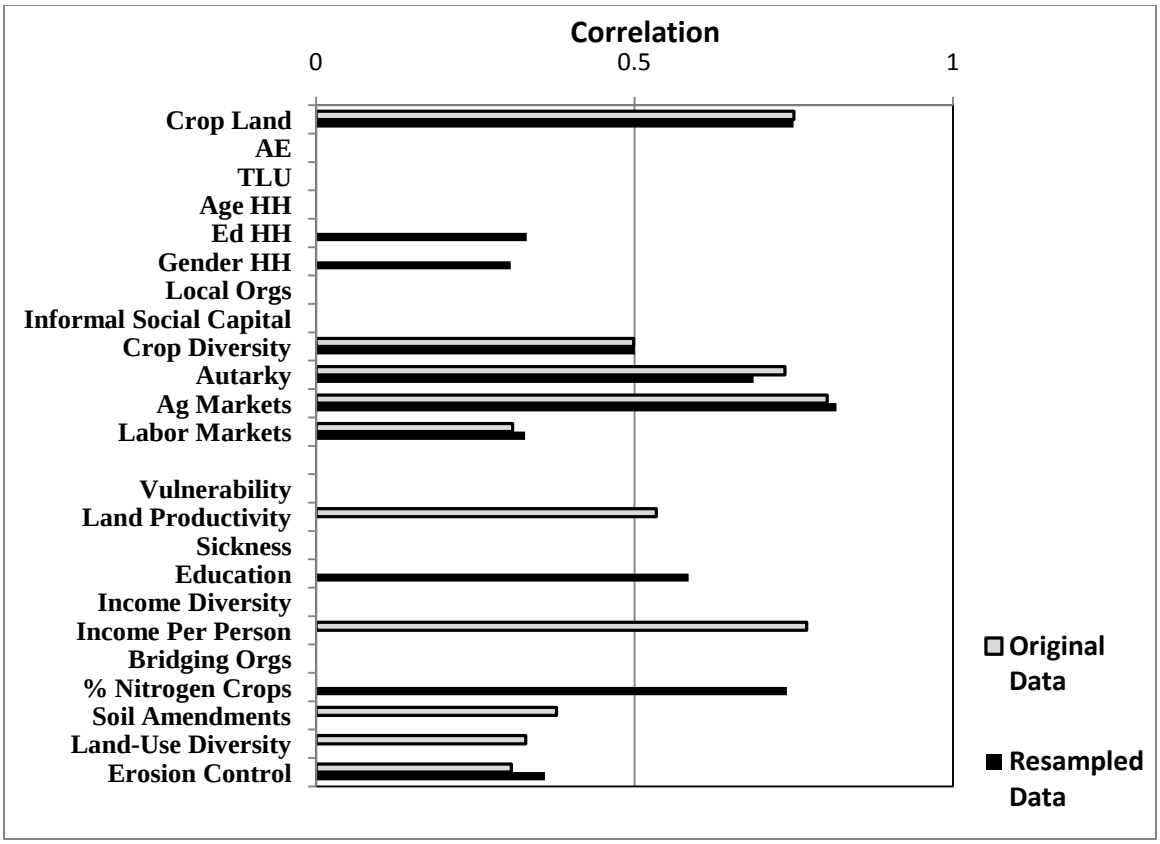


Figure V.1The correlation between variables and their canonical variable.

Although the above analysis is not identical to the original sample data, it does express the relationships that are likely in the population that the original data was collected from if that original sample was random and fairly representative of the entire population.

If the model is significant for many of the canonical variables using the original data, resampling may not increase the variance that the model extracts. In cases with small sample sizes, such as the communities, where sample size severely restricts the canonical analysis, resampling will most likely increase the explanatory power of the model dramatically. In Ancoraimes, resampling was able to increase the predictive power of the model marginally (Table V.3).

Table V.3 Predictive power of the model with original and resampled data

| | **Original (N=149)** | **Resampled (N=500)** |
|---|---|---|
| **Cumulative Standardized Variance in Response Variables Explained by Opposite Significant Canonical Variables** | 0.3299 | 0.3482 |

## Appendix VI: Auxiliary tables for canonical analysis

Table VI.1 Test for significance of the canonical correlation in Umala

| Multivariate Statistics and F Approximations | | | | | |
|---|---|---|---|---|---|
| S=11 M=0 N=78 | | | | | |
| **Statistic** | **Value** | **F Value** | **Num DF** | **Den DF** | **Pr > F** |
| **Wilks' Lambda** | 0.020364 | 6.05 | 132 | 1310.1 | <.0001 |
| **Pillai's Trace** | 2.792033 | 4.76 | 132 | 1848 | <.0001 |
| **Hotelling-Lawley Trace** | 5.988572 | 7.09 | 132 | 839.44 | <.0001 |
| **Roy's Greatest Root** | 2.281616 | 31.94 | 12 | 168 | <.0001 |
| NOTE: F Statistic for Roy's Greatest Root is an upper bound. | | | | | |

Table VI.2 Test for significance of the canonical correlation in Ancoraimes

| Multivariate Statistics and F Approximations | | | | | |
|---|---|---|---|---|---|
| S=11 M=0 N=62 | | | | | |
| **Statistic** | **Value** | **F Value** | **Num DF** | **Den DF** | **Pr > F** |
| **Wilks' Lambda** | 0.010843 | 5.86 | 132 | 1048.2 | <.0001 |
| **Pillai's Trace** | 3.126777 | 4.5 | 132 | 1496 | <.0001 |
| **Hotelling-Lawley Trace** | 7.529493 | 7.09 | 132 | 661.07 | <.0001 |
| **Roy's Greatest Root** | 3.389493 | 38.41 | 12 | 136 | <.0001 |
| NOTE: F Statistic for Roy's Greatest Root is an upper bound. | | | | | |

Table VI.3 Variables at the community level in Umala

| | San José Llanga (N=96) | | San Juan Circa (N=31) | | Vinto Coopani (N=29) | | Kellhuiri (N=25) | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **Std Dev** | **Mean** | **Std Dev** | **Mean** | **Std Dev** | **Mean** | **Std Dev** |
| **Crop Land** | 5.62 | 3.32 | 7.37 | 4.47 | 1.91 | 1.25 | 1.97 | 1.31 |
| **AE** | 4.50 | 2.23 | 4.02 | 2.32 | 5.14 | 2.56 | 4.12 | 2.24 |
| **TLU** | 9.88 | 6.54 | 10.02 | 6.24 | 6.73 | 2.79 | 11.05 | 9.01 |
| **Age HH** | 49.33 | 16.45 | 48.61 | 15.45 | 50.41 | 11.72 | 52.44 | 17.81 |
| **Ed HH** | 8.07 | 4.08 | 6.19 | 4.46 | 5.31 | 2.54 | 6.00 | 4.64 |
| **Gender HH** | 0.85 | 0.35 | 0.74 | 0.44 | 0.72 | 0.45 | 0.80 | 0.41 |
| **Local Orgs.** | 0.03 | 0.17 | 0.23 | 0.50 | 0.07 | 0.26 | 0.36 | 0.57 |
| **Informal S.C.** | 0.83 | 0.95 | 0.58 | 0.72 | 0.59 | 0.68 | 0.68 | 0.85 |
| **Crop Diversity** | 2.92 | 0.97 | 2.76 | 0.88 | 3.13 | 1.09 | 3.38 | 1.06 |
| **Autarky** | 8.84 | 0.73 | 8.85 | 0.75 | 8.12 | 0.67 | 8.47 | 0.80 |
| **Ag Markets** | 8.86 | 1.11 | 8.68 | 1.04 | 7.29 | 1.04 | 6.82 | 3.18 |
| **Labor Markets** | 4.40 | 3.73 | 2.89 | 3.57 | 5.22 | 3.48 | 5.95 | 2.98 |
| **Vulnerability** | 33.95 | 10.03 | 35.49 | 9.95 | 37.33 | 11.32 | 35.89 | 9.77 |
| **Sickness** | 0.28 | 0.29 | 0.25 | 0.30 | 0.13 | 0.17 | 0.21 | 0.28 |
| **Income Per Person** | 8.55 | 0.75 | 8.45 | 0.74 | 7.60 | 0.56 | 8.25 | 0.72 |
| **Land Productivity** | 7.93 | 0.50 | 7.70 | 0.44 | 7.86 | 0.48 | 7.96 | 0.42 |
| **Education** | 1.36 | 1.58 | 0.77 | 1.12 | 0.86 | 1.13 | 1.16 | 1.46 |
| **Income Diversity** | 1.74 | 0.50 | 1.54 | 0.42 | 2.00 | 0.53 | 2.11 | 0.52 |
| **Bridging Orgs** | 1.49 | 0.99 | 1.13 | 0.85 | 1.45 | 1.18 | 1.28 | 0.98 |
| **Land-Use Diversity** | 4.05 | 1.12 | 3.30 | 1.23 | 2.97 | 1.50 | 2.86 | 1.21 |
| **% Nitrogen Crops** | 0.33 | 0.18 | 0.29 | 0.20 | 0.35 | 0.21 | 0.21 | 0.17 |
| **Soil Amendments** | 6.06 | 0.91 | 0.61 | 1.91 | 6.92 | 1.02 | 6.96 | 1.75 |
| **Erosion Control** | 6.95 | 6.22 | 9.38 | 6.32 | 4.75 | 4.38 | 6.12 | 6.50 |

**Data source:** SANREM CRSP 2006

Table VI.4 Communities in Umala: Canonical correlation between each variable and its canonical variable

| | San José Llanga | | | San Juan Circa | | | Vinto Coopani | | | Kellhuiri | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **D 1** | **D 2** | **D 3** | **D 1** | **D 2** | **D 3** | **D 1** | **D 2** | **D 3** | **D 1** | **D 2** | **D 3** |
| **Crop Land** | | 0.91 | | 0.56 | 0.74 | | 0.46 | 0.40 | 0.47 | 0.76 | | |
| **AE** | | 0.29 | -0.33 | 0.51 | 0.36 | | | 0.65 | | 0.32 | | |
| **TLU** | | 0.36 | -0.31 | | 0.57 | | | | 0.47 | 0.54 | | |
| **Age HH** | -0.43 | | 0.32 | 0.78 | -0.44 | | | | | -0.42 | | |
| **Ed HH** | 0.33 | 0.36 | | | 0.57 | | | | -0.40 | 0.36 | | |
| **Gender HH** | 0.31 | 0.31 | | | 0.63 | | | | | 0.36 | | |
| **Local Orgs.** | | | 0.34 | | 0.41 | -0.66 | -0.36 | 0.32 | | 0.37 | -0.38 | |
| **Informal S.C.** | | | | -0.44 | -0.33 | | | | | | | |
| **Crop Diversity** | 0.45 | | | 0.54 | | | 0.31 | -0.42 | | | 0.40 | |
| **Autarky** | 0.70 | 0.59 | | | 0.60 | | 0.65 | 0.55 | | 0.80 | 0.36 | |
| **Ag Markets** | 0.57 | 0.54 | | | 0.84 | 0.32 | 0.51 | 0.34 | | 0.37 | | 0.42 |
| **Labor Markets** | | 0.32 | | -0.32 | | 0.33 | | | | -0.32 | 0.43 | |
| **Vulnerability** | | | | 0.43 | -0.44 | | | -0.31 | | | -0.56 | 0.51 |
| **Sickness** | | | 0.30 | | -0.55 | | -0.37 | | | -0.34 | | |
| **Income Per Person** | | 0.58 | 0.70 | 0.31 | 0.36 | 0.70 | 0.56 | | | -0.37 | 0.52 | |
| **Land Productivity** | 0.60 | | 0.51 | -0.51 | | | 0.59 | | -0.51 | | | |
| **Education** | 0.35 | | -0.34 | | 0.42 | -0.67 | | 0.77 | -0.30 | 0.52 | | |
| **Income Diversity** | -0.34 | | | | | 0.50 | | | | -0.47 | | 0.54 |
| **Bridging Orgs** | | 0.30 | -0.50 | -0.34 | 0.42 | | | 0.47 | | 0.51 | | 0.34 |
| **Land-Use Diversity** | 0.62 | | | 0.58 | 0.47 | | 0.35 | | | | | |
| **% Nitrogen Crops** | -0.32 | 0.43 | | | | | 0.36 | | 0.45 | | -0.30 | -0.48 |
| **Soil Amendments** | | 0.61 | | | | -0.52 | 0.53 | | | 0.65 | | 0.40 |
| **Erosion Control** | | 0.70 | | | | | | 0.41 | | | | -0.56 |

**Data source:** SANREM CRSP 2006

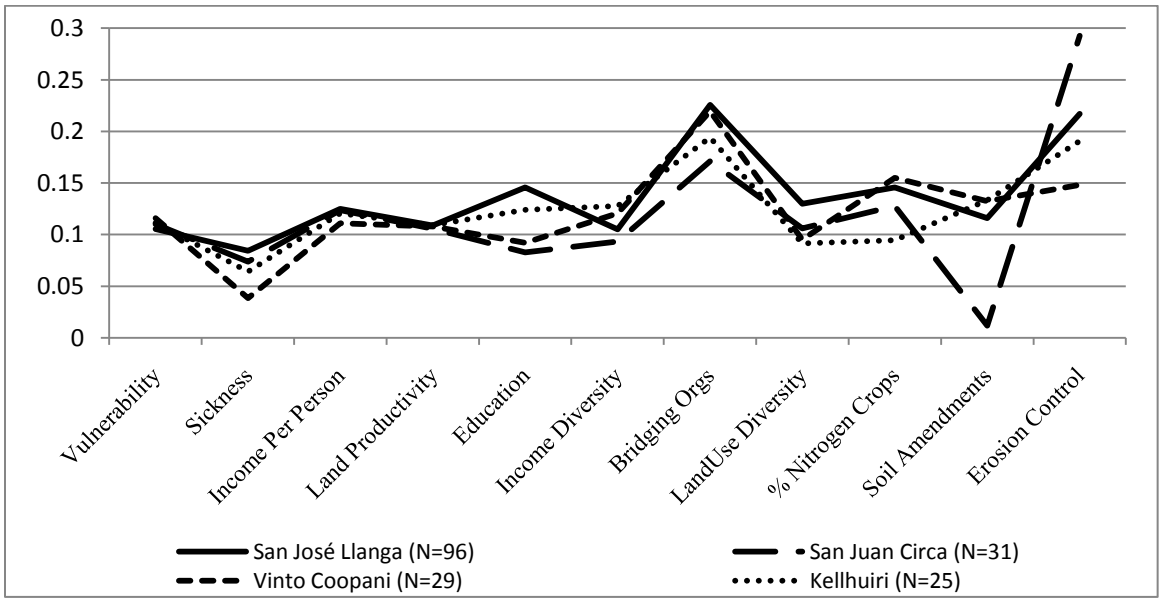


Figure VI.1 Impact of livelihoods dimensions on factors of the SES in Umala

Table VI.5 Variables at the community level in Ancoraimes

| | Chinchaya (N=57) | | Karkapata (N=15) | | Chojñapata (N=27) | | Calahuancani (N=23) | | Cohani (N=27) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **Std Dev** | **Mean** | **Std Dev** | **Mean** | **Std Dev** | **Mean** | **Std Dev** | **Mean** | **Std Dev** |
| **Crop Land** | 0.88 | 0.61 | 0.38 | 0.23 | 0.34 | 0.18 | 0.46 | 0.27 | 0.22 | 0.13 |
| **AE** | 3.76 | 1.71 | 3.89 | 1.65 | 3.67 | 2.43 | 3.11 | 1.15 | 3.13 | 1.34 |
| **TLU** | 5.59 | 2.73 | 4.26 | 2.50 | 15.76 | 9.88 | 6.62 | 3.61 | 3.00 | 2.01 |
| **Age HH** | 49.26 | 14.11 | 48.07 | 14.40 | 48.93 | 15.94 | 45.83 | 13.45 | 44.48 | 13.78 |
| **Ed HH** | 7.96 | 4.75 | 5.20 | 5.09 | 5.15 | 3.44 | 5.35 | 4.27 | 4.33 | 2.90 |
| **Gender HH** | 0.91 | 0.29 | 0.60 | 0.51 | 0.78 | 0.42 | 0.74 | 0.45 | 0.59 | 0.50 |
| **Local Orgs.** | 0.65 | 0.69 | 0.73 | 0.59 | 0.67 | 0.68 | 0.87 | 0.63 | 0.67 | 0.55 |
| **Informal S.C.** | 2.53 | 1.44 | 1.53 | 1.06 | 1.67 | 1.00 | 2.04 | 0.82 | 1.48 | 0.94 |
| **Crop Diversity** | 4.67 | 1.08 | 4.06 | 0.84 | 3.91 | 1.32 | 4.38 | 1.38 | 3.50 | 1.04 |
| **Autarky** | 7.26 | 0.49 | 6.80 | 0.68 | 7.45 | 0.45 | 7.19 | 0.47 | 6.33 | 0.59 |
| **Ag Markets** | 8.39 | 0.87 | 5.88 | 1.30 | 7.10 | 1.41 | 7.04 | 1.23 | 4.98 | 1.85 |
| **Labor Markets** | 4.42 | 3.84 | 5.27 | 3.53 | 5.05 | 3.22 | 6.57 | 2.97 | 5.79 | 3.02 |
| **Vulnerability** | 31.58 | 7.91 | 40.23 | 10.69 | 32.79 | 9.26 | 36.60 | 5.81 | 38.51 | 9.78 |
| **Sickness** | 0.41 | 0.41 | 0.50 | 0.38 | 0.55 | 0.37 | 0.44 | 0.39 | 0.56 | 0.40 |
| **Income Per Person** | 7.61 | 0.78 | 6.76 | 0.89 | 7.38 | 0.71 | 7.49 | 0.83 | 6.27 | 0.91 |
| **Land Productivity** | 8.84 | 0.64 | 7.97 | 0.34 | 8.39 | 0.35 | 8.31 | 0.46 | 7.94 | 0.40 |
| **Education** | 1.07 | 1.25 | 1.33 | 1.50 | 0.70 | 1.14 | 1.35 | 1.27 | 0.74 | 0.90 |
| **Income Diversity** | 1.57 | 0.47 | 1.66 | 0.60 | 2.09 | 0.45 | 1.96 | 0.49 | 1.88 | 0.48 |
| **Bridging Orgs** | 0.33 | 0.48 | 0.27 | 0.46 | 0.30 | 0.47 | 0.13 | 0.34 | 0.22 | 0.42 |
| **Land-Use Diversity** | 3.80 | 1.64 | 2.94 | 1.50 | 3.53 | 1.61 | 4.39 | 1.53 | 3.34 | 1.33 |
| **% Nitrogen Crops** | 0.28 | 0.16 | 0.31 | 0.14 | 0.02 | 0.08 | 0.16 | 0.22 | 0.30 | 0.17 |
| **Soil Amendments** | 6.56 | 0.84 | 6.60 | 0.64 | 6.60 | 0.62 | 6.43 | 0.46 | 5.49 | 1.06 |
| **Erosion Control** | 1.55 | 1.88 | 2.23 | 3.23 | 0.40 | 0.66 | 0.45 | 0.48 | 0.23 | 0.47 |

**Data source:** SANREM CRSP 2006

Table VI.6 Communities in Ancoraimes: Canonical correlation between each variable and its canonical variable

| | Chinchaya | | | Karkapata | | | Chojñapata | | | Calahuancani | | | Cohani | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **D 1** | **D 2** | **D 3** | **D 1** | **D 2** | **D 3** | **D 1** | **D 2** | **D 3** | **D 1** | **D 2** | **D 3** | **D 1** | **D 2** | **D 3** |
| **Crop Land** | 0.47 | 0.53 | 0.62 | -0.35 | | 0.37 | 0.61 | | | | | 0.44 | 0.77 | | |
| **AE** | | -0.49 | | | | | | | 0.70 | | 0.74 | 0.45 | | | 0.38 |
| **TLU** | | | 0.50 | | | 0.58 | | | -0.29 | | | 0.68 | 0.38 | | 0.52 |
| **Age HH** | | | | | | | 0.65 | | | | | | | -0.34 | -0.43 |
| **Ed HH** | | | | | | | -0.34 | | | | 0.62 | | | | |
| **Gender HH** | | | | | | -0.55 | | 0.38 | | | 0.34 | 0.33 | | | -0.40 |
| **Local Orgs.** | | -0.72 | | | | | -0.36 | | 0.49 | | | | | 0.45 | |
| **Informal S.C.** | | | | 0.54 | -0.32 | | 0.49 | | | | | | | | |
| **Crop Diversity** | | | | | | 0.38 | | 0.82 | | | -0.35 | 0.76 | | 0.82 | |
| **Autarky** | 0.44 | | 0.48 | | | 0.34 | 0.44 | | 0.35 | | 0.42 | 0.74 | 0.68 | 0.41 | 0.36 |
| **Ag Markets** | 0.89 | | 0.37 | | 0.46 | | 0.32 | | | | 0.33 | 0.50 | 0.40 | 0.49 | |
| **Labor Markets** | 0.32 | 0.34 | -0.69 | | | | -0.30 | | | 0.64 | | | 0.66 | | |
| **Vulnerability** | | 0.52 | 0.37 | -0.51 | | 0.64 | 0.30 | | -0.60 | | -0.47 | | | | 0.34 |
| **Sickness** | | 0.76 | | -0.31 | | | | | -0.59 | | -0.31 | 0.40 | 0.58 | | |
| **Income Per Person** | 0.73 | 0.48 | | | | | 0.67 | | -0.34 | 0.64 | | | 0.79 | | |
| **Land Productivity** | 0.68 | -0.58 | | | | | | | 0.82 | 0.42 | | 0.40 | | 0.74 | |
| **Education** | | -0.50 | | | | 0.66 | | -0.46 | | | 0.69 | 0.43 | | | 0.72 |
| **Income Diversity** | | 0.51 | -0.69 | | 0.44 | | -0.56 | | | | | 0.61 | 0.37 | | |
| **Bridging Orgs** | | 0.44 | | | | | | | -0.46 | | 0.34 | | | | |
| **Land-Use Diversity** | | 0.29 | | -0.33 | | | | 0.78 | 0.43 | | | 0.49 | | 0.64 | |
| **% Nitrogen Crops** | | 0.37 | | | 0.50 | | | 0.56 | | | -0.34 | | 0.48 | | |
| **Soil Amendments** | | | | | | | 0.41 | | | | 0.67 | | | | 0.45 |
| **Erosion Control** | | | 0.42 | | | | | | -0.56 | | 0.44 | 0.40 | | | |

**Data source:** SANREM CRSP 2006

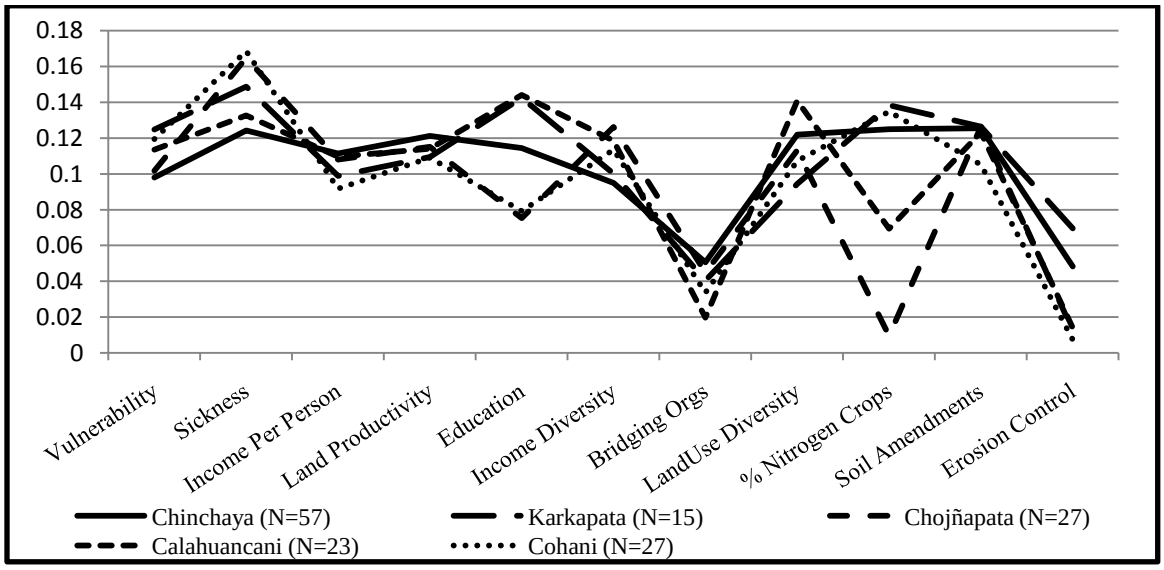


Figure VI.2 The impact of livelihoods dimensions on factors of the SES in Ancoraimes

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