The Dissertation Committee for Joshua Martin Rudow Certifies that this is the approved version of the following dissertation:

Uphill Cultivation: Farmers in the Changing Environments of the Rio Ica Watershed, Peru

Committee:

William E. Doolittle, Supervisor

Kenneth R. Young

Gregory W. Knapp

Rebecca M. Torres

Arlene M. Rosen

Uphill Cultivation: Farmers in the Changing Environments of the Rio Ica Watershed, Peru

by

Joshua Martin Rudow B.A.; M.A.

Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

May 2016

Dedication

This dissertation is dedicated to my grandparents Ben, Miriam, John, and JoAnn.

Acknowledgements

This dissertation would not have been possible without the help and support of numerous people. My advisor Dr. William Doolittle kept the progress of this dissertation on track and was essential during the editing process. I thank the entire team at The German Federal Enterprise for International Cooperation on Adaptation to Climate Change in Ica and Huancavelica, who graciously opened up their office and helped me develop regional contacts. I also must thank the farmers who gave me their valuable time and patiently answered my questions. Dr. Kenneth Young was of great assistance in providing context to my research. My sincerest gratitude also goes to the following people: Gregory Knapp, Rebecca Torres, Arlene Rosen, Claus Kruse, Aldo Ortega, Chris Jensen, Carlos Martinez, Rony Reyes, Cesar Aquino, Christian Schindler, Valeria Silvestri, Daniel Malasquez, Gari Solorzano, Jose Fernandez, Rocio Mariela, Marita Hurtado, Edgar Armas, Teófilo Altamirano, Frank Altamirano, Rafael de Grenade, David Muñoz, Manuel Checa, David Bayer, Carlos Herz, Maria Jose La Rota, Matt LaFevor, Matt Fry, Alexandra Ponette-González, Gregory Schwartz, Marc Rudow, Deborah Miles, Caleb Rudow, David Rudow, Finnegan Rudow, Galit Church, and Rebekah Miles,

The research was funded by the Donald Brand pre-Dissertation Fellowship and the Lozano Long Summer Research Grant.

Uphill Cultivation: Farmers in the Changing Environments of the Rio Ica Watershed, Peru

Joshua Martin Rudow, Ph.D.
The University of Texas at Austin, 2016

Supervisor: William Doolittle

Abstract: This dissertation examines how smallholders in the upper Rio Ica watershed respond to climate change and other agricultural challenges. It focuses on four themes associated with agricultural change. First, it elucidates farmer observations, perceptions, and awareness of climate changes that include decreased precipitation and more extreme temperature variations. Second, it provides a typology that categorizes climate change adaptations by smallholders and development organizations. Third, it analyzes how kikuyu, an invasive grass species, impacts agricultural strategies and limits production. Fourth, it discusses how development agencies and farmers work to reduce agricultural vulnerability.

The impetus for the research is threefold: 1) effective climate change adaptations are much needed and understudied; 2) the upper Rio Ica watershed is undergoing climate changes that force many farmers to migrate, resulting in the loss of "traditional" agricultural strategies, a crucial piece of adaptation and; 3) current development programs seem to be less effective than desirable at reducing farmer vulnerability. The dissertation contributes to literature on human-environment geography, cultural and political ecology, and adaptation studies.

The research methods include: farmer surveys, semi-structured interviews, community meetings, informal conversations, soil analyses, remote sensing, and archival research. Results of the individual component studies vary. Recent climate changes that include decreased precipitation and more extreme temperatures have pushed the limits of “traditional” agricultural strategies and forced farmers to adapt more modern agricultural additions. Adaptation development programs must also recognize that climate change is one of many disparate challenges affecting farmers, and that increasing resiliency will involve adaptation programs that may have little connection to climate.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

In the upper Rio Ica watershed (RIWS) of southern Peru, smallholders are exposed to a multitude of external forces that impact agriculture. This dissertation focuses primarily on one force—how climate changes affect agriculture—while recognizing that farmers also adapt their strategies to non-climate forces that include invasive species and external markets. It is comprised of five chapters, each written as a stand-alone article. There is some repetition of figures and data, so that each can be submitted to professional journals independently, but this is minimized to improve reading. Figure 0.1 illustrates how all of the chapters fit together, and how each chapter describes a different external factor or adaptation strategy that increases resiliency. Not all factors that impact smallholders are discussed within this dissertation but are reserved for future research. This dissertation does, however, describe the primary pressures that affect agriculture within the upper RIWS and responses by farmers and development agencies. Research was conducted over two six-month periods in 2013 and 2014 in the regions of Ica and Huancavelica in southeastern Peru. Data are mainly from 105 farmer surveys, 55 semi-structured interviews, and hundreds of informal conversations and

The first chapter is a Field Note that will be submitted to the *Geographical Review*. It describes the study area and agricultural responses to a variety of factors in the upper RIWS through the experience of a single farmer, Teofilo. Chapter one focuses on adaptations to water shortages from precipitation variation, and also argues that the subfields of cultural and political ecology are well-suited to elucidate specific farmer adaptations and how the occur in a rapidly changing world.

Chapter two compares meteorological data with farmer observations on climatic variation. Farmer observations are then ranked against other perceived agricultural challenges. The chapter discusses farmer awareness of global climate change, and the impact that increased climate education may have on the implementation of adaptation programs. It is anticipated that this chapter will be submitted to *Human Ecology*.

Chapter three systematically characterizes agricultural adaptation strategies to climate change. These include "traditional" or indigenous agricultural strategies and more modern applications promoted by governmental and non-governmental agencies. The chapter demonstrates the various forms that agricultural adaptations can take along with the stakeholder and decision-making processes involved. It will be submitted to *Climate Change*.

Chapter four diverges from the climate focus and reveals how kikuyu, an invasive grass from east Africa, severely limits agricultural production. Farmers rank kikuyu as a major hindrance to their agricultural production, and a remote sensing analysis of kikuyu confirms its spread across most agricultural fields. Current kikuyu management strategies available are ineffective. It will hopefully published in the *Journal of Latin American Geography*.

Chapter five discusses how farmers cultivate with the support of a multiplicity of non-governmental and governmental agencies. It describes how international, national, regional, and local development programs work to support farmers and the obstacles that arise. The aim is to publish it in *World Development* or *Agriculture and Human Values*

The primary impetus of this dissertation was to uncover how farmers observe and respond to climate change. To accomplish this goal, a detailed farmer survey was necessary, which can be found after the final chapter. I created the survey after interviews with farmers and development agents, and I believe that it can be tailored for use throughout regions with smallholder agriculture. This farmer survey, when used with other environmental methodologies (e.g. remote sensing, soil analyses, meteorological records), is a useful tool that can help to better understand climate changes and agricultural responses, and is a novel contribution to the field.

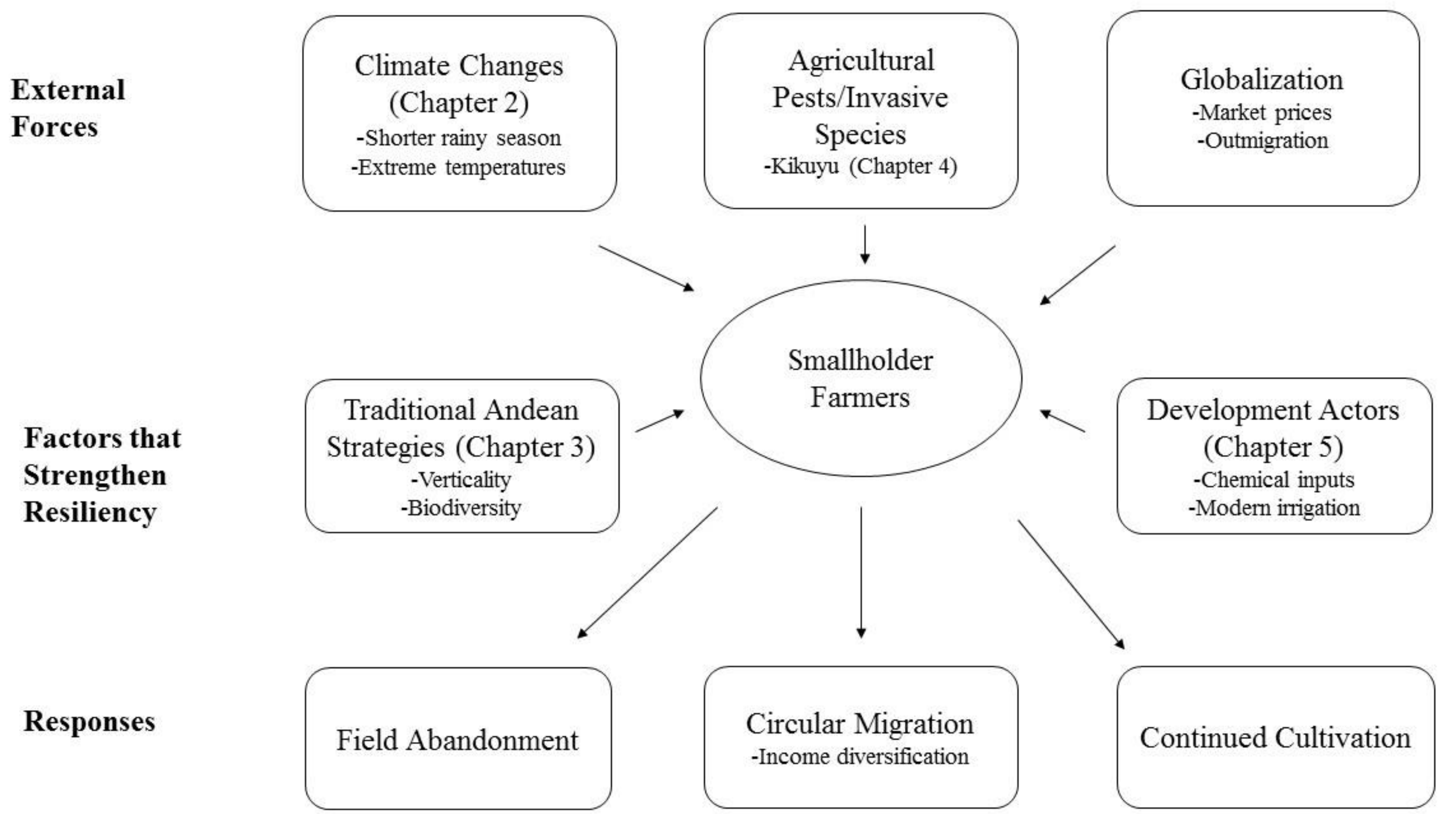

Figure 0.1: Diagram of dissertation structure.

CHAPTER ONE

Geographical Field Note: Smallholder Farmers in the Upper Rio Ica Watershed

Introduction

Teofilo wakes up at 5:00 am every morning to tend to his animals.[1] He lives in Tambo, a small town in the upper Rio Ica watershed (RIWS) at 3,200 meters above sea level (m.a.s.l.). Like many other villages in this area, Tambo is remote and is a four-hour ride by *colectivo* to the city of Ica. Teofilo cares for 21 cows and seven sheep. To maintain such a herd he needs access to several hectares of alfalfa while also supplementing their diet with kikuyu, an invasive grass that now blankets most of his fields. Teofilo has more resources than most farmers in the area. His father and grandfather were major landowners in Tambo, their herd once numbered nearly 100 cows and they employed 25 people. He is now the sole caretaker of his family's extensive landholdings. All of his seven brothers and sisters have left to find opportunities in Lima and abroad. He supplements his income through a variety of sources that include the sale of cheese and meat, along with help from his family. Teofilo lamented the current state of agriculture in Tambo and was unsure how long he will continue. Political,

[1] Teofilo is fictional, but his situation is common and based on a real person.

socioeconomic, environmental, and climatic factors all combine to make agriculture more difficult. The farming techniques he applies have evolved over hundreds of years to best utilize the scarce water resources and steep mountain slopes, and he has begun experimenting with some modern practices.

The story of Teofilo is similar to many smallholder farmers who cultivate this mountainous landscape. They are pushed by a multiplicity of factors that are changing their agricultural techniques. The original focus of this research was to determine how climate change affected their agricultural strategies and what type of support farmers received from governmental and non-governmental organizations. Data from three meteorological stations maintained by the Servicio Nacional de Meteorología e Hidrología del Peru in the RIWS show that the climate is changing through warmer temperatures and decreased precipitation (Oria and Ovalos, 2013). Smallholder farmers reported a less predictable rainy season and more extreme temperature variation. However, when climate factors are compared to an assortment of influences, climate changes are not always the most important. My research consisted of interviews and surveys conducted with farmers to understand what techniques they applied and how they responded to a range of changes. I also developed a partnership with a project implemented by the German Federal Enterprise for International Cooperation on Adaptation to Climate Change in Ica and Huancavelica (GIZ-ACCIH) and spoke with other governmental and non-governmental organizations working in the region. What began as a seemingly simple question on climate change adaptation, developed into the larger context of development and vulnerability.

A unique component of this research project is the focus on agrarian change on the watershed scale to understand how all farmers collectively respond to the effects of climate change and other factors. The RIWS is located on the southeastern Peruvian coast inside of the departments of Ica and Huancavelica (Figure 1.1). All actors within this watershed must collectively manage their shared waters source, but their agricultural strategies vary considerably.

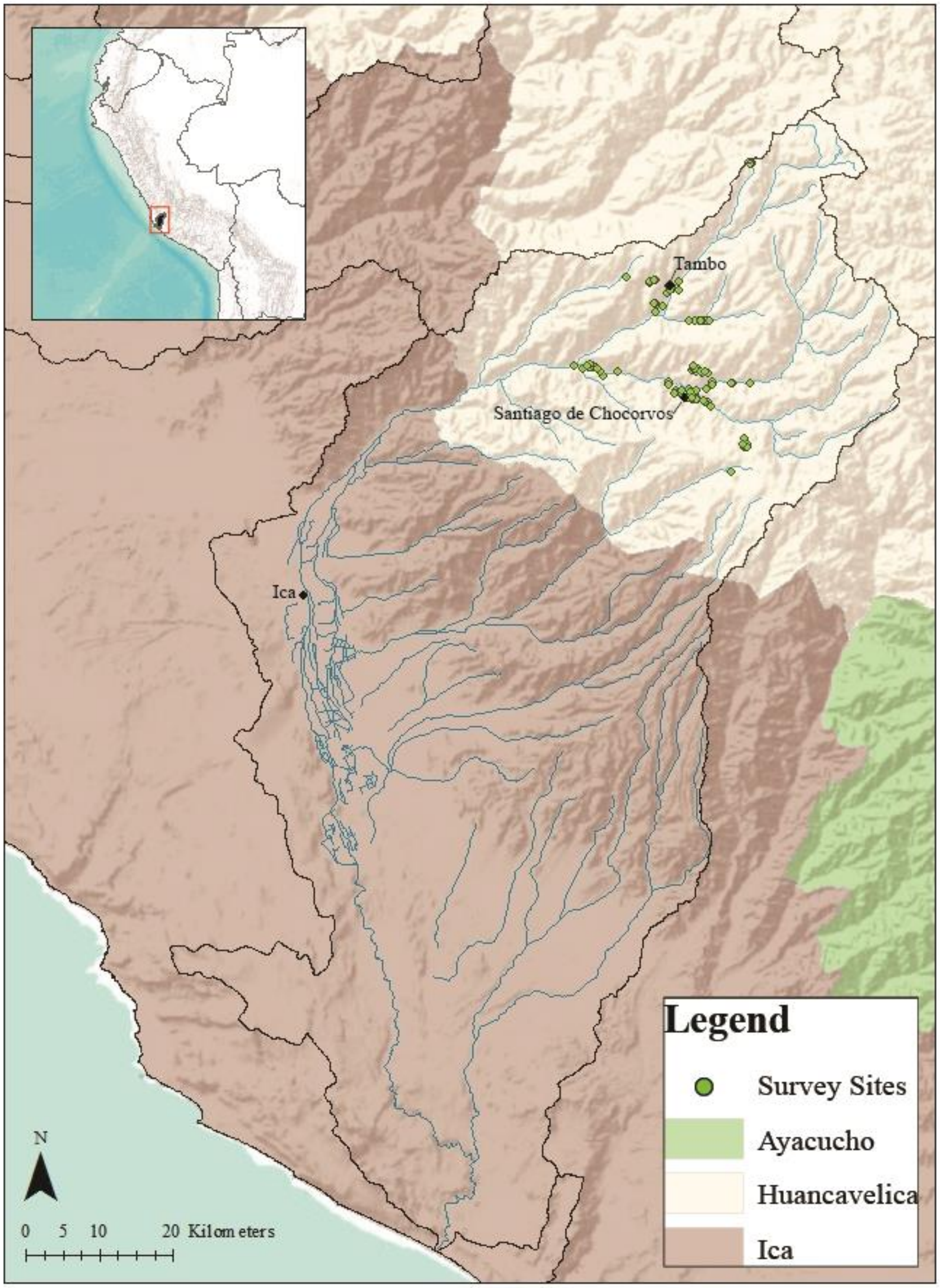

Figure 1.1: Map of the Rio Ica watershed with surveys sites.

Landscapes and Cultivation

The climate along the RIWS shifts from semi-arid in the sierra (424 mm/year at Tambo, 3,080 m.a.s.l.) to hyperarid in the lower valley (2 mm/year at Ocucaje 325 m.a.s.l.) (Oria and Ovalos, 2013; Hepworth et al., 2010). Stream flow is extremely seasonal and erratic. Steep gorges characterize the eroded sierra, broad and deep alluvial deposits characterize the valley floor near the coast. The dry climate and abrupt topographical changes create sharply defined ecological zones and three distinct agricultural landscapes. Following a transect from the Pacific Ocean to the high sierra, the RIWS goes from commercial export agriculture, through smallholder farms, to high Andean pastoralism. The bulk of my dissertation research was among smallholder farmers in the department of Huancavelica. These smallholder farmers are isolated from the city of Ica and rely mainly on traditional agricultural strategies. The other two landscapes are not ignored however, as they rely on the same water and therefore are politically, socially, and economically entangled. Corporate export farmers take advantage of the predictable desert conditions of the Ica valley and favorable trade relations with the United States and Europe and labor policies to grow largely non-traditional crops (asparagus, pomegranate, red globe grapes, and dates) (Meade et al., 2011). They hold substantial political control and are routinely in conflict with smallholder farmers in Huancavelica over water rights while also providing seasonal employment. At the upper end of the watershed, a small number of pastoralists live on the high Andean plain above 4,000 m.a.s.l. and raise llamas and alpacas for the regional market. Due to their high elevations they are unable to grow field crops and thus focus entirely on pastoralism.

Smallholder Farmers "Caught in the Middle"

Smallholder farmers in the department of Huancavelica are located between 1,700 and 4,000 m.a.s.l. This study was conducted within five districts (Tambo, Ayavi, Santiago de Chocorvos, San Francisco de Sangayaico, and Santo Domingo de Capillas) of the upper RIWS with a population of 6,599, according to the 2007 census. They grow primarily alfalfa, an introduced species of forage legume used as a feedstock. These smallholders also cultivate wheat, barley, corn, lima beans, quinoa, and several varieties of potatoes, along with other cultivars. Depending on elevation and access to water, they may raise tree crops such as avocados, oranges, figs, and apples. Their livestock consists predominantly of cattle, though farmers also raise sheep, goats, and pigs. Nearly all of the farmers surveyed owned the land they cultivated though some rented additional lands (in some cases the best lands) from people who recently migrated to Ica.

The landscape is one of tremendous climatic and topographic diversity, often over short distances (Zimmerer, 1999). In response, farmers have developed a corresponding mosaic of adaptive strategies for food production. They apply a variety of political and social organization strategies known as "verticality" to take advantage of as many vertical microclimates as possible (Murra, 1968). By doing so, they are not utilizing one zone for gain, but a variety of zones to ensure against crop failure. They have a diversity of crops that grow best at specific altitudes and climate variations thus making them more resilient to climate anomalies. Brush (1976) describes this as compressed ecological zonation, spacing of crop zones by a steep environmental gradient that places different zones very close to one another.

The mountainous topography contains little flat land and thus farmers rely on a patchwork of bench terraces and canals (Brooks, 1998). The primary functions are to facilitate the even distribution of irrigation water over the cultivation surface and provide leveled terrain and deep soil. Today's farmers did not build the bench terraces, but have clearly benefitted from their ancient construction, and are responsible for their ongoing maintenance. Recent archaeological research suggests the terraces within the RIWS are prehispanic in origin (Lane, Personal Communication).

The arid landscape presents a separate challenge for smallholder farmers. Rainfall is minimal and only occurs from December to May. Outside of the rainy season all agriculture must be irrigated. A small number of fields above the canal system rely only on precipitation during the rainy season. Therefore, most communities are strategically located near a water source (Figure 1.2). Farmers use canals to transport water from further upstream with sluice gates that regulate the volume of water that enters. As the stream continues to drop towards the Pacific Ocean, canals slowly divert water parallel to the slope contours with a minimal gradient until it is above the agricultural fields. Canals serve two purposes: 1) deliver the necessary water in the amount needed, and 2) do so without either excessive maintenance, scouring or sediment deposition (Denevan, 2001).

Once the water passes directly above the field, the farmer can open up a second gate that will flood the field in a system known as gravity-fed irrigation. Canals supply nearly year-round irrigation though they may run dry before the start of the rainy season. The canal systems provides a buffer for farmers that extends their growing season and makes them more resilient to climate changes than non-irrigated agriculture (Liverman, 1990).

Figure 1.2: Satellite image of Tambo and its surrounding agricultural fields.

Smallholder farmers in Huancavelica are connected to the regional market in Ica but historically have been more self-reliant. *Colectivos* and government vehicles connect villages to the city of Ica, though the four-hour ride on a single lane dirt road maintains a certain isolation. Farmers in Huancavelica have traditionally brought cheese, livestock, and produce to sell at the larger markets in Ica. However, as commercial agriculture continues to grow in Ica, the surfeit of cheap produce and material goods now flood the smaller markets in Huancavelica. Noodles and white rice now make up a large portion of diets while more nutritious, traditional foods (e.g. *kiwicha*, *quinoa*, and *olluco*) are rarely consumed. Farmers find it difficult to sell their products and have become more reliant on material goods from Ica. The lack of a market to sell their products and an increase in material goods from Ica appears to be one cause of migration from the sierra to the coast but there are a range of other factors to consider. According to the 2007 Peruvian census, the population of the district of Tambo dropped by 44% since the 1981 census while the district of Ica grew by 54 % over the same period (INEI, 2007). An increasingly unpredictable climate pattern has made agriculture more difficult. Yearly precipitation totals show little change though the intensity and duration of rain events has altered significantly (Oria and Ovalos, 2013). Farmers report fewer precipitation dates but an increase in high precipitation events. Farmers now find it harder to plan for the upcoming season as they can lose an entire crop if they plant at the wrong time and are limited to drought tolerant crops (e.g. barley and wheat). Another influence is an invasive grass species that is ubiquitous in the region known as kikuyu that chokes out alfalfa. Decades earlier, farmers introduced kikuyu as forage for livestock but in the cold high elevations of the sierra its vertical growth is stunted and instead extends horizontally and covers the fields and terraces. The invasive grass provides some nourishment for livestock but not enough to maintain high milk production milk production. Farmers battle with kikuyu on a daily basis using a combination of herbicides and manual labor and see it as a major limitation to their agriculture.

Migration is not limited to the district of Tambo or the larger department of Huancavelica. There is a larger trend of rural to urban migration in Peru and throughout the developing world (Montgomery, 2008). A range of factors make farming continually more challenging, which is then exacerbated by a younger generation that appears eager to leave it all behind and move to the city. I spoke with many youth who lamented the lack of opportunities outside of being a smallholder farmer in the sierra and felt a greater connection to life in the city. The thriving export agriculture in the Ica valley requires workers to pick and process their crops and has almost zero percent unemployment (Hepworth et al., 2010). The concatenation of factors that strain agriculture in this region may seem to be insurmountable, however, there are a variety of indigenous strategies and modern agricultural additions that appear to provide relief.

Drivers and Responses

Most smallholder farmers rely on gravity-fed irrigation, a technique that requires minimal capital investment and has been applied for centuries (Inbar and Llerena, 2000).

Using this technique, a farmer opens up the sluice gate of the canal above their field and water rushes in. Fields and terraces are both designed for this type of irrigation. The farmer must be active during this process. They use a shovel to direct water into furrows and smaller canals to ensure that all of their crops are equally irrigated (Figure 1.3). This irrigation process is effective but also squanders precious water resources as much of the water evaporates or flows back down into the river below.

Figure 1.3: Farmer using gravity fed irrigation.

One GIZ-ACCIH project is to encourage and facilitate the use of artisanal sprinklers that can be built cheaply using supplies that all farmers can access (Figure 1.4). They also require less than half of the water as traditional gravity-fed irrigation, which is increasingly important as farmers reported more extreme precipitation variation. Some farmers also reported that sprinklers helped lessen agricultural pests. However, only 14% of farmers surveyed chose to implement this new irrigation strategy.

Figure 1.4: GIZ worker showing a farmer how to build a sprinkler with plastic tubing, pen, metal wiring, and bottle cap.

To further increase water conservation, several development agencies have worked with farmers to help increase water storage capacity. Large concrete pools can capture water when it is plentiful and then slowly release it to farmers in times of drought (Figure 1.5). Water storage pools compose a major capital investment but can extend a farmer's access to water for several months during the dry season. An additional benefit of water storage pools is that farmers do not have to drastically change their agricultural strategies, which often impedes implementation.

Another component of preserving water resources is more effective management before the water reaches the field. Many canal systems have a dirt or gravel bottom and lose significant water between the river and the field. One project of GIZ-ACCIH and other organizations is to line the bottom and sides of the canal with cement to diminish infiltration. They provide farmers with bags of cement who then organize a *faena*, community work party, themselves to improve the canal.

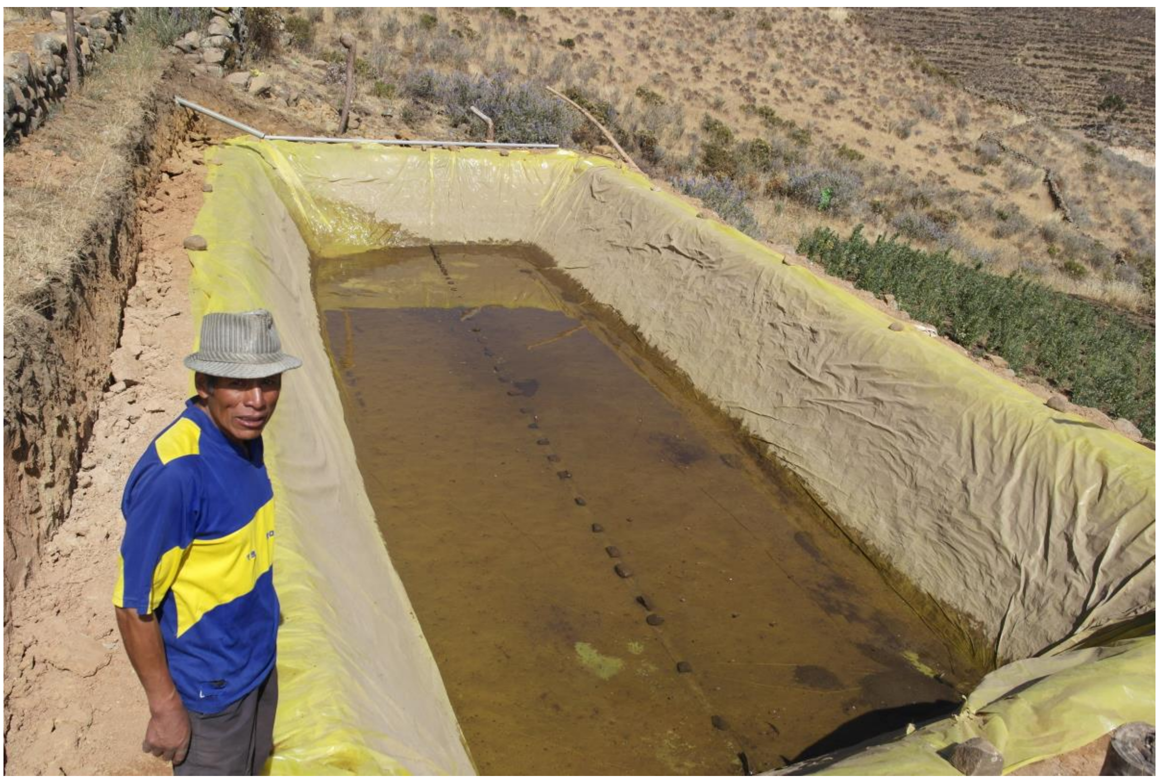

Figure 1.5: A new water reservoir above the annex of San Miguel de Curis.

There is often the assumption that indigenous or “traditional” agricultural strategies are best suited to preserve indigenous identity and that modern additions lead to migration and are seen as not sustainable. Modern additions, such as water storage pools, cement lined canals, and irrigation sprinklers, as part of a strategy can still be seen as indigenous or traditional as the overall objective to sustain a material base that will offset out-migration, a larger threat to indigenous identity and independence than any new technology (Bebbington, 1993). Farmers repeatedly asked for modern agricultural inputs to help them continue farming while maintaining the use of long-standing methods as the base of their agricultural strategies. Nonetheless, all modern additions may not be applicable and should not be seen as a panacea. There has been difficulty in the early implementation of some development projects primarily because they require practices that contrast significantly from traditional agricultural methods and thus farmers are reluctant to implement them.

Water scarcity is not solely impacted through climatic variation and inefficient irrigation management but also by underlying political and cultural forces. Political conflicts between corporate agriculture in the Ica valleys and smallholders in the upper RIWS over water rights limit available resources. Representatives from La Autoridad Nacional del Agua del Peru, a national regulatory agency, want to formalize water rights throughout the watershed to increase irrigation in the lower watershed, bypassing smallholder farmers. This relationship must be understood when speaking with smallholder farmers who feel they do not receive enough government support and also elucidates why many development programs fail. The impacts of outmigration have left fewer farmers to practice traditional cultural practices to maintain irrigation infrastructure. Smallholder farmers may apply long-standing agricultural techniques in a remote region, but this does not signify that larger external forces do not heavily influence their decision-making process.

Cultural and Political Ecology in Adaptation Literature

As the effects of climate change become further apparent in the upper RIWS, there is a strong need for agricultural adaptation. The legacy of cultural ecology is uniquely positioned to contribute to the discussion as adaptation, the process by which individuals respond to their surroundings, is a core concept (Head, 2009). There is a general call by politicians and policy makers for adaptation without a recognition that adaptation strategies will differ greatly based on geographic location. Cultural ecology draws on local knowledge studies from field-based research that is location-specific and ecologically particularistic (Basset and Zimmerer, 2003). This research situates local knowledge and practices within political, socioeconomic, culturally, and historically changing contexts (Bassett, 1994; Batterbury, 1996). Adaptation programs must understand complexities and speak directly with farmers to understand how they are impacted by both environmental changes and socioeconomic forces and how they respond. There is an abundance of research within cultural ecology that recognizes the historical rationality of indigenous technologies (irrigation, terraces, raised fields, and food plant diversity) to environmental variability (Knapp, 1991; Sandor and Eash, 1995; Erickson, 1988; Whitmore and Turner, 1992). Traditional agricultural strategies in the RIWS have evolved from hundreds of years and are well-suited to the environmental and climatic context. However, maintaining traditional technology may not be a priority for landowners whose vision for improving their lives may involve modern additions (Agrawal, 1995).

Political ecology provides a complementary lens to cultural ecology, while also critiquing its focus on rural communities as cohesive and bounded entities. Political ecology laments the dearth of historically and analytically grounded, calling for investigations on the socio-ecological relations that cause social vulnerability (Taylor, 2014). Farmers in the upper RIWS are economically and politically marginalized by a variety of factors, several of which have no relation to climate change such as outmigration, market prices, and invasive species. Without considering how these hierarchical forces influence farmers, adaptation programs are likely to have minimal impact. Political ecology also critiques approaches that involve a “shopping list of conditions for adaptive governance” and instead calls for an analysis of the complex political, cultural, and social dynamics at work (Peet et al., 2011: 9). Technocratic adjustments as a form of adaptation without examining the pre-existing social differentiation as a cause of vulnerability are unlikely to succeed (Taylor, 2014).

Current studies of adaptation have delivered insights but have shown only a moderate effect in reducing vulnerabilities (Smit and Wandel, 2006). Greater success can be found in applying studies of cultural and political ecology that help incorporate adaptation into existing resource management systems. Cultural ecology is particularly situated at understanding indigenous technologies, while political ecology complements this view of adaptation by situating these indigenous strategies in a larger social, political, and cultural context.

Unknown Future

The story of Teofilo illustrates the trials that smallholder farmers face within the RIWS. Even under ideal climate conditions, farmers would struggle to cultivate crops and raise livestock in the face of an uncertain agricultural future. Adapting to change will involve more than simply increasing resiliency to climatic factors. Strategies should be considered that are both indigenously developed and that involve modern additions. The literature and research methods of cultural and political ecology can play an important role to understand agricultural adaptations to climate change using local knowledge studies and how farmers function a larger political and socioeconomic context. In the end, the decision to leave smallholder agriculture may in itself be its own form adaptation (Black et al. 2011) and is a choice that should and will be made by the farmer.

CHAPTER TWO

Observations, Perceptions, and Awareness: How Farmers Experience and Interpret Climate Changes

Abstract

Smallholder farmers in the upper RIWS are in an exceptional position to elucidate climate changes. These farmers apply uniquely adapted agricultural strategies tied directly to climate patterns, and possess climate knowledge passed down by previous generations that illuminates past climate history further back than existing meteorological data. The available meteorological data on the RIWS are limited, but they do show a decrease in precipitation and a warming of temperatures. Responses from farmer surveys and semi-structured interviews portray climate changes that include a shorter, less predictable rainy season, and more extreme temperature fluctuations. Farmer perceptions also reveal that climate change plays a major role in decision-making, but other agricultural challenges have significant impacts that must be better understood. Knowledge of the origins of global climate change and its perceived risk varies among farmers. A greater understanding of how farmers perceive climate changes and how farmers rank climate challenges among external impacts would aid in sustainable development programs.

Introduction

The effects of climate change are typically examined on a global scale, and are generally negative. Most international treaties must focus on global emissions reductions, while impacts are seen as how they affect continents or countries (Field et al., 2014). Adaptation programs are often planned on a similarly large scale. Most research on agricultural impact focuses on how climate changes will alter large-scale crop production with minimal attention devoted to how smallholder farmers perceive climate changes, and how these changes impact agricultural decision-making (Lobell et al., 2011). There is insufficient information on the people who are most affected by climate change: those living in the developing world (McSweeney et al., 2010). As a result, many development projects that seek to increase farmer resiliency using “sustainable” adaptations to climate change are unsuccessful. The impact of climate change is different for farmers across the planet. These people use diverse tools and strategies to facilitate climate change adaptation. A “one size fits all” approach may not work in many areas where smallholder farmers perceive and are affected by climate changes differently. Little is known about how rural populations perceive and experience climate changes. The importance of local responses is exacerbated by the fact that climate change impacts are not evenly distributed over landscapes and rural populations (Boillat and Berkes, 2013).

Smallholder farmers in the upper RIWS are in a unique position to provide insight on climate change. Most have spent their lives working in this agropastoral environment, and their livelihoods are inherently intertwined with climate. They are attuned to even small changes in temperature and precipitation that can have substantial effects on agricultural production. Their understanding not only covers their own lifetime, but also incorporates climate and agricultural knowledge passed down from previous generations. Smallholder farmers apply adaptive strategies that make the best use of a difficult agricultural environment where lack of water for irrigation is a primary limitation, and they are reservoirs of valuable climate knowledge in an environment that lacks detailed and extensive meteorological data. This information is not perfect, as exaggerations and idealizations of previous climate patterns are possible. However, when farmer climate observations are combined with meteorological data, they are the best available tool to document climate change and to understand how these changes will most affect agriculture.

This chapter analyzes farmer *perceptions* of climate changes and how climate factors are ranked along with other agricultural challenges. Climate is a major driver of agricultural decision-making, but farmers and herders also face other challenges that may present more immediate threats. There is a paucity of research that looks specifically at how farmers themselves perceive climate changes within the context of development. Many development programs that focus on climate change adaptation and smallholder farmer vulnerability are often unsuccessful. These approaches often emphasize short-term benefits and pursue simple technological fixes without addressing the multiple factors that can interact with system resilience and the vulnerability of a population (Adger et al., 2011). More development programs are thus needed that better appreciate current farmer realities and the myriad of factors that force farmers to abandon smallholder agriculture.

This chapter also discusses farmer *awareness* of global climate change. Farmers reported a changing climate in the upper RIWS, but many were not aware of the larger global process that may be influencing these variations or had inaccurate knowledge of its origins. The lack of accurate knowledge may be a reason for low implementation of development projects. Educational programs on climate change origins, impacts, and adaptations are important tools to decrease vulnerability. Smallholder farmers are a critical resource to explain climate changes and to also develop successful adaptation plans. These farmers are an important resource that should be further consulted.

Study Area

The upper RIWS is an ideal environment to study farmer perceptions of climate change. There is a pressing need to study this region, as traditional agricultural techniques are being lost due to outmigration. This scale of analysis is across the upper RIWS, allowing for an understanding of how the effects of climate change can be seen, not just in one specific area, but across a transect that includes varying actors.

The mountainous environments within the RIWS have high climatic variability and uncertainty, and microclimates created by slope, aspect, elevation, and exposure can have different effects on water resources, agrobiodiversity, and native ecosystems (Pepin and Lundquist, 2008; Buytaert et al., 2010; Veteto, 2014). These extreme topographical variations often support high biodiversity, endemism, and microrefugia in both natural and agricultural systems (Zimmerer and Douches, 1991; Perrault-Archambault and Coomes, 2008; Dobrowski, 2011). Farmers have developed a corresponding mosaic of adaptive strategies for producing food and, particularly, strategies for managing water (Zimmerer, 1999).

I assessed farmer perceptions in two of three landscapes in the RIWS, one area between 1,700 and 4,000 meters above sea level (m.a.s.l.) is dominated by smallholders and another between 4,000 and 4,500 m.a.s.l. is composed of highland herders. The area below 1,700 m.a.s.l. is dominated by large-scale commercial production within the coastal region of Ica. This area is briefly discussed as the area where commercial farmers are often in conflict with smallholder farmers and herders over water resources. An analysis of the commercial farmer perceptions in the Ica valley is saved for future research.

The first landscape, between 1,700 and 4,000 m.a.s.l., is composed of smallholder farmers who grow a variety of cultivars that include alfalfa, potatoes, corn, wheat, barley, quinoa, and lima beans. Farmers also raise livestock that include cows, goats, and sheep. They produce predominantly for household consumption but also for the local and regional market in Ica. These smallholder farmers rely primarily on traditional Andean agricultural strategies that include pre-Inca terraces and canal irrigation to cultivate in a mountainous landscape. Within the study area, there is pronounced landscape variability, thus further classification is necessary. According to Pulgar Vidal (1987), who created a system that divided Peru's unique landscape into eight natural regions, the study area can be divided into three zones: *yunga*, *quechua*, and *suni*.

The first region, *yunga* (1,700-2,300 m.a.s.l.), is a semi-arid region that is characterized by year-round sun. There is low humidity during the day that increases at night. Average temperatures fluctuate between 20° and 27°C in the day with cool nights (Allende et al., 2012). Over a period of 10 years (2000-2010), average rainfall in the town of Challaca was 88.5 mm per year (Oria and Ovalos, 2013). Because of the warmer temperatures, farmers grow primarily alfalfa, beans, peas, and corn. The climate also permits cultivation of warm weather tree crops that include avocado, orange, *cherimoya*, and *lúcuma*. Cattle are the most important livestock, though farmers also care for goats and sheep. The *yunga* is located at the base of the Andes, and most fields have gradual slope gradients, therefore requiring less agricultural terracing than higher elevations.

Figure 2.1: View of Challaca and Acora in the *yunga* region.

Within the *quechua* (2,300-3500 m.a.s.l.), the average temperature fluctuates between 11° and 16°C, while maximum temperatures are between 22° and 29°C during summer months (September to April). Minimum temperatures over winter (May to August) fall between -4° and 7°C (Allende et al., 2012). Average precipitation in the population center of Tambo (3,080 m.a.s.l.) is 424 mm/year (Oria and Ovalos, 2013). It is the most productive region in the study area due to fertile soil and greater access to irrigation. Accordingly, most of the upper RIWS population is found here. Agricultural land in this region is dominated by alfalfa, a forage legume used to feed livestock. Other principal crops are wheat, barley, corn, potatoes, lima beans, and peas. This region has pronounced terraces that farmers use to cultivate along the steep canyon walls.

Figure 2.2: Terraced in Santiago de Chocorvos in the *quechua* region.

The final region within this first landscape is the *suni* (3,500-4,000 m.a.s.l; Figure 2.3). Average annual temperatures fluctuate between 7° and 10°C, maximum temperatures reach 20°C during summer, and minimum temperatures range from -1° to 16°C during winter. Precipitation, on average, is 800 mm per year, which is higher than the *quechua* (Allende et al., 2012). However, unlike the *quechua* region located along river canyons, the *suni* is found just below the *altiplano* and must rely on small mountain springs for irrigation (Allende et al., 2012). The primary crops in the *suni* include potatoes, barley, wheat, and, to a smaller extent, Andean tubers such as *oca*, *olluco*, and *mashua*. These crops flourish in the *suni* due to their frost resistance and low water needs. Natural pastures commonly serve as food for cows and sheep during the rainy season.

Figure 2.3: Agricultural fields in the *suni* region in Sangayaico.

The second landscape is located high in the Andean grasslands between 4,000 and 4,500 m.a.s.l. (Figure 2.4). This region is categorized as *puna*, and it has cold days and very cold nights. The average annual temperature is between 0° and 7°C, while maximum temperatures vary between 15° and 22°C during summer, and minimum temperatures during winter months can fall between -9° and -25°C. Precipitation fluctuates from 200 to

400, up to 1,000 mm per year (Allende et al., 2012). This high Andean environment is especially susceptible to climate changes (Gonzalez et al., 2010). The system of production is based almost exclusively on raising camelids (llamas and alpacas) and sheep. Herders rely on natural pastures that are rejuvenated in the rainy season. Freezes that fall during the coldest winter months threaten livestock health and prohibit traditional cultivation. Recent construction greenhouses now allow farmers to cultivate small gardens. These farmers are highly reliant on international prices of alpaca wool, their primary source of income.

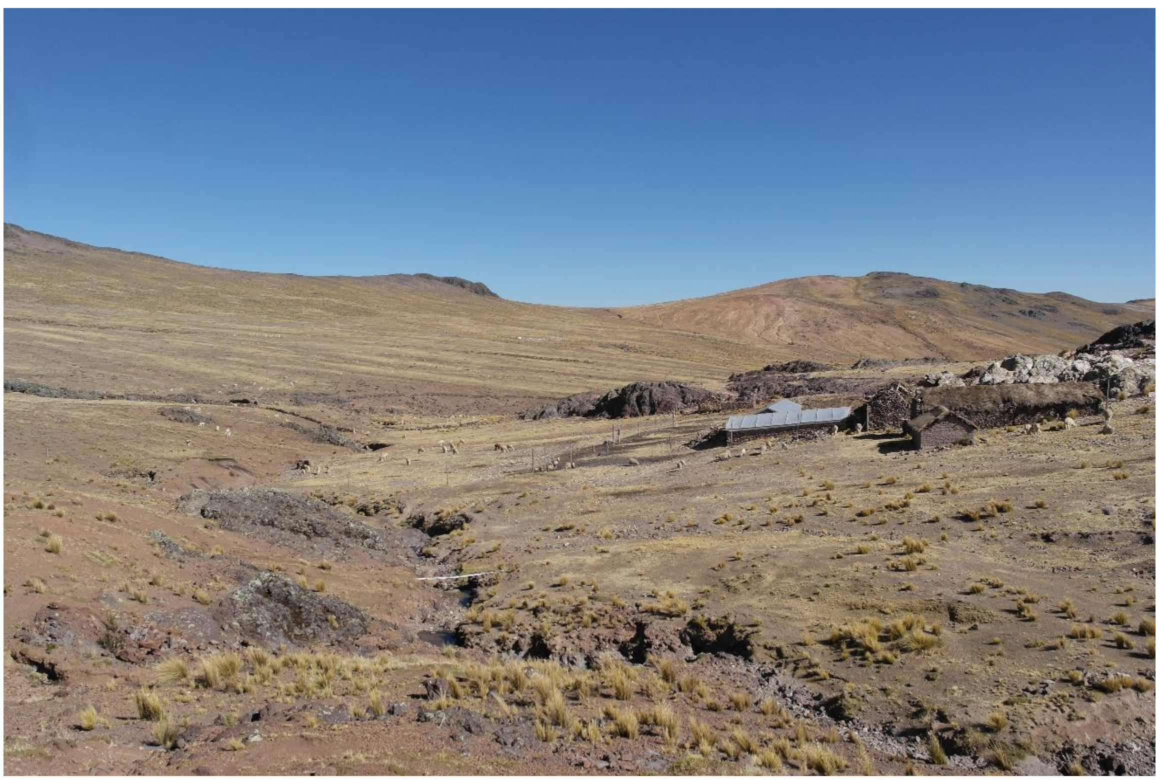

Figure 2.4: Alpacas and llamas in the *puna* region in Los Libertadores.

Methods

This project involved surveying 105 farmer surveys within the upper RIWS between 1,760 and 4,392 m.a.s.l. (Figure 2.5). The average age of farmers surveyed was 56 years old, with an age range of 23 to 86 years old. Whenever possible, I conducted surveys on the farmer's land to document their agricultural strategies and to mark each survey site with a GPS point. To create the surveys, I conducted 18 interviews with smallholder farmers in order to understand their agricultural challenges. The impetus of the surveys is to document how climate change impacts agriculture, farmer perceptions of agricultural challenges, and climate change awareness. The farmer surveys contain questions on the following climate topics: 1) precipitation trends by decade; 2) duration of frost susceptibility; 3) additional climate changes; 4) ranking of agricultural challenges; and 5) climate change awareness. Participants were given pictures and names of Peruvian presidents by decade to promote accuracy. As suggested by Thomas et al. (2007), the survey avoided the use of the words climate change whenever possible and saved all climate-centered questions until the end of the survey to avoid bias.

Population centers in the upper RIWS are small and remote; therefore, there are not enough potential respondents to apply a random sampling method. Moreover, a small number of farmers refused to speak with me. Based on these limitations, I began with a snowball sampling method where respondents are used to refer other respondents, a technique that is particularly advantageous in hard-to-reach, isolated populations (Atkinson and Flint, 2001). However, snowball sampling can create a selection bias that limits the validity of the sample (Van Meter, 1990). To decrease this sampling bias I also walked from field to field to survey farmers who would not otherwise be contacted through snowball sampling. I believe that this dual sampling method creates minimal bias and provides a data set that is representative of the population.

Farmer livelihoods are tied to climate, and they are consequently in a unique position to elucidate past temperature and precipitation fluctuations. However, recalling decadal trends from 30 to 40 years ago can be difficult and may favor past climate patterns as ideal conditions. In attempt to increase accuracy, I printed pictures of past Peruvian presidents by decade and provided them to farmers during the survey process to encourage accurate accounts. Farmers could then associate decadal climate patterns with the events of Peruvian presidents.

I also conducted semi-structured interviews with other actors in the RIWS. All interviews were recorded with the permission of the interviewee. This included seven interviews with development agents and 13 interviews with government officials to best understand what types of organization and support is provided to farmers. Men are generally responsible for agricultural decisions while women are in charge of the household and care for livestock. I recognized this unique perspective on environmental and agrarian change, so I also conducted 10 interviews with female leaders in the region.

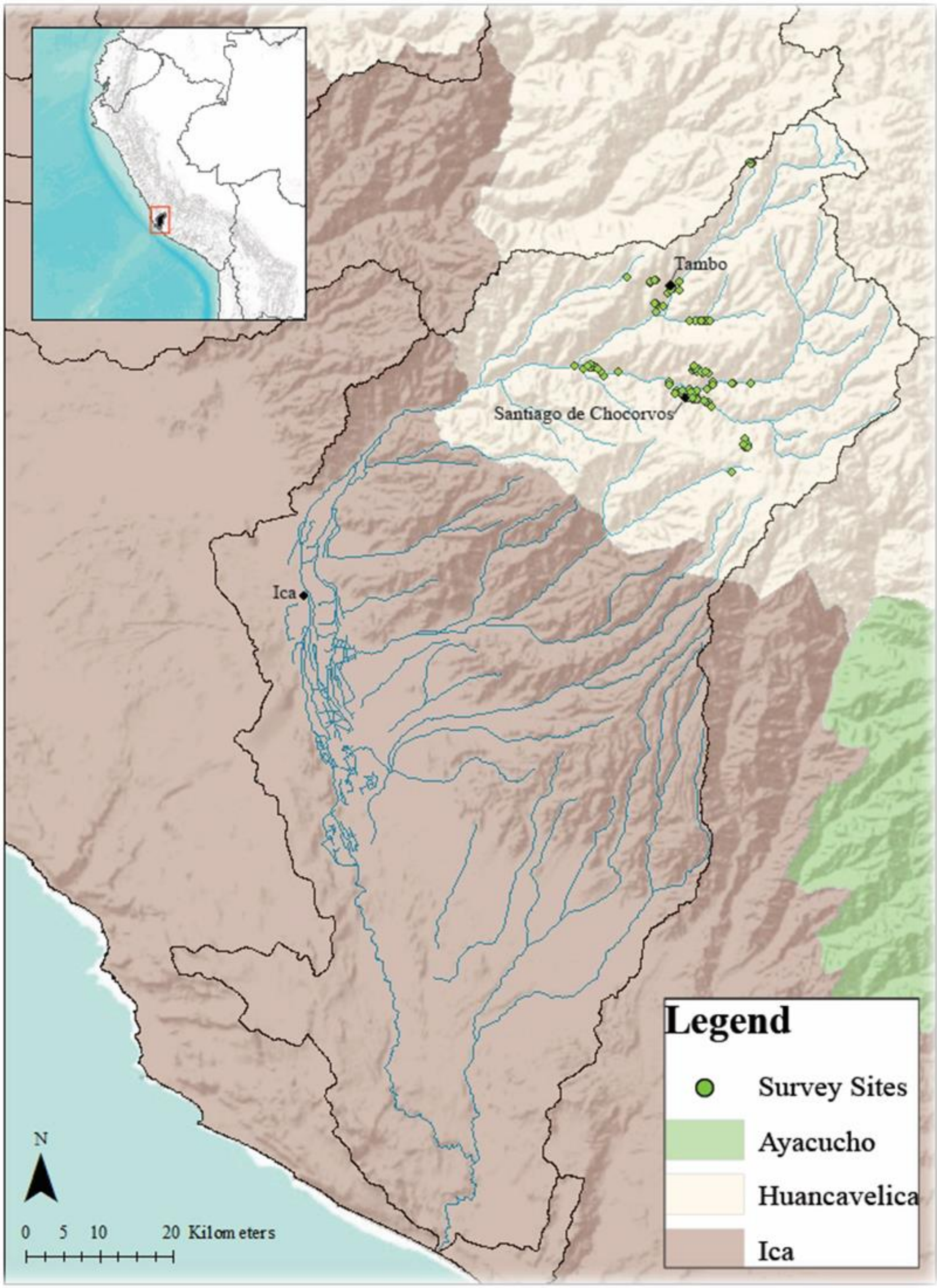

Figure 2.5: Map of farmer surveys within the Rio Ica watershed.

Meteorological Data

Andes Region

Climate data from 279 stations in the Andes between 1°N and 23°S show a 0.1°C per decade warming trend and an overall temperature increase of 0.68°C since 1939 (Vuille et al., 2008). From 1988 to 2008, only two years (1996 and 1999) were below the long-term (1961-90) average (Vuille et al. 2008). Changes in precipitation are less notable than changes in temperature and lack long term and high quality records. There is, nevertheless, a tendency for increased precipitation north of 11°S in Ecuador, and a decrease in Southern Peru along the Peru/Bolivia border (Haylock et al., 2006). These large models are useful to understand regional and global changes, but more research is needed to understand what climate change means on a smaller scale and how farmers perceive and respond to these changes.

Rio Ica Watershed

There are three primary weather stations run by the Servicio Nacional de Meteorologia e Hidrologia (SENAMHI) located in the RIWS with data from 1964 to the present. Each station represents a different climate region: San Camilo (398 m.a.s.l.) in the *costa*, Huamani (1,060 m.a.s.l.) in the *yunga*, and Tambo (3,113 m.a.s.l.) in the *quechua*. Unfortunately, the meteorological data available from the RIWS are incomplete. Insufficient resources for station maintenance, and conflicts during the 1980s and early 1990s, left major gaps in the meteorological record. There is no meteorological record from higher altitudes of the *suni* or *puna*. However, the available data can still illuminate precipitation and temperature trends within the watershed. Oria and Ovalos (2013), on behalf of SENAMHI, analyzed the available meteorological data and provide annual trends of temperature and precipitation, along with projections for the year 2030.

Determining precipitation trends is difficult due to its geographic scope, complex spatial distribution, differences in seasonal distribution, and interannual variability. Over a period of 48 years (1965-2012), the entire RIWS has shown a general trend of decreasing annual precipitation that increases with elevation (Table 2.1). In Huamaní and Tambo, the periods of consecutive days without rain increased over this period, while decreasing in San Camilo. The trend for the number of very wet days is negative in San Camilo and Huamaní, while they are positive in Tambo, meaning that higher elevations have experienced more extreme precipitation events (Oria and Ovalos, 2013). Unfortunately, there are insufficient data to provide annual trends for temperature minimum and maximum for Tambo, an area of focus for this project. Nevertheless, trends of warming in the lower and middle watershed at San Camilo and Huamaní indicate increases in both minimum and maximum temperatures (Table 2.1). The Huamaní weather station has a particularly robust data set, showing that cold nights are decreasing and warm nights are increasing with a high level of statistical significance. These results indicate a strong signal of nocturnal warming (Oria and Ovalos, 2013).

Table 2.1: Annual trends for precipitation and temperature (Oria and Ovalos, 2013).

	Precipitation (mm/decade)	**Maximum Temperature (C°/decade)**	**Minimum Temperature (C°/decade)**
San Camilo (398 m.a.s.l)	-1	+0.3	No Trend
Huamaní (1,060 m.a.s.l.)	-2.5	+0.1	+0.1
Tambo (3,113 m.a.s.l.)	-6.3	Insufficient Data	Insufficient Data

Oria and Ovalos (2013) also created temperature and precipitation projections for the year 2030 using the average of the four best-available global climate models. Precipitation percentages again decreased with elevation, up to 5.2% in Tambo by 2030 (Table 2.2). Temperature projections for San Camilo show the average maximum annual temperature will increase by 0.4°C and the average minimum annual temperature will increase by 0.3°C, whereas Huamaní will increase by 0.2°C.

Table 2.2: Average of four global models projections for 2030 (Oria and Ovalos, 2013).

	Precipitation Percentage	**Maximum Temperature (C°)**	**Minimum Temperature (C°)**
San Camilo (398 m.a.s.l.)	-2.6	+0.4	+0.3
Huamaní (1,060 m.a.s.l.)	-4.6	+0.2	+0.2
Tambo (3,113 m.a.s.l.)	-5.2	Insufficient Data	Insufficient Data

Farmer Observations

Data gathered from farmer surveys and interviews reveal rural people's observations of climate changes in the upper RIWS. Their responses disclose nuanced descriptions of climate variation of the rainy season duration and temperature fluctuations, and how these changes affected their agriculture.

Rainy Season

Precipitation in the RIWS is highly seasonal and diminishes with decreases in elevation. The average rainfall in the upper RIWS in Tambo (3,080 m.a.s.l.) (Oria and Ovalos, 2013), within the *quechua*, is 424 mm/year, while the city of Ica (325 m.a.s.l.), in the *costa,* a region of lower watershed, receives only 2 mm/year (Hepworth et al., 2010). Farmers depend on a consistent and predictable rainy season that historically began in December or January and lasted until April. Even small changes of when the rain arrives and with what intensity can lead to poor harvests and limit crop diversity. Farmers in the upper RIWS are accustomed to high climatic variability and have created complex irrigation and water management strategies that respond accordingly. Nearly all farmers depend on terraced agriculture that allows them to cultivate sloped fields and are designed to equally distribute water for irrigation. An intricate canal system taps water from the rivers below and distributes it above to the fields, thus providing irrigation nearly year-round. However, farmers routinely reported that water is often inadequate in November and December, as they wait for a recharge of the hydrologic cycle.

The farmer survey asked participants to describe the duration of the rainy season in the 1970s, 1980s, 1990s, and the present. I created the survey to comprehend general trends of precipitation, rather than specific values for each year, which can help buffer against strong singular year events such as El Niño. Farmers listed the month the rainy season began and ended. Point values were then assigned for the number of months listed (one month equals one point). Farmer responses were categorized by region to show how farmers experience climate changes at varying elevations (Table 2.1).

The *yunga* (1,700-2,300 m.a.s.l) is the warmest and driest region in the study area. Fifteen farmers were surveyed here. Farmers reported a shortened rainy season over the past 10 years (2004-2014) that lasts only 3.33 months, whereas previous rainy seasons (1970s to 1990s) persisted between 4.25 and 4.13 months on average. This represents a decrease of 28 days from the 1970s. Farmers stated that previous rainy seasons would begin in December and last until April, but now precipitation often does not begin until January or February.

The *quechua* is (2,300-3,500 m.a.s.l.) is drier and colder than the *yunga*. It has a larger population, and 71 surveys were conducted here. Farmers stated the current rainy season lasted only 3.52 months, but that previous rainy seasons were longer in duration between 4.51 and 4.43 months, a decrease of 30 days.

In the *suni* (3,500-4,000 m.a.s.l.), precipitation rates are higher and temperatures are colder. There are sparse populations and only 15 farmers were surveyed here. These farmers reported a longer rainy season than lower regions, but one that is also shortened.

Earlier rainy seasons were 4.8 months from the 1970s to the 1990s, but current rainy seasons now only last 3.71 months, a difference of 33 days in rainy season duration.

The *puna* (4,000-4,500 m.a.s.l.) is the coldest region that often has higher precipitation rates than the *suni*. It is also the most sparsely populated and comprised of isolated communities of camelid herders, thus only four herders were surveyed. They reported that previous rainy seasons were longer, 5.67 months in the 1970s, 5.75 months in the 1980s, and 5.75 in the 1990s. Currently, herders stated that the rainy season is much shorter, only 2.75 months. This is the largest change in the study area, amounting to an 88-day decrease from the 1970s. Herders in this region have minimal access to irrigation and rely heavily on native pastures that are rejuvenated during the rainy season.

Table 2.3: Farmer responses to the duration of the rainy season in months.

	Number of Respondents	**1970s**	**1980s**	**1990s**	**Present**
Yunga	15	4.25	4.13	4.13	3.33
Quechua	71	4.51	4.43	4.47	3.52
Suni	15	4.8	4.8	4.8	3.71
Puna	4	5.67	5.75	5.75	2.75

Respondents from the four regions all report a shortened rainy season. In further conversations on the changes in precipitation, the most common response was, “Now is not like before (*Ya no es como antes*)[2]." Farmers consistently replied that rain is less predictable. When it does arrive, it is torrential and difficult to manage. More intense and irregular rainfall degrades the soil, increases the likelihood of pests, and can decrease crop output. One farmer from Santa Rosa de Olaya, in the *quechua region*, expounded on the current unpredictability of precipitation by saying, "The rain varies more now and it is not natural. Before the rains were gentle but now they are stormy (*La lluvia varia mas ahora y no es natural. Antes era suavecita pero ahora es tempestada*)." Another farmer from Sangayaico, in the *suni*, spoke of how the rainy season was consistent and predictable when he was younger but now says, "Sometimes the rain does not come or it only comes for one month (*A veces la lluvia no viene o solo para un mes*)." Several farmers mentioned that before they had cultivated fields above their intricate irrigation canal system, relying exclusively on precipitation as a means of irrigation. Nearly all of these fields have fallen out of use as farmers reported that there is not enough rain to sustain them. In the annex of San Miguel de Curis in the *suni*, a farmer explained the change in precipitation patterns as follows:

> …I have noticed a lot of changes in the climate. The rain does not come during the normal season. Before, the rain was from December to March or April. Now, the rains come in January or February, but only temporarily. Sometimes the rains come as storms with hailstorms and flooding. This can flood the damage the fields and cause erosion.

[2] All quotations by farmers are translations done by the author.

> *...Si he notado bastante cambios del clima. Y la lluvia no da en su misma época. Antes la lluvia era de Diciembre hasta Marzo o Abril. Actualmente, viene Enero o Febrero pero temporalmente. Y algunas veces en forma tempestuosa con granizada y huaycos. Y ese pues se malogra la tierra. Erosiona la tierra.*

Reported observations of climate changes that include increased variability and timing shifts of precipitation patterns within the RIWS are consistent with other regions in Peru (Milan and Ho, 2013; Sperling et al., 2008) and with research in the Peru-Bolivia Altiplano (Boillat and Berkes, 2013; Postigo, 2014; Seth et al., 2010; Valdivia et al., 2010).

Temperature Fluctuations

During the surveys, farmers also reported temperature variation. In the upper RIWS, frosts fall primarily during May, June, July, and August. Frosts threaten crops, especially younger plants, and limit crop diversity at higher elevations. They can also harm young livestock. The farmer survey reported an increase in the total number of months when frosts occur. Farmers were asked to describe the duration of when frosts occur in the 1970s, 1980s, 1990s, and the present. Farmers listed the month that frosts began and ended, which was again translated into a number value. Farmer responses show an increase in frost duration, and frost is more pronounced at higher elevations (Table 2.2).

In the *yunga*, frosts are less common. Farmers reported the number of months when frosts transpire has increased slightly from an average of 1.58 in the 1970s, 1.86 months in the 1980s, and 1.79 in the 1990s. Presently, farmers reported 2 months of the year when frosts can occur, translating to a 13-day increase from the 1970s average.

In the *quechua*, frosts pose a larger threat to agriculture, but respondents did not show a significant change. Responses fluctuated between averages of 2.7 and 2.63 months from the 1970s to 1990s, and stated the current duration is 2.86 months. This is only a 5-day increase from 1970s values.

In the *suni*, frosts are more common. Farmers stated that previous frost susceptibility was 2.5 months from the 1970s to the 1990s, whereas it currently lasts 2.79 months. This is a 9-day increase from 1970s values.

Within the *puna*, the coldest area in the study site, frosts are a major threat. They can kill younger camelids, forcing farmers to adapt strategies to protect their animals. Herders stated that previous frost susceptibility lasted 3.5 months in the 1970s and 3.25 months during the 1980s and 1990s. Currently, herders stated that frosts threaten their animals for an average of 4.25 months, a 22-day increase from 1970s values.

Table 2.4: Farmer responses on the duration (in months) of when frosts pose a threat

	Number of Participants	**1970s**	**1980s**	**1990s**	**Present**
Yunga	15	1.58	1.86	1.79	2
Quechua	71	2.7	2.66	2.63	2.86
Suni	15	2.5	2.5	2.5	2.79
Puna	4	3.5	3.25	3.25	4.25

The results from the four regions portray increases in the duration of colder temperatures. Farmers consistently reported that frosts now can fall over a longer time period. In conversations with farmers and herders, they further described these climatic changes. One farmer from Santiago de Chocorvos in the *quechua* mentioned, "Before the climate was healthy, but now it can be cold during any time of the year (*Antes el clima era sano. Ahora puede ser frio en cualquier tiempo del año*)." When frosts became unpredictable and fall outside of their expected season, crops and livestock are at risk. Another farmer from Sangayaico spoke about the intensity of frosts and stated, "There is more variation in the frosts than before…the climate is more extreme (*Hay variaciones de las heladas mas que antes…un clima mas extremo*)."

After asking specific questions about the duration of frost events, farmers were asked, "Any other climate changes (*Otros cambios del clima*)?" Farmers were not prompted to discuss a particular focus of climatic variations but instead volunteered information on changes. Responses were grouped into four categories: 1) both increases and decreases in temperature; 2) colder temperatures; 3) warmer temperatures; and 4) no response on temperature (Table 2.3).

Within the *yunga*, only 1 farmer (6.6% of those surveyed) claimed that temperatures had both increased and decreased, 4 (26.7%) stated that temperatures had gotten colder, and 2 (13.3%) mentioned warmer temperatures. Eight farmers (53.3%) did not discuss temperature changes. In the *quechua*, 20 farmers (28.2%) stated that they noticed both colder and warmer temperatures, 21 (29.6%) claimed that temperatures had decreased, whereas 12 (16.9%) specified warmer changes. Eighteen (25.4%) did not respond on temperature values. In the *suni*, seven (46.7%) farmers said climate changes included colder and warmer temperatures, five (33.3%) claimed colder temperatures, and one farmer (6.7%) said that temperatures increased. Two (13.3%) did not state temperatures changes. Within the *puna*, two (50%) farmers said that temperatures had increased and decreased, and two (50%) claimed a decrease in temperature.

Table 2.5: Farmer responses on temperature variation.

	Number of Respondents	**More Extreme Temps.**	**Colder Temps.**	**Warmer Temps.**	**No Temp. Response**
Yunga	15	1	4	2	8
Quechua	71	20	21	12	18
Suni	15	7	5	1	2
Puna	4	2	2	0	0
Total	105	30	32	15	28

Farmer observations on temperature changes do not depict climate changes as a simple increase in temperature. Instead, most farmers reported temperature variation as either more extreme temperatures (colder and warmer temperatures) or colder temperatures. Thirty (28.6%) respondents described a more extreme climate that includes colder nighttime and warmer daytime temperatures. One farmer in Sangayaico stated simply, “The climate has changed. There is more cold and hot weather. (*El clima ha cambiado. Hay frio y mas calor*).” Another 32 (30.5%) respondents claimed that temperatures had decreased. A decrease in temperatures signifies that frosts occur more often and with a greater intensity. A farmer in the annex of Acora, in the *yunga*, stated, “It is colder than before and with more frosts (*Mas frio que antes. Mas heladas*).” Fifteen (14.3%) farmers elucidated on only warmer temperatures. One farmer from Santiago de Chocorvos explained the warming as, “The heat that we have now is like the coast. (*El calor que tenemos ahora es como la costa*).” Warmer temperatures in the upper RIWS may increase evapotranspiration rates, thus crops need more irrigation, but they appear to have a lesser impact than colder temperatures. Therefore, it may be possible that farmers under-represent warmer temperatures because there is less of an agricultural impact.

Regrettably, SENAMHI meteorological stations do not have sufficient temperature data from the upper RIWS to directly corroborate or contradict farmer observations on temperature trends. Meteorological data from the lower RIWS (San Camilo and Huamani) show a warming in nighttime temperatures (Oria and Ovalos, 2013). Reports of colder nighttime and warmer daytime temperatures are consistent with research changes due to shifts in evapotranspiration elsewhere in the Andes (Postigo, 2014; Sperling et al., 2008; Thibeault et al., 2010; Valdivia et al., 2010).

Farmer Perceptions of Climatic Change

Climate change is not the only challenge that affects farmers in the upper RIWS, as they deal with a range of "exogenous" factors (Brooks, 2003). I designed the farmer surveys to decipher which of these factors—climate included—present the largest challenge to livelihoods as perceived by farmers (Mertz et al., 2009). Participants were asked to choose their five greatest challenges from a list of factors and place them in order of severity. I created a list of the 11 most common response options that were generated from 18 primary farmer interviews to understand the main challenges that farmers face. The majority of the farmer survey focused on agricultural strategies, and when respondents asked for further clarification, I explained that they should provide responses that have an agricultural focus.

Farmer responses illustrated a clear pattern on the primary challenges to farmer livelihoods. Of the 105 farmers surveyed, 39 (37.1%) mentioned that a “lack of water” for irrigation was their primary concern, while 21 (20%) listed it as a secondary concern, and another 16 (15.2%) mentioned it as tertiary. There is a direct climate link as precipitation patterns have been less predictable and more torrential within the RIWS, but a lack of water can be mitigated in part through the application of more effective water management strategies. Most farmers have access to irrigation throughout the year and there is significant opportunity to increase efficiency. Farmers have the ability to increase water storage capacity and improve irrigation infrastructure so that less water is lost during transport. In addition, farmers also have access to different crops with varying irrigation needs and can rely on crops and varieties that have less irrigation requirements.

Table: 2.6: Farmer survey responses to their primary challenges and concerns.

	1st	2nd	3rd	4th	5th
Lack of Water	39	21	16	11	1
Kikuyu	37	9	20	13	8
Agricultural Pests	8	29	25	22	8
Lack of Manual Labor	8	13	6	10	8
Lack of Organization	5	13	17	10	7
Frosts	4	8	11	13	4
Low Market Prices	2	5	5	6	4
Seeds Do Not Produce	2	2	2	5	3
Lack of Mobility	0	0	1	4	2
Erosion	0	0	1	2	4
High Temperatures	0	0	1	1	1

Another concern for farmers was kikuyu (*Pennisetum clandestinum),* an invasive grass. Thirty-seven (35.2%) of the farmers stated that kikuyu was their primary agricultural concern. Another nine (8.6%) stated it as their secondary concern, and 20 (19%) as their tertiary concern. Kikuyu is highly invasive and is nearly devoid of nutrients. It invades agricultural fields and chokes out alfalfa, the primary forage crop for livestock, along with other vegetation. It is difficult to remove, and farmers generally rely on a combination of manual labor and harsh herbicides to extract it from their fields. Kikuyu is most common at lower elevations (below 3,800 m.a.s.l.) with greater access to water and warmer temperatures. How kikuyu arrived in the upper RIWS is unknown, though it is believed that farmers brought it into the region roughly 30 to 40 years ago as a new forage crop. Kikuyu is not directly caused by climate change. However, some research suggests that because it is a C4 plant, typically adapted to lower elevations that are drier and hotter, the climate change impacts of warmer temperatures and less precipitation may increase its growth at higher elevations (Giraldo-Cañas, 2010; Hernández et al. 2012). Its presence exacerbates existing stressors on farmers who are already marginalized, increasing their vulnerability.

The third primary challenge to agriculture was “agricultural pests”, with eight (7.6%) farmers responding. As a secondary challenge, 29 (27.6%) farmers claimed it affected them and 25 (23.8%) stated it as a tertiary concern. The appearance of new agricultural pests has been blamed on climate change and variability, but there is some doubt if climate change is the actual culprit (Kronik and Verner, 2010). Climate variability may weaken crops and make them more vulnerable to pests. The increase may also stem from the inadvertent introduction of new seeds from local fairs, development agencies, or regional markets. Agricultural pests that farmers reported included aphids, mites, grasshoppers, and moths. Regardless of the cause, over the last 20 years farmers reported a significant increase and have had to apply chemical pesticides to maintain productive harvests. Many of these products are highly toxic and may expose farmers to health risks if they are not properly handled. Chemical pesticides are an expensive capital input that many farmers cannot afford, leaving them more vulnerable.

The fourth farmer challenge was the “lack of manual labor”, as eight (7.6%) of the farmers stated this factor as their primary limitation. Another 13 (11.4%) saw a “lack of manual labor” as a secondary challenge, and six (5.7%) stated it as tertiary. Sufficient manual labor is vital during planting, harvesting, and maintenance of irrigation infrastructure. All farmers that pull water from a specific irrigation canal are responsible for its routine maintenance. Traditionally, farmers relied on an Inca communal custom known as a *faena* and worked together to clean out the canal, typically twice a year. With less available manual labor, the intricate and fragile irrigation networks are at risk of failure. *Faenas* are also used for the removal of kikuyu, as farmers work together with pick axes and shovels to remove the invasive grass from agricultural fields. Rural to urban migration is the primary reason for the lack of manual labor in the upper RIWS and throughout Peru. Export agriculture surrounding the city of Ica provides a plentitude of wage-labor jobs, so that farmers that migrate are generally guaranteed employment.

A "lack of organization" was fifth, and five farmers (4.8%) listed it as their primary challenge. Another 13 (12.3%) stated it as a secondary issue and 17 (16.2%) said that it was tertiary. Many of the farmers within the upper RIWS rely on a portion of income from selling agricultural products to the region of Ica, but many of their activities are not organized, and it is problematic competing in the regional market. Many farmers lamented that goods sold in the regional market in Ica—primarily dairy products—regularly received a much lower price than comparable products, and that they could barely cover their costs. There are several NGOs and government agencies that have worked with farmers to increase efficiency and help them demand a higher price for their goods. These development agencies are looking to increase efficiency through the centralization and modernization of dairy production.

Other farmers reported "frosts" as a problem. Four (3.8%) farmers stated frosts as a primary concern, while eight (7.6%) said that it was a secondary concern, and 11 (10.5%) considered it a tertiary concern. Frosts are most common at higher elevations (above 3,000 m.a.s.l.). Farmers reported that climate changes have made them stronger.

Several other responses received minimal support. “Low market prices” affects both farmers and herders that are attempting to sell their products to the regional market. Highland alpaca herders are especially vulnerable, as the majority of their income comes from selling alpaca wool, which can fluctuate significantly in price due to a variety of international pressures. Another minor response was that “seeds do not produce.” Farmers in the upper RIWS rely primarily on traditional Andean cultivars but are now experimenting with more hybrid varietals. Farmers further reported issues with seed germination. The last three responses, “lack of mobility,” “erosion,” and “high temperatures” all commanded some responses, though none were listed as a primary concern or challenge.

Farmer responses show that the primary concerns that affect farmer livelihoods in order of severity are “lack of water,” “kikuyu,” “agricultural pests,” “lack of manual labor,” and “lack of organization.” Of these primary concerns, only “lack of water” appears to share a direct connection to climate changes. Many of these challenges have existed for centuries with climate changes only intensifying their effects. The upper RIWS is an arid region, and farmers are accustomed to insufficient irrigation. Farmers in the area have developed irrigation strategies that siphon off water from the rivers and mountain springs. Frosts have also always been an issue, particularly at higher elevations, as an early frost can kill or damage crops. Climate changes appear to be stressing water usage. Climate factors do have major impacts on agriculture, but there are also a variety of other stressors that impact farmer decision-making.

Awareness of Global Climate Change

During the early stages of interviews and fieldwork, I discovered that many farmers had only a minimal understanding of global climate change. Farmers consistently mentioned that recent climate variations had negative effects on their livelihoods but did not comprehend the larger climate forces that may be playing a role in the variation of temperature and precipitation patterns. One of the last questions of the farmer survey asked, "What does global climate change mean (*Que significa el cambio climatico*)?" The responses varied, but they follow several general trends. I grouped the responses into 14 general categories (Table 2.5).

Of the 105 farmers surveyed, 35 (33.3%) stated that they had never heard of the term global climate change. Nearly all of these farmers reported changes in precipitation and temperature, but when asked about larger global climate forces, they stated that they had not heard of them.

Table 2.7: Categorized responses of farmer awareness of climate change.

Response	**Number of Responses**
Never heard of climate change	35
Higher temperatures	18
"Now is not like before"	12
Higher and colder temperatures	10
Caused by pollution	10
Change in the climate	5
Colder temperatures	3
Directly related to hole in ozone layer	3
Heard about it	3
Drought	2
"Climate always changes"	1
Eclipse	1
Agricultural pests	1
El Niño	1

Another 18 (17.1%) farmers said that climate change signifies warmer temperatures. Several of these farmers mentioned that warmer temperatures cause a "loss of glaciers (*perdido de glacieres*)" and the "melting of the poles (*la descongelacion de los polos*)." This knowledge is illuminating, as there are no glaciers within the RIWS. Farmers must have learned this information from outside sources. Others saw evidence of the warming in their agriculture, particularly in the dissipation of their irrigation canals.

An additional 12 farmers (11.4%) mentioned that climate change signifies that "The climate is not like before (*[El clima] ya no es como antes*)." This was a common sentiment among farmers, acknowledging that there have been significant climate changes, but they were not able to expand on a connection to global climate change.

Ten farmers (9.5%) said that climate change means both colder and also warmer temperatures. One farmer said, “It is a change of the climate. There are cold days and warm days (*Es cambio del clima. Hay días con calor y dias con frio*).” For this specific farmer, climate change did not just portray a warmer environment but greater temperature variation. This response appears to be close to the reality of climate changes within the upper RIWS, as farmers and meteorological data both report greater temperature variation.

Additional farmers did not state the effects of climate change, but instead mentioned what they believed was the cause. Ten (9.5 %) of the respondents claimed that climate change was caused by anthropogenic pollution. One respondent stated, “The fault is with man and the big industries, which produce a lot of smoke in countries that have manufacturing (*Culpa del hombre y los avances de los grandes industrias. Producen bastante humo. Paises que manufacturan*).” Many of the other respondents answered correspondingly and believed that the culpability of climate change belonged to industrialized nations. They did not blame Peru’s own greenhouse gas emissions, which are minimal in comparison to larger developed countries. Instead, the farmers saw Peru as unfairly disadvantaged. Some respondents believe climate change was the direct effect of “atomic bombs and wars (*Las bombas atomicas y las guerras*).” These responses show that some of the farmers do understand that industrialized countries principally cause climate change, even if they assigned blame erroneously. There is also a clear frustration and distrust among these farmers that another external influence, created by foreign powers, was affecting their agriculture.

Five farmers (4.7%) simply listed that climate change indicated climate variation. They gave no reference to the specifics of variation.

Three farmers (2.9%) believed climate change is directly related to the depletion of the ozone layer. Another six farmers mentioned the ozone layer as an auxiliary response, which leaves a total of nine farmers (8.6%) surveyed that believed climate changes were connected to the depletion of the ozone layer. One farmer characterized this sentiment, "[Climate change] is caused by holes in the ozone layer in the atmosphere and the sun's rays pass through, which causes global warming (*[Cambio climático] produciendo por lo que la capa de ozona que protege la atmosfera tiene huecos en el espacio donde pasa los rayos. Produciendo el calentamiento global*)." Such responses are informative, as they show that participants have access to scientific knowledge, even if some of that information may be outdated. It may also signify that information on the causes of climate change is slow in making its way into the community.

Other farmer responses were less common. Several farmers believed that climate change was related to drought, and others stated that they had heard of it before but were unable to provide further details. A smaller number of farmers stated that the climate always changes, was tied to El Niño or the eclipse, or leads to an increase in agricultural pests.

The responses illustrated that many farmers do have a basic understanding of the significance of climate change, even if they lack specific knowledge on how climate change has and will continue to affect agriculture in the upper RIWS. There is an understanding that the climate in the RIWS is changing, and that it may be unlikely that the climate will return to what many farmers were accustomed to in earlier decades. However, the climate change is often seen as a global-scale problem that may not resonate with smallholder farmers in the upper RIWS, whose values are more associated with traditional and ethnocentric worldviews. An emphasis on global climate change may contribute to antagonism and cognitive dissonance (Adger et al., 2013).

At the request of several school administrators, I led six workshops on climate change to over 200 people (Figure 2.6). These talks explained the basics of climate change science, how it will continue to impact them and will likely increase, and what possible adaptation strategies exist for the upper RIWS. The majority of these talks were conducted for students with the realization that climate change will have the largest effect on the youngest generation, and that they will be responsible for developing adaptation solutions. Accurate knowledge of climate change is the single strongest predictor a person will engage in a given behavior (Bord et al., 2000). Therefore, farmers who are aware of climate change, and have accurate knowledge of its origins and impact, are more likely to use more sustainable agricultural strategies that will have long-term success.

Figure 2.6: Climate change workshop in San Miguel de Curis.

Discussion

Data from meteorological stations in the RIWS and farmer observations from surveys and interviews both describe a changing climate. The meteorological data are illuminating and helpful for development agencies to plan long-term, sustainable agricultural projects. However, the data lack the necessary temporal resolution and have minimal coverage in the upper RIWS. Therefore, it is of marginal use to the typical farmer, who likely does not have access. SENAMHI views their data as proprietary, and it is only available at a cost. The distribution and intensity of precipitation is more important than annual or seasonal precipitation trends. Extreme precipitation events that are followed by long periods of drought averages out to a “normal” precipitation year but can be devastating to farmers. Knowledge of when the rainy season begins would help farmers save irrigation sources until the rains arrive. Projections that show decadal trends in precipitation may not be as useful to individual farmers, although it may encourage the construction of more efficient irrigation infrastructure or other long-term projects on larger scale. More meteorological stations are needed in the upper RIWS, along with higher resolution data, that shows not only annual and seasonal changes but provides more accurate information on the duration of the rainy season and monthly temperature minimums and maximums. This quantitative meteorological data, when combined with farmer knowledge and perceptions of climate changes, can provide useful data for planning agricultural adaptations to climate change.

Farmer observations of climate change are an important tool to help understand climate changes, even if farmers may exaggerate climate changes or romanticize a better agricultural climate in the past. It is also difficult to ascertain if climate variation that farmers report is in fact caused by global climate change. When looking at mostly qualitative data, accuracy is important, but complete accuracy is an impossible expectation. However, farmer climate observations do help fill gaps in the meteorological record and inform our understanding of how climate impacts agriculture. Meteorological data in the upper RIWS provides daily readings of precipitation rate and temperature minimum and maximums. Though this information can be illuminating, it is missing years of data and does not give other important values that include hourly temperature and precipitation. The meteorological data is only available from three stations, leaving the vast majority of the RIWS without a climate record. In addition, farmer observations help understand how climate factors impact agriculture. When discussing climate changes, farmers described impacts on agriculture such as irrigation limitations from a shorter rainy season and erosion caused by extreme precipitation events. Meteorological data, combined with farmer perceptions, creates a robust climate understanding.

Furthermore, farmer surveys and interview data reveal that climate forces are one of many challenges that face smallholders. There are a variety of additional external forces that affect farmers; therefore, programs aimed at reducing vulnerability to climate change should support farmers against a variety of challenges. Of the top five farmer concerns (lack of water, kikuyu, agricultural pests, lack of manual labor, and lack of organization), only lack of water has a direct climate connection. Although, there is some research that suggests that both kikuyu and other agricultural pests are worsened under climate change (Giraldo-Cañas, 2010; Hernández et al., 2012; Kronik and Verner, 2010). Lack of organization and lack of manual labor are both tied primarily to migration. The younger generation does not have significant career opportunities and most leave for Peru's coastal cities. Farmer vulnerability is influenced by an array of factors that include the effects of globalization (market prices, increased outmigration). Comprehending the variety of factors that increase vulnerability and how farmers perceive them is crucial to developing development programs that strengthen farmers' abilities to respond to change.

Climate change is a problem of great importance. However, because it is viewed holistically with concern for climate feedback, human systems, and ecosystems, there is a large amount of uncertainty and a plurality of legitimate perspectives (Etkin and Ho, 2007). Such a complex problem is difficult to explain, which is one reason why only 70 (67%) of the farmers surveyed had heard of climate change, and many had inaccurate knowledge of its origins and impacts. Increased education programs may help farmers understand basic climate change science and increase the implementation of development programs designed to increase adaptive capacity. Weber (2010) suggests that "attention-catching and emotionally-engaging information" may be required to provoke necessary individual action in response to climate change. The impact of climate change needs to be tailored to each community, highlighting the importance of understanding farmer perceptions, additional agricultural stressors, and their specific development needs. It is also crucial to resist over-exaggerating climate impacts or scaring farmers into action, as this may have unintended negative consequences and increase inaction (Weber, 2010). Most farmers cultivating in the upper RIWS are older (average age of 56) and are less likely to be affected by the more severe impacts of climate change or implement adaptation strategies that fundamentally change their agriculture. Therefore, many of the burdens of benefits of risk reduction through adaptation will instead fall on future generations.

Conclusion

Farmer observations of climate change are a critical component to understanding its impacts the implementation of adaptation strategies. In the upper RIWS, and throughout similarly inaccessible mountainous regions in Peru and the world, there is a dearth of modern meteorological equipment, limiting comprehension of climate change and its impacts. Farmers in these regions are highly attuned to climate changes, and their observations appear to match the limited meteorological data on precipitation rates: both show a decrease. Temperature data is less clear. Meteorological data and farmer observations both reported daytime warming but differed in regards to nighttime temperatures. Meteorological data from the lower watershed reported nighttime warming, while most farmers in the upper watershed said that there was a decrease in nighttime temperatures and an increase in the duration of frost susceptibility. These climatic variations are not simply isolated to the upper RIWS, but can also be found in similar regions in Peru and the Peru-Bolivia *altiplano* (Boillat and Berkes, 2013; Postigo, 2014; Seth et al., 2010; Valdivia et al., 2010). The available data in the upper RIWS shows climatic variation over the last 40 years in the RIWS that appears to be tied to global climate change.

More meteorological data that cover all regions in the upper RIWS are needed. Farmers would benefit from a greater knowledge of meteorological data, especially if this data can help forecast the beginning and end of the rainy or frost intensity and duration. Both sources of data, quantitative meteorological data from SENAMHI and more qualitative explanations of climate from farmers, are vital to understand climate change and its impacts. Most importantly, the data can also provide knowledge on how to best respond effectively, especially when understood within the context of “traditional” agricultural strategies.

More research is needed on how climate change falls into the larger context of farmer vulnerability and resilience. Development strategies must be implemented to help farmers adapt to climate changes, but they must also recognize the concatenation of factors that negatively impacts agriculture. Farmers in the upper RIWS face a “double exposure” of both climate change and globalization pressures (O’Brien and Leichenko, 2008). Climate changes are not the sole—or possibly even the primary—cause of field abandonment and outmigration, though they do appear to be an additional factor. This creates a positive feedback cycle where rural, poor, mountainous communities become increasingly isolated, marginalized, and their livelihoods vulnerable to major impacts from relatively small events. Policy implications show that development programs should be flexible instead of looking directly at climate change solutions.

Education programs are vital to show the connection between climatic variation in the upper RIWS and global climate change. The knowledge that temperature and precipitation patterns in the upper RIWS are unlikely to return to previous “normal” conditions and are expected to worsen may encourage farmers to apply strategies that adapt to current and future climate changes. Agricultural adaptation programs will aid in coping with current climatic variation but also work as “anticipatory adaptations” that may be even more effective under future, more extreme climate patterns. The knowledge that future climate changes will bring more challenging agriculture environment information may inspire an older generation of farmers to implement adaptation strategies into their traditional agricultural methods. However, most of the worst impacts of climate change will be felt by the younger generation. Therefore, education programs will have the greatest impact when conducted in schools and with younger farmers.

CHAPTER THREE

Ancient Wisdom and Modern Technology: Agricultural Adaptations to a Changing Climate

Abstract

Agricultural strategies that adapt to changing climatic conditions are needed in order to maintain food security. In the upper Rio Ica Watershed, decreased precipitation and increased temperature extremes have reduced agricultural production. This chapter provides a typology of agricultural responses used by farmers to increase their resiliency to climate change. Many "traditional" Andean agricultural strategies are inherently adaptable to climate changes, but farmers also rely on modern additions. Semi-structured interviews and surveys form the core methodology to understand how farmers respond. Survey and interview results show that the significant environmental and cultural changes require agricultural strategies that rely on a plethora of tools, both modern and traditional. Adaptation strategies do not have be climate-focused but instead work to increase farmer resiliency so that they are more prepared to deal with climate change.

Introduction

Climate change is a pressing environmental challenge that demands adaptation, particularly in agriculture. As temperatures rise, global climate patterns become less predictable and impact agriculture through crop phenology, water availability, and soil productivity (Parry, 2007). Climate change is directly linked to decreasing agricultural yields and, as a result of such, to declining incomes, which affect food purchases, lead to an unstable food supply, and decrease dietary diversity (Hoddinott and Yohannes, 2002; Ortiz et al. 2008; Leichenko and O'Brien, 2008). Without sustainable, long-term agricultural strategies that adapt to climate fluctuations, there is a significant risk of a decrease in food production and an increase in food prices. For vulnerable populations, even small changes in prices and agricultural production can have severe consequences on food security. Therefore, to ensure the security of food resources for vulnerable populations, agricultural strategies adaptable to climate change must be better understood.

Peru is especially vulnerable to climate change because of its fragile Andean ecosystems and a population in which 28% live in poverty (INEI, 2012). To guarantee reliable food systems in Peru, it is crucial to understand regional agricultural strategies that can adjust to variations in climate change and the role that governmental and non-governmental policies play in facilitating these strategies. This chapter documents and compares agricultural adaptions that counter the effects of climate change within the upper Rio Ica watershed (RIWS) of southeastern Peru, while also considering other forces that have a negative effect on farmers, including low market prices, invasive species, and migration. The focus of this study is on smallholder farmers and herders in the upper RIWS who are vulnerable to the effects of climate change because they have limited access to resources and depend primarily on what they grow for sustenance. Smallholder farmers and herders reduce their vulnerability by applying a range of long-standing agricultural methods that have been adapted to climatic variability over centuries and new modern agricultural additions. Understanding how these agricultural methods are implemented will provide critical insights into climate change adaptation.

Numerous studies have focused on either subsistence farmers in one locale or on one farming system (Knapp, 1982; Knapp, 1991; Erickson, 1992; Glaser et al., 2000). What is needed is research that documents how a diversity of farmers share the resources of a watershed and collectively respond to climate change. No farming system operates in isolation. Farmers across a watershed all vie for access to the same water for irrigation and are exposed to similar market forces and pest problems, just to name a few. The mountainous topography of the upper RIWS produces varied agricultural strategies, and by analyzing this scale, research can uncover patterns of how farmers and development agencies develop adaptation strategies to climate change.

Studies on Andean farmer innovation and their unique agricultural strategies are not novel. There is myriad research that looks at how Andean farmers adapt to a difficult agricultural environment by making use of a variety of microclimates (Murra, 1968; Zimmerer, 1999) and by constructing canal and terrace systems to adapt to the mountainous topography and arid climates (Knapp, 1991; Sandor and Eash, 1997). This project examines Andean agriculture through the lens of global climate change to better understand which of these traditional agricultural strategies flourish amid climatic variation while also meshing with other changes in the agricultural landscape. The few studies that do emphasize the effects of climate change on agriculture in Peru concentrate predominantly on glacial melt and irrigation (Mark et al., 2010; Postigo, 2012). The RIWS has no glaciers, thus making it an ideal place to study water-fragile agricultural systems.

Significantly, there is also a paucity of research on the implementation of agricultural adaptations to climate change. A substantial amount of research on climate change adaptation emphasizes the conceptual theories and practices of adaptation and vulnerability (Füssel and Klein, 2006; Smit and Wandel, 2006). Research on the theories on adaptation and vulnerability is important, but there is also a need to understand the most effective and sustainable adaptation strategies and whether or not farmers will actually use them. Compounding this situation, much of the indigenous knowledge of adaptation strategies is not well documented in the scientific literature and is in danger of being lost, if it has not been already. As the negative impacts of climate change increase, there is a heightened need for innovative research strategies to determine the effects of climate change on the environment and agriculture and to implement climate-smart agricultural strategies that are also applicable to a variety of other twenty-first century agricultural challenges. Using a collection of agricultural strategies (e.g. biodiversity of crops, efficient irrigation management, and pest control) farmers will have more options thus making them less vulnerable.

This study borrows from an adaptation-vulnerability approach that emphasizes the socio-economic context in which adaptation must occur (Richardson et al., 2011). It recognizes the nature of the institutional, cultural, equity, economic, social and governance that helps to define vulnerability, along with the range of external factors that affect people's livelihoods and well-being. Within the vulnerability approach, climate change is seen as an additional external factor that interacts with existing stressors rather than impacting in isolation (Richardson et al., 2011). Thus it can often be difficult to separate climate change adaptation decisions or actions from actions triggered by other social or economic events (Adger et al., 2003).

Adaptation can manifest itself in ways that are not immediately recognizable as tied to climate change. I use the definition from Smit and Wandel (2006; p. 282) that describes adaptation as a "process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity." Adaptation can be conducted through market exchanges (Smit et al., 2000), the extension of social networks, (Adger et al., 2003), or through actions of individuals or organizations to meet their own individual or collective goals.

This dissertation also employs the concept of resiliency. Resiliency is closely related to the vulnerability approach because the aim of building resilience is to reduce vulnerability. A benefit of using resiliency in conjunction with the vulnerability approach is that it is not dependent on climate change projections. Building resilience prepares societies to deal with a range of climate futures (Richardson et al., 2011).

To better understand the wide variety of adaptations to climate change within the upper RIWS, I applied a typology from Smit and Skinner (2002) to characterize agricultural adaptation strategies. It is intended to provide order to these adaptation options, showing both the forms that these adaptations can take along with the stakeholder and decisions processes involved. This chapter does not, however, attempt to recommend or prescribe specific adaptations.

Study Area

The upper RIWS has experienced recent climate changes through greater temperature fluctuations and a shorter rainy season. Such changes are exacerbated by agriculture challenges like invasive species and volatile market prices. The adaptive strategies adopted by farmers in the watershed offer climate-smart solutions, but rural to urban migration is facilitating their erosion and threatens their documentation. The need to capture the farmers' adaptive strategies to climate changes make the RIWS an ideal environment of study.

The watershed scale analysis allows for an understanding of how the effects of climate change can be seen, not just in one specific area, but across different actors throughout the watershed. I conducted research on a transect that extends from export agriculture in the lower, coastal Ica valley to alpaca and llama herding in the high Andean grassland across 10 population centers (Figure 3.1). The climate within the RIWS is moderated by the cold Humboldt Current, the steep relief of the Cordillera de los Andes, and the South Pacific Anticyclone. The climate transitions from the highly arid coast to the moist *altiplano*.

This highly diverse landscape results in a range of adaptive strategies and challenges. The mountainous environments within the RIWS demonstrate high climatic variability and uncertainty on both spatial and temporal scales, and microclimates created by slope, aspect, elevation, and exposure can have differential effects on water resources, agrobiodiversity, and native ecosystems (Pepin and Lundquist, 2008; Buytaert et al., 2010; Veteto, 2014). This extreme topographical variation often supports high biodiversity, endemism, and microrefugia in both natural and agricultural systems (Zimmerer and Douches, 1991; Perrault-Archambault and Coomes, 2008; Dobrowski, 2011). Farmers have developed a corresponding mosaic of adaptive strategies for producing food and, particularly, strategies for managing water (Zimmerer, 1999).

For this project, I documented the agricultural techniques in two of three landscapes in the RIWS, one area between 1,700 and 4,000 m.a.s.l. dominated by smallholders, and another between 4,000 and 4,500 m.a.s.l. that is composed of highland herders. The area below 1,700 m.a.s.l. is dominated by large-scale commercial production within the coastal region of Ica and is briefly discussed below as the commercial farmers are often in conflict with smallholder farmers and herders over water resources. A more significant analysis of the commercial production in the Ica valley will be saved for future research.

(1) Smallholder agriculture: The first landscape is located between 1,700 and 4,000 m.a.s.l. Smallholder farmers in this landscape grow primarily alfalfa, an introduced species of forage legume used as a feedstock for the cows, sheep, and goats. These smallholders also grow a variety of cultivars that include potatoes, corn, wheat, barley, lima beans, and quinoa. They produce predominantly for household consumption but also for the local and regional market in Ica and rely largely on traditional Andean agricultural strategies that include pre-Inca terraces and canal irrigation to cultivate in a semi-arid, mountainous landscape. They apply a variety of alternative political and social organizational strategies to gain access to different ecological zones (Murra, 1968). By investing in several ecological zones, Andean farmers take advantage of each but also protect themselves against crop failure. They have knowledge of a variety of crops that grow best at specific altitudes and climate variations, making farmers more resilient to modern climate change. Significantly, climate change is not the only factor that affects their agriculture, which is also altered by migration, market prices, and an invasive species of grass known as kikuyu.

(2) Highland herding: The second landscape is located high in the Andean grasslands between 4,000 and 4,500 m.a.s.l. There, highland herders raise alpacas and llamas in a high Andean environment that is especially susceptible to climate changes

(Gonzalez et al., 2010). Agriculture is limited at this altitude, so alpaca and llama herders rely on trade with farmers at lower altitudes.

Additionally, disparities in wealth between the regions of Ica and Huancavelica further complicate the agricultural adaptations, as Ica is one of the wealthiest regions in Peru and Huancavelica is one of the poorest. This has caused significant migration from Huancavelica and a loss of agricultural knowledge. Many farmers from Huancavelica migrate to city of Ica where large-scale cultivation is the primary form of agriculture and a major employer. Peruvian and international corporations fund this export agriculture and spend millions of dollars on water from deep wells in Ica and from the highlands. The two regions have had continuous conflicts over water resources that likely will continue, as they are further stressed by climate change. This socioeconomic context, along with a challenging agricultural landscape, necessitates a research methodology that reveals adaptation strategies by speaking directly with farmers.

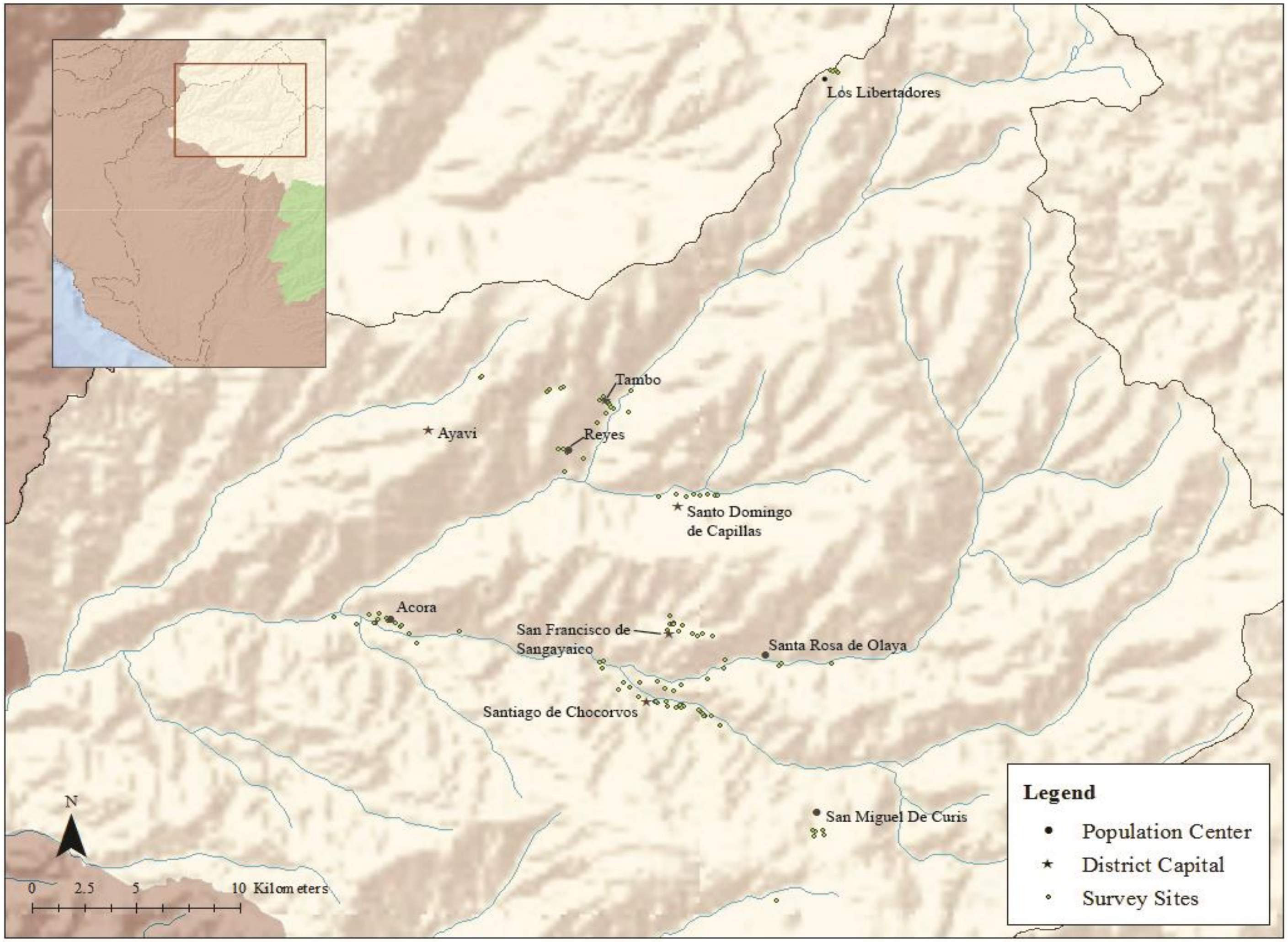

Figure 3.1: Map of surveys sites and population centers within the upper Rio Ica watershed

Methods

This project conducted 105 surveys within the RIWS between 1,760 and 4,392 m.a.s.l. The majority of the farmers were male as they are primarily responsible for agricultural management. The average age of farmers surveyed was 56 years old with an age range of 23 to 86 years old. Whenever possible, I conducted surveys at the farmer's land to document their agricultural strategies and to mark each survey site with a GPS point. A section of survey questions was directed at understanding current agricultural strategies (irrigation, pest control, seed varieties, fertilizers, etc.) and also how they had evolved within a changing environment. These questions built on the farmer observations and perceptions of climate change from chapter two.

Farmers within the upper RIWS are also aided by a variety of development actors that have largely positive effects on their resiliency. I conducted seven semi-structured interviews with development agents and 13 interviews with government officials to determine what types of organization and support are provided to farmers and what they perceived to be the most appropriate agricultural adaptations to climate change. I focused survey and interview questions primarily on agricultural strategies, but also used the adaptation-vulnerability approach to understand the socioeconomic context that these agricultural adaptations take place.

Meteorological Data

Andes Region

Climate data from 279 stations in the Andes between 1° N and 23° S show a 0.1° C per decade warming trend and an overall temperature increase of 0.68° C since

1939. Over the last 20 years only two of those years (1996 and 1999) were below the long-term (1961-90) average (Vuille et al., 2008). Changes in precipitation are less notable than changes in temperature and lack long term and high quality records. There is, however, a tendency for increased precipitation north of 11° S in Ecuador and a decrease in Southern Peru along the Peru/Bolivia border (Haylock et al., 2006). These large models are useful to understand regional and global changes, but more research is needed to understand what climate change means on a smaller scale and how farmers respond.

Rio Ica Watershed

Data from the RIWS show a changing climate. Unfortunately, the meteorological data are incomplete. There are three weather stations run by the Servicio Nacional de Meteorologia e Hidrologia (SENAMHI) located within the RIWS with data from 1964 to the present. A climate analysis conducted by SENMAHI shows climate changes since 1964 that include decreased precipitation and warmer nighttime and daytime temperatures (Oria and Ovalos, 2013).

Farmer Climate Observations

The available meteorological data plays an important role in uncovering climate changes. However, when these data are combined with farmer experiences a more complete representation of how the climate is changing and how it affects agriculture begins to emerge. Farmers consistently reported changes in the climate with a focus on the duration and intensity of the rainy season currently and also how that has changed over the 1970s, 1980s, and 1990s to the present. When creating the surveys, farmers stated that climate changes manifested themselves primarily in more extreme temperature swings and in a less predictable rainy season.

Duration of the rainy season

Precipitation in the Rio Ica watershed is highly seasonal and decreases significantly with a decreases in elevation. The average rainfall in Tambo (3,080 m.a.s.l.) is 424 mm/year while the city of Ica (325 m.a.s.l.) receives only 2 mm/year (Oria and Ovalos, 2013; Hepworth et al., 2010). Farmers depend heavily on a consistent and predictable rainy season. Even small changes in the timing, duration, or intensity of the rainy season can lead to poor harvests. An unpredictable rainy season can lead to crop loss. A decrease in precipitation limits crop variety and forces farmers to rely on complex irrigation strategies.

As part of the survey, I asked farmers to discuss the duration of the rainy season from the 1970s, 1980s, 1990s, and then currently. Responses showed a shortened rainy season. Farmers answered that the current rainy season lasts an average of 3.5 months whereas previous rainy seasons (1970s to 1990s) lasted between 4.4 and 4.6 months on average.

Table 3.1: Duration of the rainy season according to farmer surveys.

	1970s	**1980s**	**1990s**	**Current**
Rainy season duration (months)	4.6	4.5	4.5	3.5

In conversations with farmers on the changes in precipitation, the most common response was that, “The rain is not like before (*Ya no es como antes*).” They consistently replied that rain is less predictable and that when it does arrive it is torrential and difficult to manage. One farmer spoke to the current unpredictability of precipitation by saying, “The rain varies more now and is not natural. Before the rains were gentle but now they are stormy (*Antes era mas lluvia y normal. Ahora es tempestada*).” Several farmers mentioned that they had previously relied more on rain fed agriculture and used fields that did not have access to their intricate canal systems.

The reported perceptions of climate changes that include increased variability and timing shifts of precipitation patterns within the RIWS are consistent with other regions in Peru (Milan and Ho, 2013; Sperling et al., 2008). Such perceptions also coincide with research findings in the Peru-Bolivia Altiplano (Boillat and Berkes, 2013; Postigo, 2014; Seth et al., 2010; Valdivia et al., 2010).

Intensity of Frosts

Farmers were also asked about the intensity of frosts. Somewhat counter-intuitively, climate changes in the RIWS and throughout Peru do not only portray a warming climate during the day but may also have increased the intensity of nighttime frosts. Many farmers reported an increase in intensity of frosts, particularly at higher elevations, that can have a major impact on crops. Reports of colder nighttime and warmer daytime temperatures are consistent with research changes due to shifts in evapotranspiration elsewhere in the Andes (Postigo, 2014; Sperling et al., 2008; Thibeault et al., 2010; Valdivia et al., 2010).

Typology of Adaptations

In addition to a changing climate the upper RIWS, there are several other factors causing agrarian change. Many of the adaptation strategies listed are not solely directed at adaptation to climate change but instead are a response to a range of external forces that decrease farmer resiliency. The following typology from Smit and Skinner (2002) organizes agricultural adaptations into four categories and six subcategories:

1. Technological Developments

Technological adaptations are developed through research programs conducted by provincial and national governments and through initiatives of non-governmental organizations. In the upper RIWS, the principal development agency focused on climate change adaptation is the German Federal Enterprise for International Cooperation on Adaptation to Climate Change in Ica and Huancavelica (GIZ-ACCIH). The primary goal of GIZ-ACCIH is to increase resiliency for farmers facing the negative effects of climate change with a particular focus on the most vulnerable populations. Other development actors include the national and regional government, and several non-governmental organizations. Many of these developments appear to have nothing to do with climate change. However, they may increase farmer resiliency through higher agriculture production and increased farmer capital.

Crop Development

Farmers in the upper RIWS rely on a diverse mix of cultivars. All of the 105 farmers surveyed cultivated between two and 14 different crops with an average of 7.2 per farmer. The most common crop in this region is alfalfa, a forage legume, used to feed livestock. It is ubiquitous in areas with consistent access to water and is important for milk production. Potatoes are the central food crop and 91 (87%) of the farmers surveyed cultivated them followed by 78 (74%) that grew corn. Wheat and barley are also common, but primarily in areas that do not have consistent access to water. Other crops of secondary importance include *oca*, *olluco*, *mashua*, carrots, lima beans, *quinoa*, *kiwicha*, and peas.

At lower elevations (under 3,500 m.a.s.l.) farmers cultivate tree crops that include avocado, apples, oranges, figs, *cherimoya*, loquats, and bananas. Several studies suggest that tree-based systems may be more robust under extreme climatic variations than annual crops as they have numerous mechanisms that decrease the impacts of droughts, such as buffering humidity and reduction of air and soil temperature extremes (Gregory and Ingram, 2000; Schwendenmann et al., 2010). There is also the potential for economic returns. Agroforestry, as a long-term investment and adaptation strategy to uncertainties of changing climate, can help to minimize risk by diversifying products of farming households (Lasco et al., 2014). Farmers in the community of Acora (1,937 m.a.s.l.) have invested heavily in the cultivation of avocados (Figure 3.2). These non-traditional crops are both consumed within the community and also bring a high price on the regional market. Agroforestry also requires significantly less care than annual crops once they are mature. In conversations with farmers on agroforestry, they did not appear to cultivate tree crops as a current or anticipated adaptation to climate change. Instead, they saw them as a consistent source of calories and capital that requires minimal input.

Figure 3.2: Farmer in Acora walking amongst his avocado trees.

Farmers reported a decrease in the varieties of specific crops. There are 500 varieties of potatoes grown in the department of Huancavelica (CIP and FEDECCH, 2006) though farmers that grow potatoes reported cultivating only two different varieties on average. One farmer stated, “We used to farm a greater variety of potatoes, but now we rely primarily on the *canchan* because it matures the fastest and is the most resistant to pests (*Antes cultivábamos mas variedades de la papa, pero ahora usamos solo la chanchan porque madura mas rápido y es mas resistente as las plagas*).” Farmers stated that the *canchan* is a recent addition to the agricultural landscape. Another variety of potato is known as the *huayro*, which is more resistant to frost and thus more common at higher altitudes. Other potatoes are chosen specifically for taste such as the *amarillo* potato because of its sandy texture. Farmers reported that there was previously a much higher diversity of potato varieties, particularly at higher altitudes (between 3,500 and 4,000 m.a.s.l). The diversity of potatoes may aid in climate change adaptation as farmers can choose potatoes based on a variety of characteristics. Certain potatoes are more resistant to frosts while others rely on less irrigation. Instead farmers in the upper RIWS rely heavily on the *canchan*, presenting a difficult choice. When farmers lose agrobiodiversity they have fewer tools available to adapt to climatic variability, however, there are certain varieties of potatoes that provide farmers with a larger harvest, which can be translated to more food for the farmer's family or a larger income. Many adaptations function in this manner, and it is difficult to discern the long-term effects. Most development agencies encourage farmers to plant other types of potatoes in case of a bad year.

Another climate change adaptation in crop development is the reintroduction of *quinoa* (*Chenopodium quinoa*), a traditional Andean cultivar. *Quinoa* was a staple crop of both pre-Inca and Inca civilizations but fell out of use after the arrival of the Spanish (Morris, 1999). Into the twenty-first century, many Peruvians, particularly in urban centers, continued to see these traditional grain crops as backwards or antiquated. In its place, Peruvians relied heavily on imported rice and grain. Recently, quinoa has enjoyed a small resurgence in Peruvian cuisine. It has been recognized as a superfood and international demand has increased significantly. *Quinoa* seeds are exceptionally nutritious, due to their high protein content with all essential amino acids, and high mineral content (Ruiz et al., 2013). Between 2006 and early 2013, international quinoa crop prices tripled. In 2011, the average crop value was US $3,115 per ton with some varieties selling as high as US $8,000 per ton (Ruiz et al., 2013). Although the producers' association and cooperatives have worked towards a higher price on the international market, the higher price also makes it harder for Peruvians to purchase it. Farmers in the RIWS reported that when they cultivate *quinoa* they do not eat it but instead sell it and use the capital to buy other goods. Only 20 (19%) of the farmers surveyed cultivated *quinoa*. Other farmers stated that there was previously more quinoa grown in the region and that now there is a resurgence of quinoa cultivation as farmers realize the financial benefits.

The importance of *quinoa* to reduce climate change vulnerability is important not only due to its high market price, but also because the many varieties of quinoa can be adapted to diverse agroecological regions, from sea level to the *altiplano* (Ruiz et al., 2013). All *quinoa* genotypes are salt tolerant, though some are more than others, and can grow in marginal soils (Adolf et al., 2012). *Quinoa* also appears to be a model crop under climate change because it may represent an opportunity for farmers in a drier climate (Martinez et al., 2009).

GIZ-ACCIH also encourages farmers to increase forage crop diversity. There are two traditional varieties of alfalfa that farmers cultivate that are adapted to cold temperatures and drought (*montsefu* and *san pedrano*), but these also have minimal leaves, the primary protein and nutrient source for livestock. GIZ-ACCIH introduced a hybrid variety of alfalfa that several farmers have begun to implement. The hybrid varieties produce more leaves and thus will increase milk production but are also less resilient to cold and have higher water requirements. The implementation of hybrid varieties has begun over the last several years, and thus their effectiveness is yet to be determined.

Resource Management Innovations

All of the farmers surveyed employ gravity-fed irrigation, which is the opening of the canal sluice gate above the field that is then flooded. Farmers then use a shovel to direct the flow of water through furrows within the field to ensure equal distribution. This technique has been used for hundreds of years (Inbar and Llerena, 2000) though it uses more than twice as much water as artisanal sprinklers and can wash away soil nutrients and seeds if not implemented correctly. Sprinkler irrigation systems offer an alternative to gravity-fed irrigation. However, only 14 (13%) of farmers surveyed used sprinklers as an additional irrigation source to gravity-fed irrigation. Many of those who did not use sprinklers stated that they want to implement their use but lacked the necessary training and capital. Farmers who apply sprinklers as an irrigation source stated that it was a recent introduction and most began using them in the past five years. Farmers noted that the sprinklers had a positive effect on pest reduction, particularly aphids, because the sprinklers washed pests off crops. There are some difficulties in the implementation process of this new technology. Farmers have a keen understanding of how gravity-fed irrigation works and the amount of time needed to saturate their field. A new irrigation technique, however, can provide new challenges. If the farmer does not use enough water, this can encourage plants to have shallower root systems and thus be more susceptible to water shortages. The farmers are also more vulnerable to equipment failure if they have a problem with a hose or sprinkler mechanism.

There are many available systems that rely on store-bought sprinklers, which are an efficient irrigation tool but prone to malfunction and difficult to fix without the proper parts not readily available in the upper RIWS. GIZ-ACCIH and other agencies are promoting artisanal sprinklers that can be constructed cheaply from parts that all farmers can access (pen, plastic tube, nail, bottle cap, and metal wiring). Sprinkler irrigation may not fix all water scarcity issues for farmers, but a greater access to irrigation technologies can help farmers preserve precious water resources during times of drought.

Other climate change adaptations include the more efficient management of canal irrigation systems. Many canals lose significant water as they carry to the field. This water is not entirely lost as it is recycled back into the aquifer, yet it does mean that less water makes it directly to the field. During times of drought, having a more reliable and efficient canal system correlates to more water for crop irrigation. GIZ-ACCIH and several other development agencies throughout in the RIWS are working towards increasing water storage capacity during precipitation events. Canal systems that have storage pools mean that water can be stored during a large precipitation event and then released slowly to the agricultural fields below (Figure 3.3).

Figure 3.3: Water storage pool along a canal.

An alternative way to manage water resources is to harvest water through the construction of infiltration trenches at high altitudes where there are higher precipitation levels. When the rainy season arrives (typically in December) the water infiltrates into an underground network of springs, meaning there is more of a water hydrological cycle for irrigation once the rains disappear. Infiltration ditches normally measure three meters across and can be over one hundred meters in length. These trenches are so large that it is difficult to complete this work by hand; instead, large machinery is utilized to dig the trenches. At the time of this study, both GIZ-ACCIH and another NGO groups were working on this program.

A similar, yet more capital-intensive, technique to capture water at high elevations is through the construction of a dam. Rain will collect in the dam and can then be slowly let out into the network of canals. Both infiltration trenches and canals are water harvesting strategies that work to keep water at higher elevations. By keeping more water in the local hydrological system in the upper RIWS, both of these water techniques can significantly increase water available for crop irrigation.

2. Government Programs and Insurance

Agricultural Subsidy and Support Programs

Within the RIWS, there are no direct programs that provide crop insurance or agricultural subsidies. There are also no government programs that are dedicated solely to climate change adaptation. There are, however, two nationally supported programs that provide assistance to the most vulnerable populations and much of the funds are used to respond to a changing climate. "Pension 65" provides farmers over 65 years old 250 Peruvian soles (~US $85) every two months. The primary goal is to support elderly farmers who are in extreme poverty and may not be able to rely on the cultivation of their own crops. The second program is known as "Juntos Crecer", which pays parents 200 Peruvian soles (~US $69) every two months as long as they keep their school age children in school. By decreasing vulnerability of the participants, both of these programs may be seen as climate change adaptations.

3. Farm Production Practices

Farm production practices involve changes in farm operational practices, which may be stimulated or informed by government programs.

Farm Production

Changing farmers' production strategies is a difficult form of adaptation. Farmers in the RIWS raise a variety of different animals. The most important and pervasive is cattle. Of the 105 farmers surveyed 62 (59%) raised cattle and on average each farmer owned 7.7. Cattle appear throughout the watershed though they are more numerous at elevations below 3,000 m.a.s.l. Cattle are valued for their milk and meat. Farmers within the RIWS make dairy products that they sell at the local and regional market. Sheep are second in importance and 47 (45%) of the farmers cared for them with an average of 8.1 per farmer. Sheep are found primarily at farms over 3,500 m.a.s.l and are used mainly for their meat and sometimes their hide. Only 16 (15%) of the 105 farmers surveyed cared for goats, most of which were at a lower altitude. Smaller numbers of farmers also cared for rabbits, pigs, and guinea pigs. At elevations over 4,000 m.a.s.l., farmers raised alpacas and llamas.

Several governmental and non-governmental organizations are working to improve livestock genetics. The primary method is that most small communities have a representative from El Ministerio de Agricultura y Riego artificially inseminate animals. New breeds are also brought from the city of Ica to the Sierra to improve the genetics. Most cows within this portion of the RIWS, particularly at the higher altitudes, are known as *corriente,* a breed descended from the Spanish. *Corriente* cattle are small, lean, and require less human intervention than other larger breeds. Over hundreds of years, the animals that survived in this harsh environment developed longer hair to handle the colder temperatures and are nimble enough to traverse the rocky landscape (Figure 3.4). Farmers also reported another cattle breed known as *chuzco*, which are typically a mix between the *corriente* cattle and dairy cows such as Holstein and Brown Swiss. The primary intention of these genetic improvement programs is to increase milk production. Most farmers reported only getting eight liters of milk per day, which is much less than from animals in similar regions of Peru that produce up 30 liters a day. Holstein and Brown Swiss are two breeds of cattle that can significantly increase milk production (Figure 3.5). Government officials believe that if one increases milk production then farmers will have a larger income that will buffer them against climate changes and make them more resilient. There is some truth to this rationale, but it must also be noted that these introduced animals may not be best suited to the topography and environmental variability. A balance is required. Dairy production is an important factor that relates to vulnerability to climate change, but interventions must be coordinated with animals that can thrive in this challenging environment.

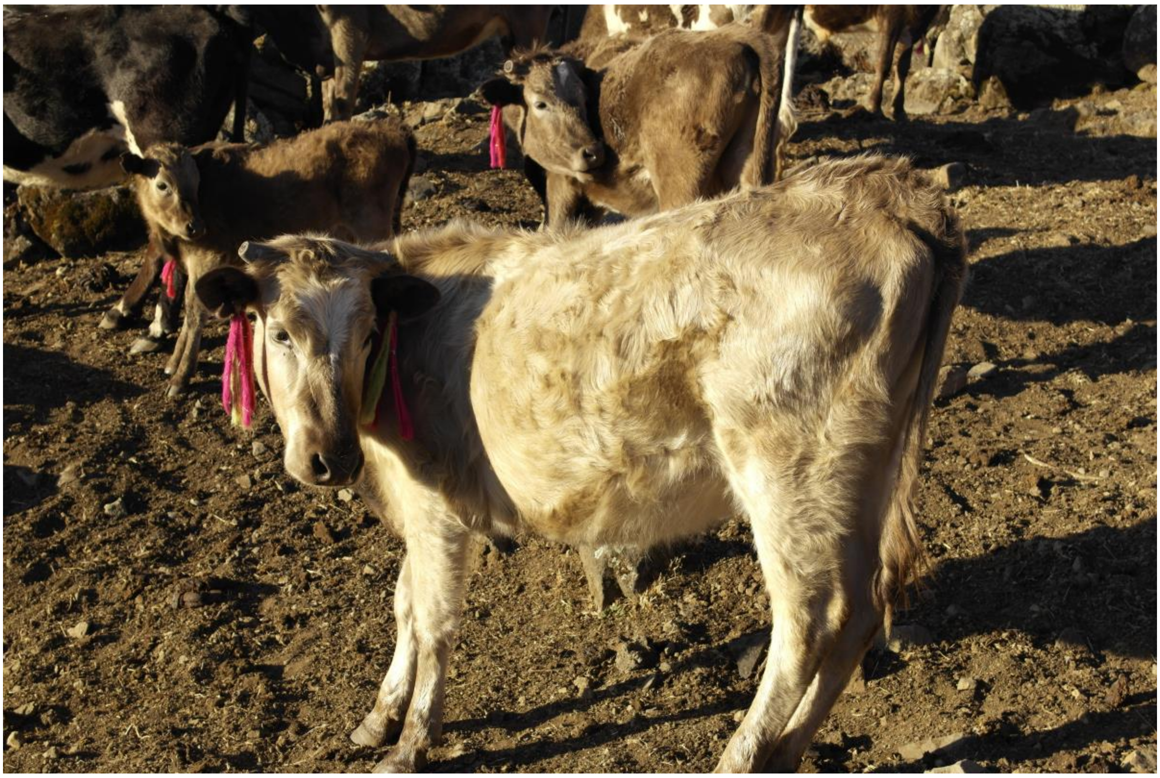

Figure 3.4: A *corriente* breed of cattle in San Miguel de Curis.

Improving cattle genetics can increase milk production and household incomes, but it should not be seen as a panacea. To increase milk production farmers also have to intensify alfalfa cultivation and improve the quality of available pasture. Many of the projects of genetic improvement for cattle are implemented alongside programs that focus on pasture management. Hybrid pasture varieties often have higher water requirements and may not be adapted to the extreme temperatures of the RIWS. Several development agencies working in this region pushed farmers to change their harvest techniques. The strategy of multi-cropping pasture crops (alfalfa with ryegrass) particularly provided a variety of benefits, but the primary advantage is to increase the nutrients available to livestock. Livestock that eat only alfalfa, a legume with a high protein level, can cause a bloating of the stomach known as tympanism. It is important to provide cattle with a combination of proteins (alfalfa) and carbohydrates (rye grass or oats). Multi-cropping also creates denser and more populated vegetation that is kept warmer and therefore more protected against cold temperatures and freezes.

Figure 3.5: A large Holstein cow in Acora.

Another adaptation involving livestock is the pasture storage. Several development agencies have encouraged farmers to save pasture for a bad year either through dry storage in the form of hay or silage. Alpaca herders at higher elevations buy and store hay and then retrieve it during a bad year to feed the animals. Farmers can also use the silage process, which can increase the nutrient and protein content.

Not all farm production practices advocated by development agencies are feasible. Traditional Andean livestock grazing styles involve significant animal movement. Cattle are often left alone while grazing and can become difficult to control. Other livestock management adaptations call for the use of animal stables and modern management techniques. The traditional technique is to shepherd animals across the mountainous landscape often relying on labor from women and young children. Alfalfa and other forage crops are normally located in non-contiguous fields, thus farmers may have to move their animals often many kilometers across a treacherous landscape. Several non-governmental and government organizations are pushing farmers to create stables or corrals for their livestock. There are several benefits to stabling. First, animals are exposed to injury as they traverse across the mountainous landscape, and they also burn calories that could be translated into dairy or meat. Second, farmers have more genetic control when they restrict livestock movement, which can help them improve milk and meat production. Finally, stables make it is easier to control the spread of kikuyu (*Pennisetum clandestinum*) and other invasive species. A negative aspect is that it will require more work to be done by the farmer, as they now have to bring food to the livestock. This livestock management technique is distinctively different from traditional agricultural strategies, and farmers have resisted its implementation.

A further adaptation is to increase veterinary medicine. Farmers reported that extreme temperatures and lack of consistent water has also strained livestock. At higher elevations, herders stated increases in several ailments in their alpacas and llamas that include lice, ticks, and intestinal parasites. In response, many local governments and non-governmental organizations implemented programs that give farmers access to livestock vaccinations and antibiotics. When animals are vaccinated and receive proper nutrition they are less vulnerable.

Another climate change adaptation is the construction of enclosures that protect camelids and other livestock from cold nighttime temperatures at high elevations (Figure 3.6). Freezing nights are particularly harmful for newborn livestock, while extended snowfall prevents alpacas from eating because they do not dig in the snow. Animals that are undernourished and weakened can become more vulnerable to the effects of climate change. The impetus for these structures is that they provide windbreaks and protect livestock from rain and snow. However, not all farmers rely on them. Some herders do not use them because the animals are scared by rain or sleet falling on the tin roof. The cold temperatures can stress livestock. Several non-governmental and government agencies are working with farmers to build structures at higher elevations that protect animals from the cold temperatures during the nighttime. There is some debate on the efficacy of these structures, as they do not address one of the largest problems, which is that colder temperatures and larger periods of snowfall make it difficult for them to graze natural pasture.

Figure 3.6: Enclosure for alpacas and other livestock at high elevations.

Historically, farmers relied on manure from their livestock as the primary fertilizer. Farmers collect this manure from where the livestock sleep at night and then scatter it across their fields to increase productivity. This method is productive and has changed little over the previous century. Recently, however, more farmers have begun to use a variety of chemicals to increase productivity. Of the farmers surveyed, 49 (47%) stated that they now rely on chemical fertilizers, herbicides, or insecticides. These chemicals are a new agricultural addition, and most farmers stated that they were added over the last three to 10 years. Many farmers claimed that chemical fertilizers were not necessary before, but that recent climatic and environmental pressures have made them mandatory to produce a sufficient harvest. Most farmers that apply chemicals lamented their application. They deemed them as necessary in a less predictable agricultural landscape that includes an increase in pests and invasive species paired with changing precipitation patterns and temperature swings. The primary invasive species challenge is kikuyu (*Pennisetum clandestinum*), a non-native grass that is highly invasive and virtually devoid of nutrition. Kikuyu was reportedly brought into the watershed by farmers approximately 30 to 40 years ago as a possible forage crop. During this time it has suffocated alfalfa and other forage crops. Farmers battle kikuyu using a combination of herbicides and manual labor. Fighting the spread of kikuyu is not necessarily a direct climate change adaptation, but it is an adaptation to a changing agricultural landscape and increases farmer vulnerability.

A further farm production practice is the construction of greenhouses. The primary purpose of a greenhouse is to protect crops from colder nighttime temperatures, extending their normal altitudinal limits. Farmers also reported that greenhouses protect crops from birds, a major pest in the region. I visited several greenhouses at over 3,500 m.a.s.l. in which warm weather crops such as tomatoes, corn, beans, and squash, and cold weather crops such as chard, spinach, carrots, and cabbage were cultivated. Greenhouses typically measure four by 15 meters and supplement a field crops much like a garden (Figure 3.7). Farmers can sell the greenhouse produce or use it to diversify their family’s diet but due to their limited size they have limited impact. There are several development agencies that promoted their construction within the region. The construction of greenhouses is simple. Farmers are expected to build an adobe brick structure with four walls that could support a pitched roof. Development agents then supply the farmer with a heavy transparent plastic that covers the adobe frame. Greenhouses have even turned high altitude herders into farmers. Herders in Los Libertadores live at over 4,000 m.a.s.l. and have historically been limited by cold nighttime temperatures. Within this high altitude community herders use greenhouses to cultivate and increase their caloric intake and dietary diversity.

Figure 3.7: Farmers use greenhouses to grow crops generally limited by frosts.

Land Use

Farmers in the RIWS use "verticality" to take advantage of as many vertical microclimates as possible (Murra, 1968). By doing so, they are not utilizing one zone for gain but instead cultivate a variety to ensure against crop failure. A farmer may cultivate barley and wheat, crops that are cold and drought tolerant, at higher elevations and then use fields at lower elevations to grow corn and beans, crops that are more productive yet sensitive to frosts and drought. They may also trade crops and livestock with farmers at different altitudes thereby increasing the resiliency of the entire region. Much like increased agrobiodiversity, a multiplicity of cultivation sites buffers against extreme climate fluctuations that can decrease agricultural output. Within the survey sample, the average number of separate fields that each farmer had was 3.92 per farmer. This traditional Andean agricultural technique may increase a farmer's workload as they must walk long distances between fields but also makes their harvest highly resilient.

Another land use adaptation may be an inadvertent strategy. Those visiting the upper RIWS immediately notice that the majority of agricultural fields are either not currently under cultivation or abandoned. As farmers migrate to the coast, many of the best agricultural fields are not in use. A decreased number of farmers reduces irrigation demands and lessens competition for the most productive agricultural fields. A lower population in the upper RIWS places less pressure on agricultural resources, which may be an important adaptation amongst unpredictable climate fluctuations.

Land Topography

Andean farmers in the RIWS have not recently changed the topography because they inherited an anthropogenic landscape that contained bench terraces and canals to address moisture and nutrient deficiencies. Bench terraces are characterized by: 1) high (1-5 meters) retaining walls or stacked, interlocking stones, 2) level platform planting surfaces, 3) valley-side positions following slope contours, 4) arrangements in vertical serial rows, 5) cut-and-fill construction, 6) inward sloping walls, and 7) built in irrigation and other devices (Denevan, 2001). The primary functions of terraces are to facilitate the even distribution of irrigation water over the cultivation surface, provide leveled terrain and deep soil, and prevent soil erosion (Figure 3.8).

Canals are used in conjunction with terraces as a water management system. They harness water from further upstream with sluice gates that regulate the volume of water that enters. As the stream continues to drop towards the Pacific Ocean, canals slowly divert water parallel to the slope contours with a minimal gradient until it is above the agricultural fields. Canals serve two purposes: 1) deliver the necessary water in the amount needed, and 2) do so without either excessive maintenance, scouring or sediment deposition (Denevan, 2001). The canal irrigation system systems provides a buffer for farmers that extends their growing season and makes them more resilient to climate changes than farming non-irrigated agriculture (Liverman, 1990).

Figure 3.8: Terraces with healthy alfalfa outside of Tambo.

4. Farm Financial Management

Farm-level responses using income strategies can reduce the risk of climate-related income loss. There are no government agricultural support and incentive programs in the upper RIWS.

Household Income

The farmers within this region of the RIWS are connected to the city of Ica. Many of the farmers surveyed had worked in Ica before and continue to maintain a connection. Farmers also sell dairy products to markets in Ica, providing a small supplemental income. Few of the farmers interviewed were solely dedicated to agriculture; instead, they rely on a combination of income sources. This may include working for the gas company to maintain a nearby gas pipeline or in the construction of public work projects. Other farmers lived in Ica on a seasonal basis and picked crops for commercial growers. Many of the older farmers rely on remittances that are sent by family who live and work on the coast.

Smallholder farmers do not operate in a vacuum. They are heavily affected by and interact with the greater regional economy of Ica and Huancavelica. As with many adaptations, diversification of household income is unlikely undertaken directly in response to climate changes alone (Bradshaw et al., 2000). Diversification of income sources has been identified as an adaptation option, including off-farm employment and pluriactivity, which has the potential to reduce vulnerability to climate-related income loss (Brklacich et al., 1997; Smithers and Smit, 1997; de Loë et al., 1999). Therefore it is often difficult to gauge the exact effects that climate changes will have on agriculture.

This strong connection to the city of Ica has another consequence: migration. Farmers that move between urban and rural environments are more likely to permanently relocate in Ica. When speaking with farmers, it became apparent that climate changes might be a significant stimulus for migration. An unpredictable rain pattern and intensity of temperature swings creates more difficulty in agricultural production. Farmers that cannot grow enough to feed their family or sell at the market often make the choice to find a stable income in Ica. According to the 2007 Peruvian census, the population of the district of Tambo, a population center in the upper RIWS, dropped by 44% since the 1981 census, while the district of Ica grew by 54%

over the same period (INEI, 2007). One impetus for migration is the increased demand for jobs in Ica. The growth of export agriculture in Ica has led to a surfeit of employment opportunities (Hepworth et al., 2010). Smallholder farmers may leave, but they often return and do not abandon their land. This type of circular migration is not always permanent, but instead is a way for farmers to maintain work alternatives across a number of economic sectors. In the end, the decision to leave smallholder agriculture may in itself be its own form of adaptation (Black et al., 2011).

Discussion

Environmental, climate, and market forces force smallholders in the upper RIWS to reevaluate their agricultural strategies, as they now rely on a combination of both “traditional” Andean agricultural strategies, and certain modern additions. The “traditional” strategies are intrinsically adaptable and exploit the unique topography and climatic variability of the upper RIWS. Nevertheless, I found that most farmers wanted to modernize portions of their agricultural strategies to combat decreases in productivity. It would be a fallacy to think that the same modern agricultural model that functions in Ica valley would work in the upper RIWS, but it would be equally erroneous to think that traditional agricultural strategies are the only solution to increase resiliency to climate change.

Many development agencies seek to modernize agricultural strategies in this region without understanding “traditional” techniques. They see many of the agricultural techniques in the upper RIWS as inefficient and outdated. Their ideas for agricultural adaptations often involve modernization without thought into what techniques are sustainable or whether farmers will apply them. The goal should not be to turn the upper RIWS into a modern agricultural model, but to give farmers access to a variety of tools that may increase their resiliency. Modern additions, such as genetic improvements, pesticides, or sprinklers, when implemented as part of an agricultural strategy, can still be seen as indigenous or traditional because they keep farmers cultivating.

Most of the adaptations presented above are not a direct response to climate focus, but instead are adaptations that seek to increase farmer resiliency, making them less vulnerable to climate changes. Smallholder farmers and development agencies must decide to focus their limited resources on specific agricultural adaptations to climatic variability (sprinklers, water storage, greenhouses) or on programs without a deliberate climate focus (genetic livestock improvements, off-farm income). These two options are not mutually exclusive, though they do often create difficult decisions for farmers. By increasing certain modern additions, a farmer can increase capital, but if these new additions are inappropriate for the unique topography and climate of the RIWS and/or rely on constant additions, farmers can actually become more vulnerable to climate changes, signifying maladaptation. The story of the *canchan* potato is an illustrative example. Farmers noted a significant decrease in the variety of potatoes over the last 30 years, as farmers reduced their reliance traditional potato varieties and focused on cultivating only the *canchan*, a more consistent income source. The *canchan*, however, may not be the most appropriate under climate change. It is not as drought or frost tolerant as other traditional varieties. The sole focus of adaptation strategies based on increase of farmer incomes can lead to the implementation of agricultural strategies that make them *more* vulnerable to climate changes.

The implementation of response strategies can reduce farmer resilience if they are not carefully conceived and implemented (Adger et al., 2011). A trend in emerging literature shows tensions and discrepancies between adaptations that are deemed effective and appropriate by governments and development agencies, and those considered important or desirable by individuals and communities (Adger et al., 2013). Therefore, adaptation programs must be conducted in collaboration with farmers to find responses that mesh with their current agricultural strategies without requiring consistent capital inputs or asked them to fundamentally change their entrenched agricultural practices.

Conclusion

Climate change negatively impacts agricultural production and exacerbates existing stressors. Farmers in the upper RIWS are marginalized both politically and economically but apply agricultural strategies that have made them partly resilient to decreased precipitation and more extreme temperatures. This typology illustrates the diversity of tools that help farmers in the upper RIWS respond to climate changes. The four adaptation categories of technological development, government programs and insurance, farm production practices, and farm financial management prove that increasing farmer resiliency can take many forms.

There is substantial room for further adaptation to climate change in the upper RIWS, while also understanding that adaptation programs requiring significant capital improvements may make agriculture prohibitively expensive or time-consuming, pushing farmers to migrate. Many adaptations are inherent within traditional Andean land management strategies and others are modern additions. Development agencies play a significant role in fostering successful agricultural strategies and provide capital that can reduce farmer vulnerability. A nuanced hybridity that uses the best of both traditional and modern agricultural strategies may be the most effective tool to increase farmer resiliency against climate change.

Adaptation programs must also recognize that climate change is one of many disparate challenges affecting farmers. Increasing resiliency to climate change will involve adaptation programs that have little connection to climate, but that still increase farmers' ability to respond to climate change. However, adaptations must still be appropriate for the regions unique topography and climate.

CHAPTER FOUR

Emerging from Below: Impacts of Kikuyu on Smallholder Farmers

Abstract

Kikuyu (*Pennisetum clandestinum*) is an invasive grass species of East African origin introduced by British agricultural scientists to increase forage with the hopes of increasing wool production. Like many agricultural additions, it had unintended consequences that fundamentally changed agricultural production in the upper RIWS. Kikuyu spread rapidly and crowded out more nutritious crops. Farmers reported major limitations due to kikuyu though, paradoxically, they also described a reliance on the grass. Farmer surveys and interviews show that kikuyu is a primary agricultural limitation, and that most current eradication strategies are unsuccessful. A remote sensing analysis of the several areas within the upper RIWS corroborates farmer statements on kikuyu encroachment. Long-standing land management strategies are currently ineffective at managing kikuyu, and farmers now having to rely on more modern removal strategies. Yet, these come with their own problems and require significant agricultural changes. Development agencies that work to increase farmer resilience within the upper RIWS must also work to help farmers control the spread of kikuyu.

Introduction

It is difficult to distinguish between "traditional" and non-traditional agricultural methods. In the upper Rio Ica watershed (RIWS) in southern Peru, smallholder farmers in this region rely on pre-Inca terraces and irrigation canals to grow Andean cultivars on steep, arid slopes, and they use tools of pre-Inca origin. Many of their agricultural management strategies have not changed for centuries. However, these same smallholder farmers raise crops and livestock introduced by the Spanish (primarily cows, sheep, alfalfa, and wheat) during the Colombian exchange that are now staples of their agropastoral system (Crosby, 2003). Throughout the latter half of the twentieth century, these "traditional" agricultural strategies were further transformed by agricultural additions that include new crops, pesticides, herbicides, and fertilizers. Many of these additions increase efficiency but can create new problems that further alter the agricultural landscape.

One of these new adoptions had unintended negative consequences. Kikuyu grass (*Pennisetum clandestinum*) is from east Africa and was introduced as a forage crop into the upper RIWS to increase milk and meat production. Farmers quickly learned that though it does provide some sustenance for livestock, its negative aspects far outweigh any benefits. Kikuyu contains minimal nutrients and spreads quickly between fields, crowding out more nutritious crops like alfalfa. Kikuyu decreases livestock production and is a major limitation to agricultural innovation. Most farmers do not have the necessary resources to combat this foreign invader, and many viewed it as a significant contributor to outmigration. Facing new challenges like kikuyu, farmers are increasingly pushed further from "traditional" agricultural strategies and now rely on more modern agricultural techniques. Kikuyu has significant negative impacts on agricultural production in the upper RIWS and throughout Peru.

Regrettably, there is limited academic research on the effects of kikuyu within an agropastoral system. Earlier work discussed the introduction of kikuyu into Latin America (Parsons, 1972; Boonman, 1993), but most current research only briefly mentions its agricultural effects (Knapp, 2001; Wiegers et al., 1999; Schjellerup, 2000; Sarmiento, 2002; Etter et al., 2006; Aubron et al., 2009) or application as erosion control (Harden, 1993; de la Cruz et al., 2007). Only Gonzalez (2009) analyzes the socio-economic effects of kikuyu on smallholder farmers. This chapter is intended to initiate a discussion that may fill this research gap by providing an understanding of how farmers in the upper RIWS manage kikuyu along with other external stressors to their agriculture. Relying primarily on farmer surveys and interviews with development agents, this chapter elucidates how farmers view kikuyu and what strategies they apply to manage its spread. This chapter also corroborates farmer statements by quantifying kikuyu coverage using two remote sensing images and a hybrid (supervised/unsupervised) classification.

Previous chapters focused on climate change as a primary reason for innovative agricultural adaptations. During the course of fieldwork, it became clear that climate change was altering farmer strategies, but also that the spread of kikuyu increases farmer vulnerability. Development programs must address kikuyu, which poses a major threat to “traditional”, long-standing agricultural practices. It is unlikely that farmers will be able to eradicate kikuyu and create a sustainable agricultural future without the help of development agencies who possess key tools for its eradication.

Kikuyu Characteristics

Kikuyu is a perennial grass and most botanical descriptions explain it as having a prostrate habit, however, this growth is not the result of genetic factors but the effects of local environmental dynamics. In the presence of herbivores, kikuyu forms a dense turf. When left undisturbed with access to sufficient irrigation, it has a vertical growth habit that can reach up to one meter tall (Quinlan et al., 1975). The primary problem with prostrate growth is that it provides few nutrients to livestock. Where alfalfa is grazed heavily, it is invaded and crowded out by kikuyu, thus limiting the normal life of the stand (Harrison, 1947). Kikuyu is also highly contagious and can quickly crowd other cultivars, particularly alfalfa. The spread of kikuyu is aided by runners that can rapidly cover terraces and spread between fields, as long as it has access to sufficient water and its progress is not impeded (Figure 4.1; Figure 4.2).

Figure 4.1: Kikuyu spreading across terraces.

Figure 4.2: Kikuyu root systems.

The spread of kikuyu is exacerbated by livestock management strategies. A strong symbiotic relationship has developed as the result of a co-evolutionary process; kikuyu reaches its fullest invasive potential within an agropastoral system. It requires irrigation and does not have an impact within the non-irrigated, natural environment of the upper RIWS. The plant rewards livestock with feed, and livestock then carry kikuyu seeds though their digestive tract that stimulates germination. In addition, by associating with organisms that are able to move throughout the landscape, kikuyu grass ensures that its seeds are spread to new areas to further colonization. Finally, the dung within which the grains are discharged provide a fertile medium for the propagules to root (Gardener et al., 1993a; Gardener et al., 1993b; Malo and Suarez, 1995). Farmers in the upper RIWS continually herd livestock between disparate fields and thus further facilitate the spread of kikuyu as animals graze and leave their dung along the way. Another component that aids in the spread of kikuyu and also makes it seemingly impossible to eradicate is its high capacity to tolerate intense treading, even in large concentrations of livestock (Boonman, 1993).

East African Origin

The name of the grass is derived from the name of the Kikuyu people, whose territory is in the center of the grass' native range in Kenya. The environmental similarities between the kikuyu grass zone (1,750-3,000 m.a.s.l.) of East Africa and the mid-altitude valleys of the Maritime Cordillera help to explain the grass' dominance of this region of the Neotropics (Gonzalez, 2009). East Africa is known internationally as a center of genetic diversity for many of the most important tropical grasses (Boonman, 1993). Kikuyu is not the only African grass to arrive in the American tropics, as Guinea, Para, Molasses, Jaragua, and Pangola have made a significant impact on Latin American agriculture. These six species have been principally involved in this ecological invasion, and several are now economically important (Parsons, 1972).

During the 1920s, specimens of kikuyu were imported into Peru, Colombia, Costa Rica, and Guatemala by British Agricultural scientists (Gonzalez, 2009). The importation of kikuyu grass into Peru was conducted by a former veterinary officer in British East Africa, Colonel Robert J. Stordy, hired by the Peruvian government to direct the *Granja Modelo de Chuquibambilla* research station in the southern Peruvian town of Puno. The introduction of kikuyu was a state policy that looked to modernize livestock estates in the *altiplano* to increase wool and fleece production. Unfortunately, kikuyu was not well adaptable to the frigid environments of the *altiplano* and did not thrive as hoped. It is, however, well suited to the mid-latitude environments of the Maritime Cordillera and has spread to farms throughout Peru as many farmers anticipated it would be a forage crop for livestock.

There is a general understanding how kikuyu—along with other East African grasses—arrived in Peru though it is still uncertain how and when it was introduced into the upper RIWS. Farmers stated that it arrived 30 to 40 years ago, though its initial introduction had little impact and was contained to certain areas. Farmers stated that when the fields were filled with alfalfa they would raise significantly more cattle than with kikuyu. Estimates of herd size and milk production show that areas in the upper RIWS had two to three times as many livestock in previous generations.

Farmers routinely stated that the increase in kikuyu has a negative impact on livestock populations and milk production.

Study Area

The upper RIWS is an ideal environment to study the effects of kikuyu and how farmers respond. Kikuyu is found between 1,500 and 4,000 m.a.s.l. in the upper RIWS. In this region, kikuyu significantly limits agricultural production, increasing the vulnerability of farmers who are already politically and economically marginalized. The arid climate of the RIWS is moderated by the cold Humboldt Current, the steep relief of the Cordillera de los Andes, the South Pacific Anticyclone, and transitions from the highly arid coast to the moist *altiplano*. This scale of analysis along a watershed transect allows for an understanding of how the effects of kikuyu can be seen, not just in one specific area but across a transect throughout the upper watershed.

There is high climatic variability and uncertainty in the mountainous environments of the upper RIWS on both spatial and temporal scales, and microclimates created by slope, aspect, elevation, and exposure can have differential effects on water resources, agrobiodiversity, and native ecosystems (Pepin and Lundquist, 2008; Buytaert et al., 2010; Veteto, 2014). This extreme topographical variation often supports high biodiversity, endemism, and microrefugia in both natural and agricultural systems (Zimmerer and Douches, 1991; Perrault-Archambault and Coomes, 2008; Dobrowski, 2011). Farmers have developed a corresponding mosaic of adaptive strategies for producing food and, particularly, strategies for managing water (Zimmerer, 1999).

The study area is located between 1,760 and 3,884 m.a.s.l. Smallholder farmers in this landscape grow primarily alfalfa (*Medicago sativa*), an introduced species of forage legume used as a feedstock for cows, sheep, and goats. These smallholders also cultivate potatoes, corn, wheat, barley, quinoa, and lima beans. They produce predominantly for household consumption but also for the local and regional market in Ica. They rely on traditional Andean agricultural strategies that include terraces and canal irrigation to cultivate in a semi-arid, mountainous landscape. Erratic climate changes and limited access to resources and opportunities have stimulated strong migration to the coastal cities of Lima and Ica. The few families that do remain often spend months away from their homes to stay with family members in the coastal cities.

Methods

One hundred and one farmers were surveyed in order to understand perspectives on kikuyu (Figure 4.3). The majority of the farmers surveyed were male as they are primarily responsible for agricultural management. The average age was 57 years old with an age range of 24 to 86. Whenever possible, the surveys were conducted at the farmer’s land marked with a GPS point. Most survey questions related to farmer adaptations to climate changes, but several were also added to understand how farmers responded to agricultural pests. Kikuyu was the dominant agricultural pest. The survey also ranked kikuyu against other agricultural challenges and how farmers fought against it.

This project also conducted semi-structured interviews with other actors in the upper RIWS. All interviews were recorded with the permission of the interviewee. This included seven interviews with development agents and 13 interviews with government officials to best understand what types of organization and support are provided to farmers to help kikuyu eradication. Men are generally responsible for agricultural decisions while women are typically in charge of the household and care for livestock. This study recognizes this perspective on environmental and agrarian change and conducted 10 interviews with female leaders in the region.

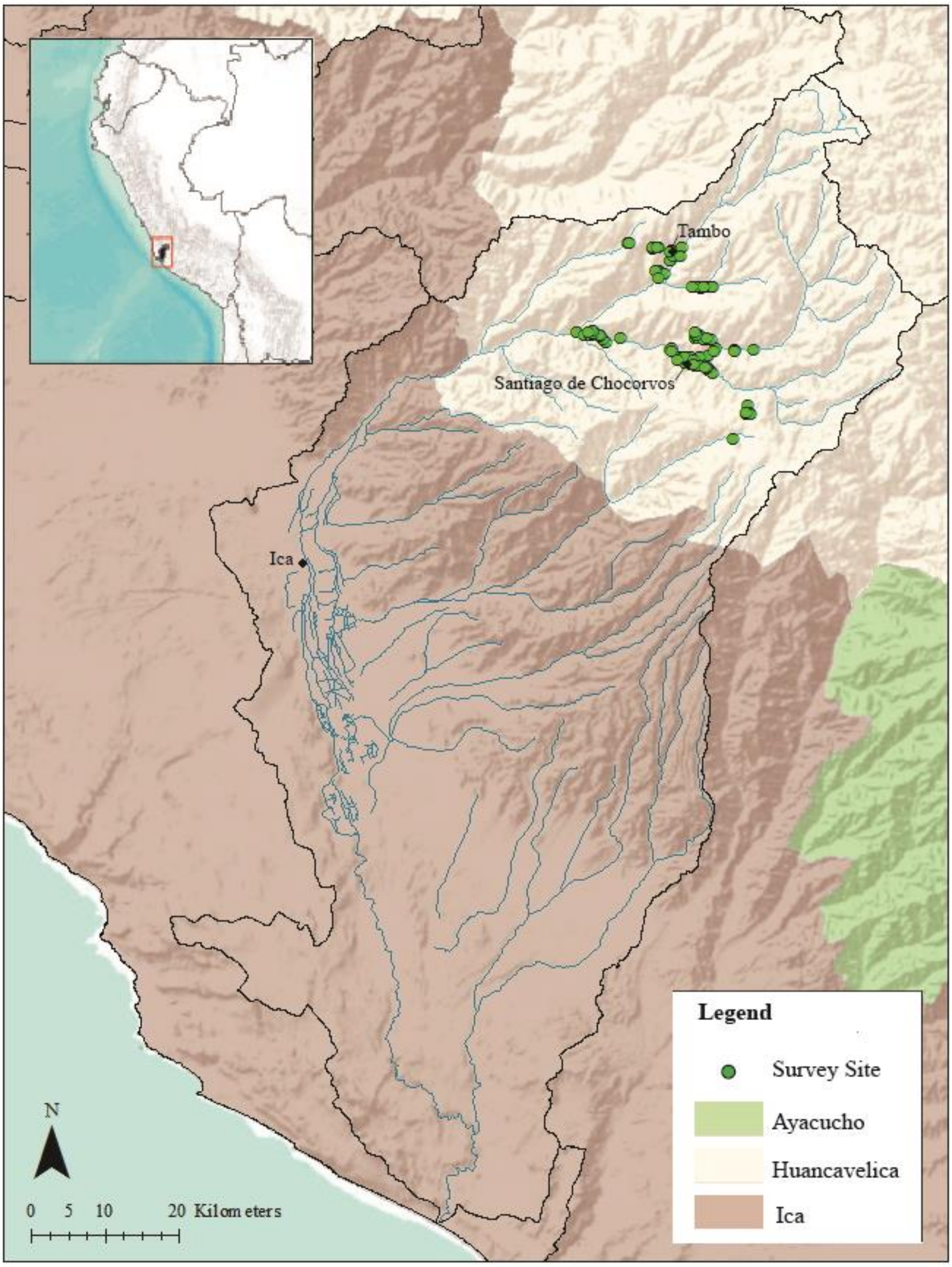

Figure 4.3: Map of survey sites

Survey Findings and Rankings

A portion of the survey was designed to better understand which factors pose the largest challenge to farmer livelihoods as perceived by the farmers. Participants were asked to choose their five greatest challenges from a list of factors and place them in order of severity (Table 4.1). I created a list of the 11 most common response options that were generated from 18 previous farmer interviews to understand their primary challenges. The majority of the farmer surveys focused on agricultural strategies, and when respondents asked for further clarification I explained that they should provide responses that have an agricultural focus. Farmers' responses show that kikuyu has a major impact on farmer strategies. Of the farmers surveyed, 36.6% responded that kikuyu is their primary challenge, while 8.9% of farmers listed it as second, and 19.8% as the third. Other issues such as agricultural pests and lack of water also had large impacts on farmer strategies. Kikuyu was even ranked higher than climate changes as a factor affecting agriculture in the watershed.

Table 4.1: Farmer challenges in the upper Rio Ica watershed.

	1st	**2nd**	**3rd**	**4th**	**5th**
Kikuyu	37	9	20	13	8
Lack of Water	37	20	15	11	1
Agricultural Pests	8	29	24	20	8
Lack of Manual Labor	8	13	6	10	8
Lack of Organization	5	13	17	10	6
Frosts	3	7	10	13	3
Low Market Prices	1	4	4	5	4
Seeds Do Not Produce	2	3	2	4	3
Lack of Mobility	0	0	1	4	2
Erosion	0	1	1	2	3
High Temperatures	0	2	1	1	1

It is important to note that certain population centers within the upper RIWS ranked kikuyu differently. Farmers in areas with more consistent water access and higher nighttime temperatures generally responded that kikuyu was a significant agricultural challenge. In Tambo, the capital of the region, 81.8% of farmers surveyed saw kikuyu as their primary agricultural challenge. Tambo is located above the Rio Tambo and has irrigation access throughout the year through a regulated system of canal irrigation that receives the inter-basin transfer of water from the Choclococha system during the dry season. In Tambo, most agricultural conversations with farmers, government officials, or development agents will contain some discussion of kikuyu, as it limits every agricultural project. When looking down from the town square in Tambo, the spread of kikuyu is clearly visible in all of the agricultural fields below (Figure 4.4). Another factor that spreads kikuyu in Tambo is the higher population and livestock density. Historically, Tambo has had a larger number of livestock because of its relatively flat topography and location just above the Rio Tambo, a constant irrigation source.

Figure 4.4: Kikuyu encroachment in fields below the town of Tambo.

Other areas in the upper RIWS do not have to combat kikuyu. Farmers living in San Miguel de Curis are on the steps of the *altipano* (3,600 m.a.s.l.) and are located high above the meandering canyon, the primary source of water for irrigation for towns located along the canyon walls. San Miguel de Curis relies on mountain springs and seasonal rain to grow crops that are adapted to arid conditions—wheat, barley, potatoes, and lima beans—as they do not have year-round irrigation access. The cold temperatures and minimal irrigation access limit the crop selection—no corn or alfalfa—but it also creates an inhospitable environment for kikuyu. None of the farmers in San Miguel de Curis listed kikuyu as a primary, secondary, or tertiary agricultural challenge. The farmers had heard of kikuyu, but it was only through conversations with farmers in lower portions of the watershed. The difference in how farmers rank kikuyu as an agricultural challenge elucidates how agricultural strategies change significantly with elevation in this mountainous environment and show that adaptation strategies that look to increase farmer resiliency must understand these complexities. Farmer perceptions and ranking of kikuyu are an important component of understanding the spread of kikuyu, but it is also important to look at more quantitative and environmental data that will show the actual spread of kikuyu.

Farmers have varying opinions of how kikuyu was introduced into the region. Most farmers claim that kikuyu was brought in specifically as a forage crop by one farmer, some respondents even provided a name. They routinely commented that kikuyu has worsened significantly since its original introduction. One farmer in Llachtacha (2,885 m.a.s.l.) stated, "All my life there has been kikuyu, but now I cannot control it. (*Todo mi vida he tenido el kikuyu. Ahora no puedo controlarlo*)." Other farmers claim that its introduction was simply an unfortunate accident from buying livestock from outside of the upper RIWS. These farmers believed that livestock from the nearby city of Ayacucho consumed kikuyu and deposited the seeds in their dung. Farmers slowly began to realize that kikuyu is not an ideal forage crop, but it is unclear when—and if—there was ever an organized national campaign to stop its dissemination. In the early twentieth century, it was actively pushed as a more productive forage crop, but by the 1950s it had spread throughout Peru and was declared a pest by the administration of President Odria (Gonzalez, 2009). By Supreme Decree Nº 35 in September of 1953 they stated:

> …That the grass "Kikuyo" (*Pennisetum clandestiunum*) constitutes a bad weed that is invading agricultural terrain in important sectors of the Sierra with grave detriment of their agricultural production; and That it is indispensable to amplify the studies around this plague and intensify the fight against it, coordinating this end with the actions of the State and private forces"
>
> *…Que el pasto "Kikuyo" (Pennisetum clandestiunum) constituye una mala hierba que está invadiendo terrenos de cultivo de importantes sectores de la Sierra con grave desmedro de su producción agrícola; y, Que es indispensable ampliar los estudios acerca de esta plaga e intensificar la lucha contra ella, coordinando para este fin la acción del Estado con los esfuerzos privados"* (Congreso de la República del Perú 1953)

It is noteworthy that the national government declared such a public war against the invasive grass, yet a sea of kikuyu still blankets agricultural fields across the upper RIWS and similar regions throughout Peru. Eradication efforts in the upper RIWS have had little to no effect at stopping the spread of kikuyu.

Other farmers see the introduction of kikuyu connected to more sinister, imperialistic intentions. One declared, "North Americans brought the kikuyu so that Peruvians stay poor and have to buy [their] herbicides (*Los Norteamericanos traeron el kikuyu como los Peruanos se quedan pobres y tienen que comprar las quimicas*)." He saw the spread of kikuyu as a ruse to force farmers to buy expensive—and previously unnecessary—agricultural inputs. For many farmers in the upper RIWS, kikuyu is yet another external force (climate change, market forces, and government programs) that pushes them to change their agricultural strategies and whose introduction and impact is largely beyond their control. The negative effects of kikuyu are evident in discussions with farmers but can also be quantified using other methodologies.

Remote Sensing Analysis

The limited amount of research on kikuyu focuses primarily on two topics: describing its effects or narrating the story of its introduction. There is a need for more quantitative analysis of kikuyu spread. Farmers and development agents routinely discuss kikuyu invasion and decreased agricultural production but do not quantify how many fields are affected. Mapping its spread will aid farmers in petitioning funds for its management and may help to change agricultural practices.

This chapter used two high-resolution multispectral images from the upper RIWS: one from Santiago de Chocorvos using the Quickbird satellite with 60 centimeter spatial resolution, and one from both Tambo and Reyes using the satellite Pleiades-1 with 50 centimeter resolution (Figure 4.5). Both satellite images were taken during the dry season (Pleiades-1, 8/22/13; Quickbird, 7/17/2010) to ensure contrast between irrigated areas and the natural environment, and to show agricultural fields that have been abandoned by farmers. Image processing and classification was conducted with ArcMap using a hybrid unsupervised/supervised classification method (Kintz et al., 2006; Postigo et al., 2008; Walsh et al., 2003). In ArcMap, I first used an iso cluster unsupervised classification to create 30 unique values that were then grouped using a supervised classification based on ground referencing. The differences in kikuyu and other crops can be clearly delineated. This analysis created five categories to illustrate the current state of agriculture: non-agricultural landscape, dried kikuyu, kikuyu, partial kikuyu, and dense alfalfa/crops. The classified images show the current kikuyu spread, but also portray the evolution of this invasive species as fields slowly turn from healthy crops to complete kikuyu invasion, which typically leads to field abandonment.

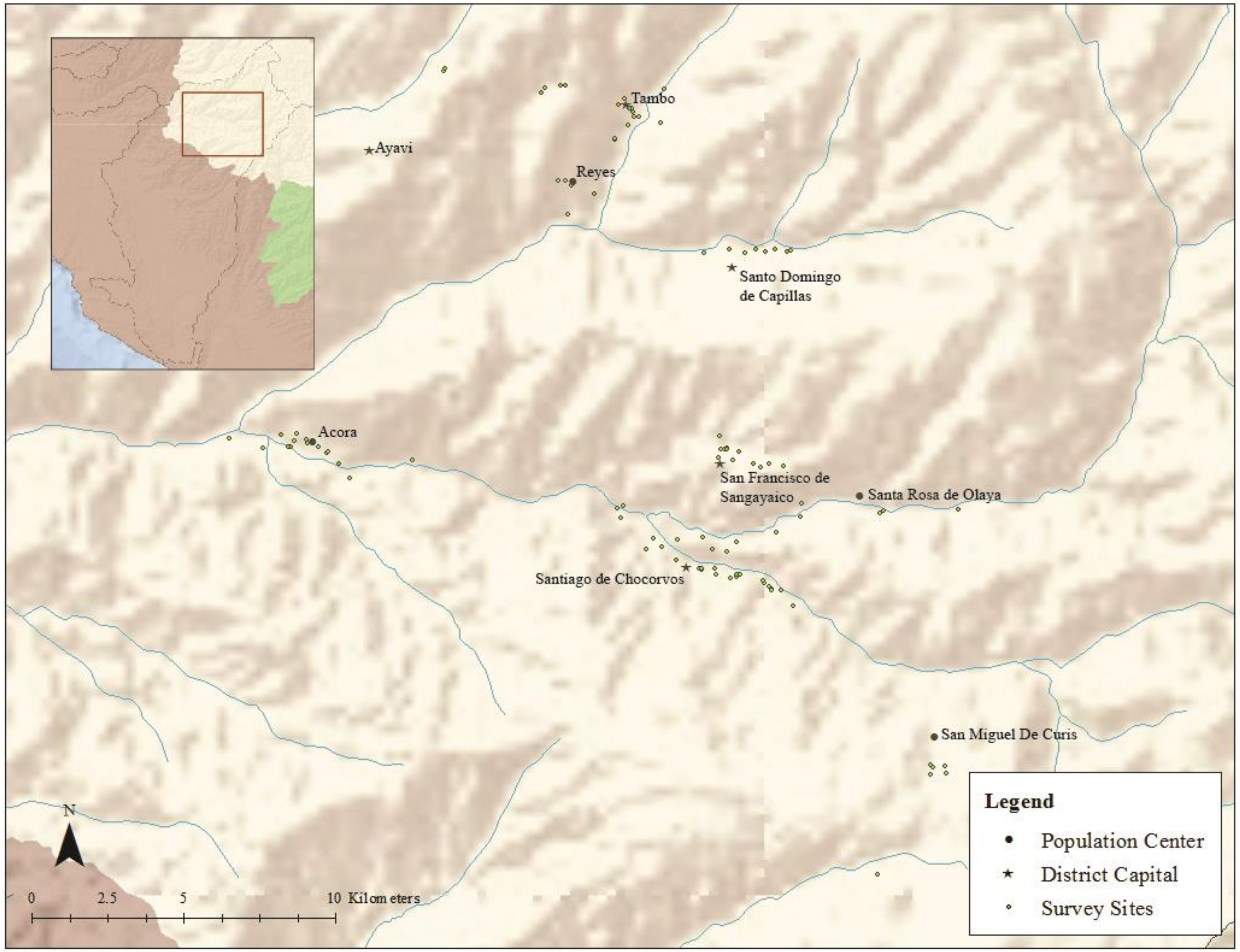

Figure 4.5: Map of survey sites with kikuyu.

Reyes

The first classified image is from the Pleiades satellite (8/22/2013) and consists of agricultural fields just below the town of Reyes (3,096 m.a.s.l.) (Figure 4.6; Figure 4.7). The farmers in Reyes spoke constantly about how kikuyu took over their fields and significantly lowered their agricultural production. This was clear during my visit as kikuyu blanketed the majority of agricultural fields. Reyes has much larger and flatter fields than many other areas within the upper RIWS, which makes it easier to analyze because terraces can often create shadows and make classification difficult. The analysis shows that 84% of the fields in Reyes had at least some form of kikuyu (Figure 4.8). Only 16% of their agriculture is untouched by kikuyu, and would be considered healthy or dense stands of alfalfa or other crops. The several stages of kikuyu encroachment can be seen in the image, particularly the 21% of the fields that are transitioning from alfalfa to kikuyu. These patches are a darker green than the lighter kikuyu because of the small stands of disconnected alfalfa that disrupt the invasive grass. Another 26% of the fields were completely invaded with kikuyu that is actively irrigated and used as pasture. The remaining 37% of agricultural land consists of dried kikuyu that is no longer irrigated. According to farmers, this land was once used as pasture, but the spread of kikuyu has decreased its use.

Figure 4.6: Pleiades satellite image (8/22/13) of agricultural fields in Reyes.

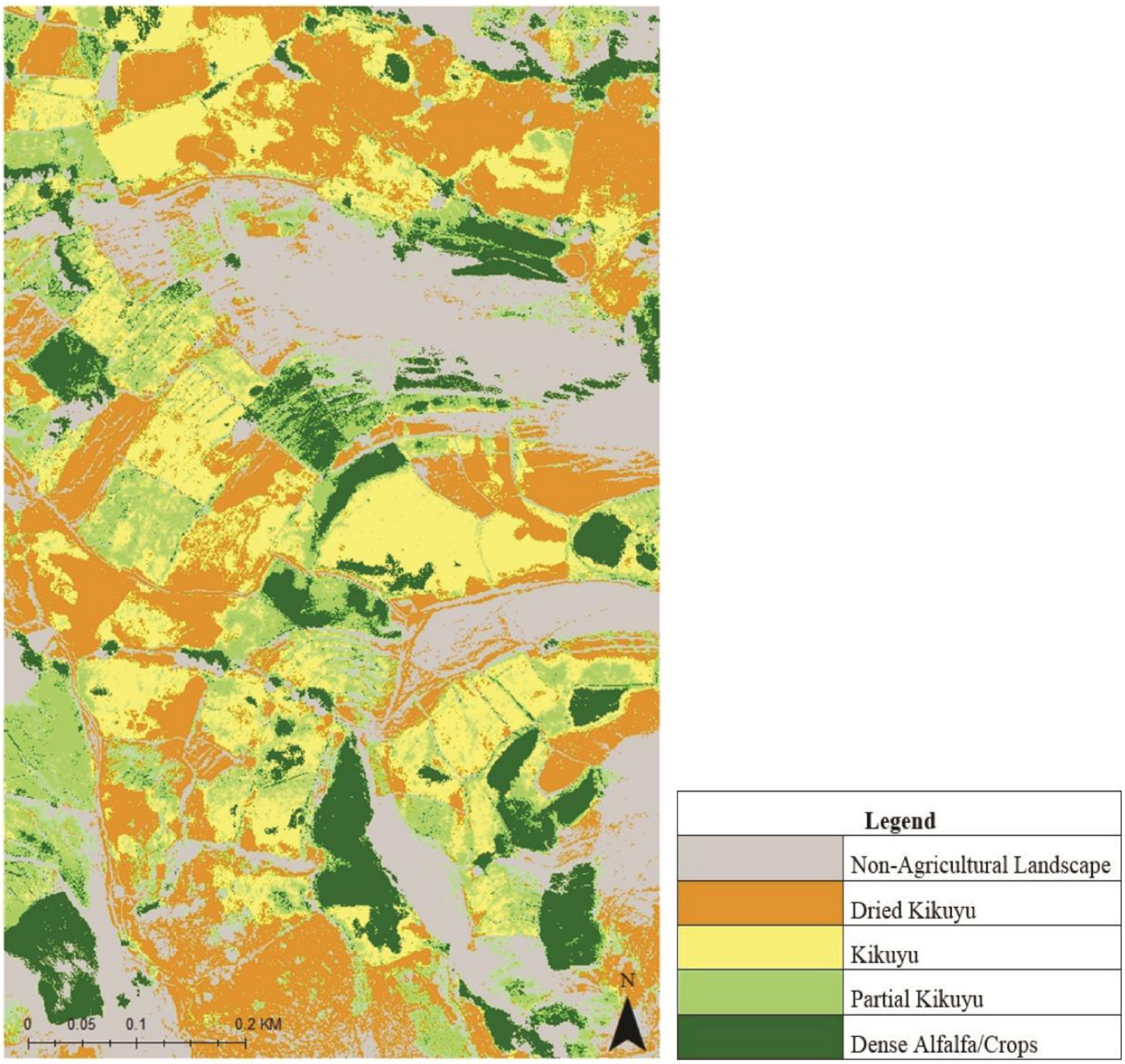

Figure 4.7: Hybrid (supervised/unsupervised) classification of Reyes fields.

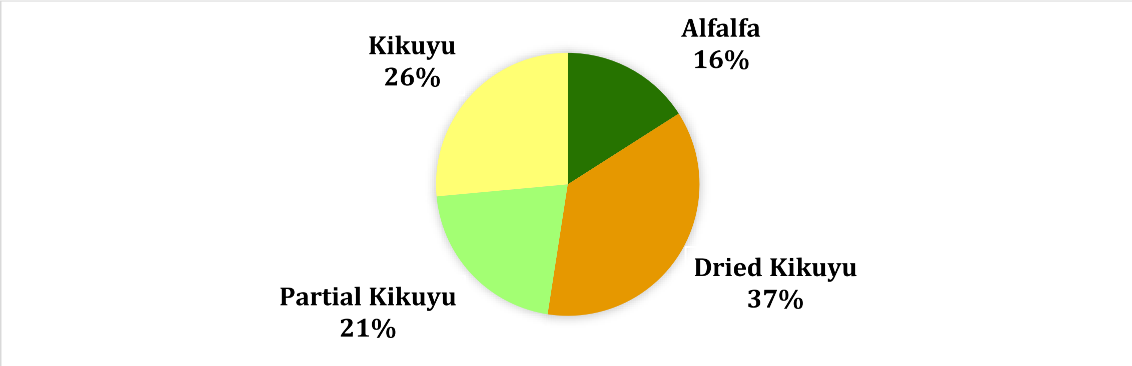

Figure 4.8: Breakdown of the hybrid classification within the Reyes agricultural fields.

Tambo

The second classified image is also from the Pleiades satellite (8/22/2013) and focuses on the fields below the town of Tambo (3,205 m.a.s.l.), three kilometers northeast of Reyes (Figure 4.9; Figure 4.10). The top left corner was cut from the image because including the buildings and streets of Tambo significantly increased the number of classes and creates erroneous classifications. The topography in Tambo is similar to Reyes, both have large sloping fields that have historically made them major centers for livestock husbandry. The results from Tambo show kikuyu encroachment similar to that of Reyes (Figure 4.11). Only 7% of the fields contain dense alfalfa or other crops. The fields in Tambo are 93% invaded with some type of kikuyu transition. These agricultural fields have 29% kikuyu invasion, 33% of the fields have partial kikuyu that is in the process of transition to full kikuyu. There is less field abandonment than Reyes, only 31% of the fields have dried kikuyu that is no longer cultivated.

Figure 4.9: Pleiades satellite image (8/22/13) of agricultural fields in Tambo.

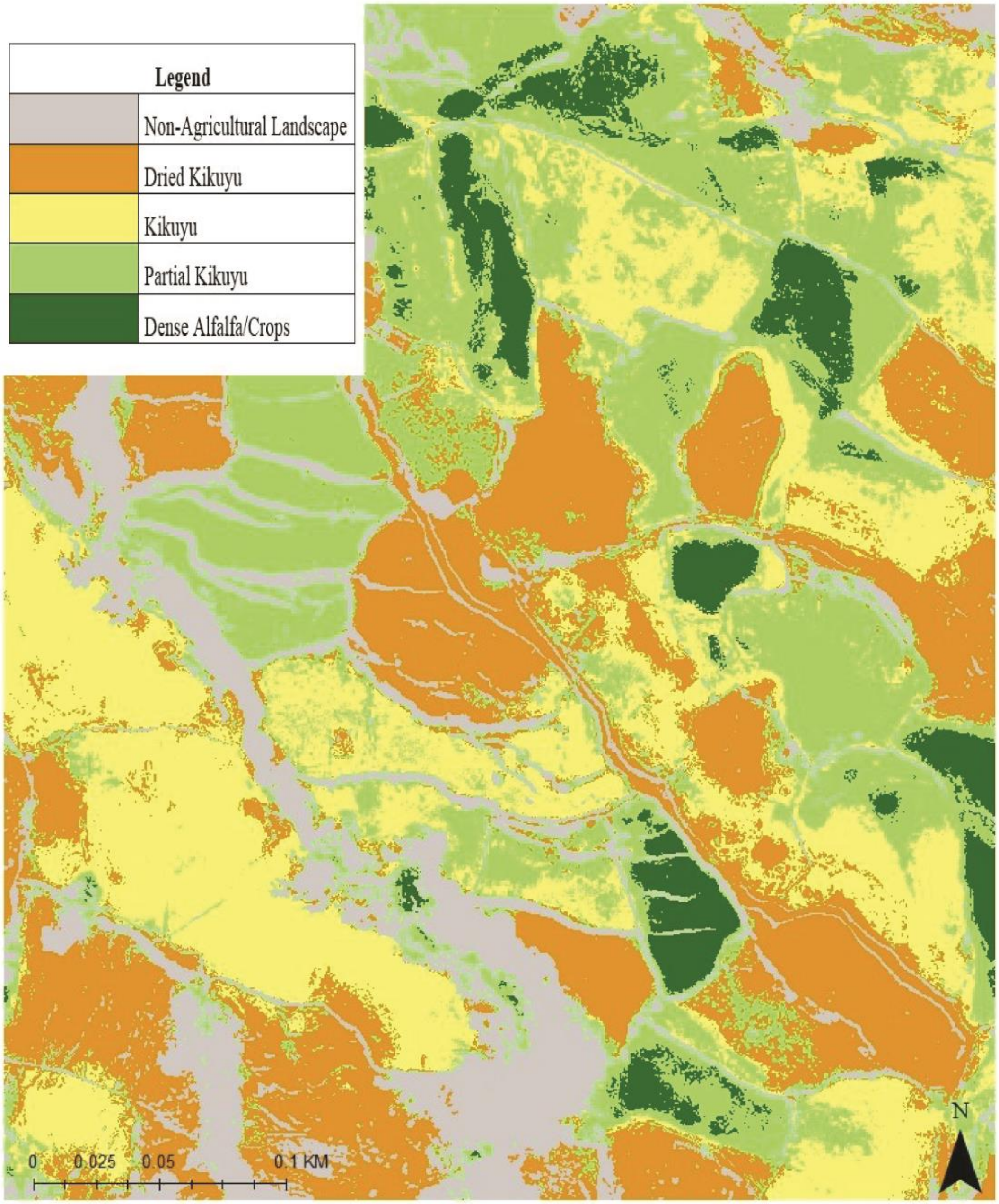

Figure 4.10: Hybrid (supervised/unsupervised) classification of Tambo agricultural fields.

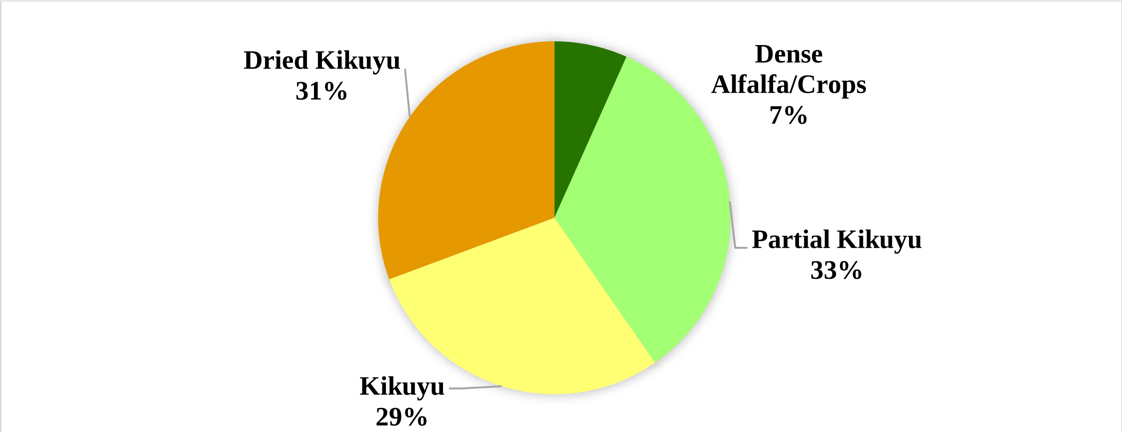

Figure 4.11: Breakdown of the hybrid classification within the Tambo agricultural fields.

Santiago de Chocorvos

The third image is from the Quickbird satellite (7/17/2010) and centers on the agricultural fields downstream from the town of Santiago de Chocorvos, 24 kilometers southeast of Tambo (Figure 4.12; Figure 4.13). There is much less available flat land in Santiago de Chocorvos so farmers rely heavily on terraced agriculture within the steep canyons. The satellite image was trimmed significantly to lessen the number of classes and analyze only irrigated agricultural land. Results show that 88% of land had kikuyu, and only 12% of represented dense alfalfa or other crops (Figure 4.14). Another 29% was partially invaded by kikuyu and 16% has undergone complete kikuyu invasion. The image from Santiago de Chocorvos also had 43% dried kikuyu, signifying that much of the agricultural land was not currently in use.

Figure 4.12: Quickbird Satellite Image (7/17/2010) of agricultural fields downstream of Santiago de Chocorvos.

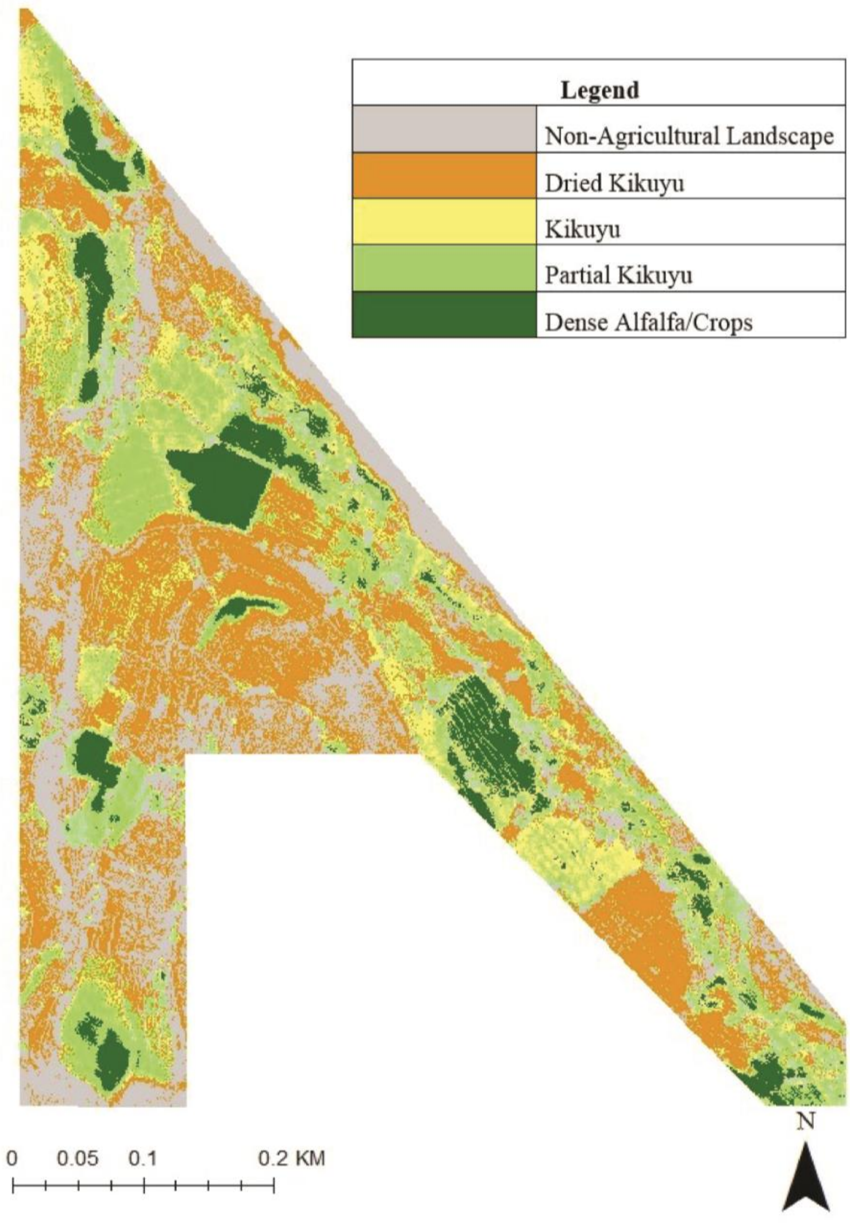

Figure 4.13: Hybrid (supervised/unsupervised) classification of Santiago de Chocorvos agricultural fields.

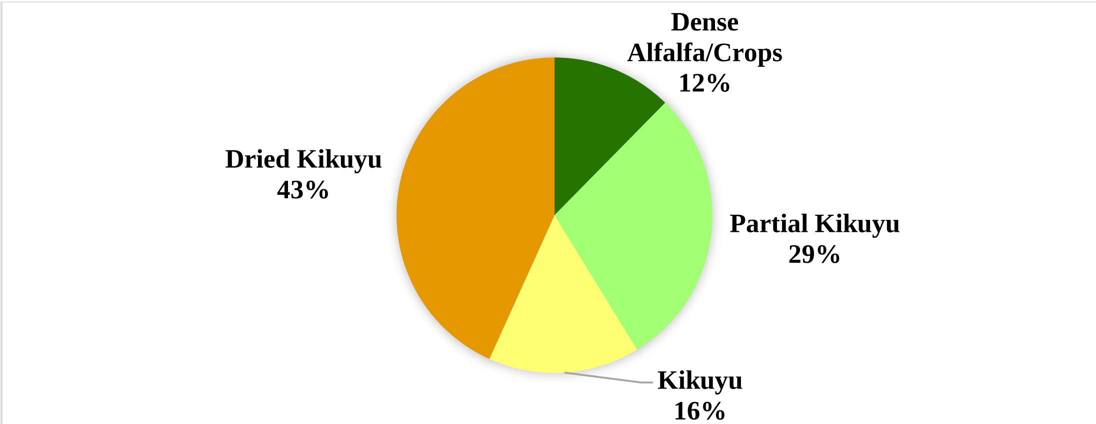

Figure 4.14: Breakdown of the hybrid classification within the Santiago de Chocorvos agricultural fields.

Results

All three images are representative of the upper RIWS within the ecological range of kikuyu with 88.3% of agricultural fields containing some form of kikuyu (partial, complete invasion, and non-irrigated) (Table 4.2). This quantitative evidence of invasion corroborates farmer statements and also emphasizes the inability to make significant steps toward its eradication. The images all show a similar pattern of kikuyu encroachment. Dense stands of alfalfa are surrounded on all sides by partial kikuyu that then slowly encroaches until it is invaded. Once a field is completely covered in kikuyu farmers are more likely to abandon it or at least lessen its use. Unfortunately, remote sensing satellites with the necessary high spatial resolution are not available in this region or previous years. A quantification of the spread of kikuyu over time is currently unavailable.

Table 4.2: Percentages of kikuyu distribution among the three satellite images.

	Reyes	**Tambo**	**Santiago de Chocorvos**	**Average**
Dense Alfalfa/Crops	16	7	12	11.7
Partial Kikuyu	21	33	29	27.7
Kikuyu	26	29	16	23.7
Dried Kikuyu	37	31	43	37.0

The images portray a landscape that is not in the process of kikuyu spread, but instead one that has already been invaded. The three images all show over 84% of fields classified showed some type of kikuyu. The remote sensing analysis corroborates farmer statements on the effects of kikuyu and the need for effective kikuyu management strategies. Management strategies that remove kikuyu and prevent its encroachment are clearly needed.

Kikuyu Management

There is an assortment of techniques used to remove kikuyu. Certain removal methods are an extension of traditional agricultural practices, while others apply modern approaches, often backed by governmental and non-governmental organizations. The applicability and sustainability of both traditional and modern removal techniques differ as farmers struggle to control kikuyu and maintain agricultural production.

The most common removal technique is manual labor. Farmers first stop irrigating a field and let the kikuyu dry out. It loses its light green color and turns a yellowish brown and remains dormant until it has access to water. This weakens the roots, making it easier to remove manually using *baretas* (large crow bars) or *chakitaqlla* (Andean human-powered plow) (Figure 4.15; Figure 4.16). The roots and stolons of the kikuyu are then exposed, and farmers take advantage of the solar radiation to kill it. Farmers leave the kikuyu exposed to the sun for 15 to 20 days. Next, they use *baretas* to further break apart the root system and leave the soil behind. The kikuyu that is left is typically burned to ensure that it is completely destroyed. This process is time-consuming and relies on a surfeit of manual labor.

Figure 4.15: Farmers manually removing kikuyu with *baretas*.

Figure 4.16: A *chakitaqlla* in a field of dried kikuyu.

Historically, farmers relied on a communal work system known as a *faena* in which farmers worked together on a particular field on a given day and then rotate. Using *faenas*, farmers can complete large projects in a single day and stop the spread of kikuyu so the field can be quickly replanted. Rural to urban migration now limits *faenas,* as many farmers from the upper RIWS leave for wage labor jobs in export agriculture in the city of Ica, leaving less available labor. Farmers continue to conduct *faenas*, but they are now infrequent. A piecemeal removal of kikuyu is ineffective because of its rapid growth. One farmer eradicating a small stand each day is not enough to stop its spread and will not permit the replanting of a new crop. Farmers simply lack the hours needed for removal, an exhausting and endless job. Many farmers concede defeat as there is an overabundance of other agricultural tasks that demand their attention.

Manual labor as an eradication tool does not always require the complete removal of kikuyu from a field. Virtually every healthy, dense stand of alfalfa within the upper RIWS necessitates constant maintenance to prevent kikuyu encroachment. Farmers remove the encroaching kikuyu by hand and with *baretas* on an almost daily basis. Without constant vigilance, a healthy stand of alfalfa (Figure 4.16) can rapidly be invaded by kikuyu, which is then is difficult to eradicate. This problem is exacerbated by rural to urban migration and an increased reliance on off-farm labor. There are less farmers consistently present in the fields and thus much of the daily field tasks are not done, which further intensifies kikuyu spread.

Figure 4.17: Healthy stand of alfalfa with kikuyu encroachment around canal.

Another removal strategy used in conjunction with manual labor is the application of herbicides. Of the farmers surveyed with kikuyu within their fields, 66% (33/50) stated that they applied herbicides as a management strategy. Farmers and development workers stated that glyphosate, a broad-spectrum herbicide, is the most commonly applied. Monsanto's patent on glyphosate ran out in 2000 and thus it is a less expensive option (Duke and Prowles, 2008). One farmer from Tambo (3,261 m.a.s.l.) spoke about the application of herbicides and stated, "I use Roundup [active ingredient is glyphosate], but it is like a bomb [kills everything]. I have to turn the soil over and expose it to the sun (*Uso Roundup pero es como una bomba. Tiene que voltear la tierra y dejala en el sol*)."

Another Tambo farmer has had less luck with herbicides and stated, "Now [kikuyu] it has invaded. Poison does not work. We need a plan to eliminate this pest. It is contagious and moves from field to field (*Ahora esta invadido. Veneno no funciona. Necesitan un plan a eliminar esta plaga. Contagia de una chacra a otra*)." The use of herbicides is problematic for these smallholder farmers, as they live more than four hours from the city of Ica and rarely have consistent access. Farmers also have minimal income from sources outside of their agriculture and thus lack the sufficient capital to purchase herbicides. The application of these chemicals can also put a farmer at risk if they are not properly handled.

Government and non-governmental groups promote new removal strategies that are in nascent and experimental stages. Traditionally, farmers in the upper RIWS herded livestock between disparate fields. A farmer may own several stands of alfalfa, but they are kilometers apart and at differing elevations. Farmers also herd their animals amongst native vegetation during the rainy season. As livestock move between fields they spread kikuyu seeds and colonize new areas. Even farmers that work diligently to keep kikuyu out may be affected by a neighbor's animals as livestock pass through or above their field. The cessation of animal herding could limit the colonization of new kikuyu stands and give farmers a foothold in eradicating kikuyu.

Several development agencies are promoting managing livestock in a central location in stables and then bringing the forage to them, which would mimic modern livestock management. Centralized livestock management would lessen the spread of kikuyu through livestock feces. It would also increase milk production as animals would be at less risk of injury moving across steep terrain to get to new fields and would expend less energy. Only a small number of young farmers apply this strategy because it requires large capital inputs and contrasts significantly with traditional livestock management strategies. One younger farmer in Acora (1,937 m.a.s.l.) experimented with keeping his animals in stables and saw both positives and negatives, “The cows are bigger and the calves grow faster, but it requires much more work *(Hay vacas grandes y los ternitos crecen mas rapido pero necesita mas trabajo*).” The number of animals is limited because farmers can only cut and transport enough forage for three to four livestock at a time. Transporting cut alfalfa is a labor intensive process that requires much more work than herding livestock between fields. Rural to urban migration decreases the available labor to help cut and alfalfa, so that farmers are more likely to herd their animals from place to place. Many agricultural engineers that visit the region push the use of stables, but its implementation is miniscule because it requires farmers to drastically change their animal herding practices and relies heavily on manual labor, something that most farmers cannot spare.

In addition, some development agencies promote the usage of mechanical tillers to break apart the kikuyu using much less manual labor. The steep topography and narrow terraces make the use of large conventional tractors impossible. However, farmers petitioned development workers to help purchase tillers that could quickly break up the kikuyu and can be moved easily between fields. An investment into this machine may help farmers overcome the lack of available manual labor, but they are also expensive and require significant capital inputs and repairs that may make their application impractical.

When livestock graze alfalfa, the field is susceptible to kikuyu invasion, which quickly encroaches alfalfa (Figure 4.18). Several development agencies encourage farmers to plant alfalfa more densely than they would otherwise or to multi-crop with more suitable grasses, such as ryegrass, so that there is not space for kikuyu to encroach. When a field is densely planted, the kikuyu roots cannot penetrate and the invasive grass is shaded out.

Figure 4.18: Cow grazing on alfalfa in a field with kikuyu encroachment.

Farmer statements on kikuyu were overwhelmingly negative, though several farmers also recognized that kikuyu now played an integral role in their agropostoral system. Farmers acknowledged that feeding their livestock kikuyu instead of alfalfa reduces the number of cows they can maintain, and consequently lowers milk production. Paradoxically, the spread of kikuyu also forced farmers to rely on it. Livestock can survive on a diet with a consistently high amount of kikuyu, but they will not thrive on it. A heavy kikuyu diet limits the number of animals they are able to raise, and they produce minimal milk. Farmers also recognized that a diet that is dominated by alfalfa can contain an overabundance of protein and may lead to a disorder known as tympanism, the distention of an animal's abdominal cavity. Therefore kikuyu that is paired with alfalfa can prevent tympanism as there are no other significant grasses that are grown in the upper RIWS. Some development agencies have worked to introduce a forage crop known as ryegrass to increase diet diversity, but its cultivation to date is minimal.

Despite its shortcomings, kikuyu grass has one undeniable positive quality—its capacity to stabilize soils. The intense rainy season in the upper RIWS can loosen soil and cause significant erosion. Kikuyu has helped to preserve many of the abandoned terraces throughout the upper RIWS because it can handle intense livestock treading. Even with these slight benefits, economic costs associated with the unwanted kikuyu grass invasions of cultivated fields and the fruitless eradication attempts have far outweighed the original hypothesized economic advantages (Browman, 1983). Kikuyu creates significant challenges for farmers and development agencies and further increases farmer vulnerability.

Discussion

Kikuyu is a significant agricultural limitation for farmers in the upper RIWS and throughout similar regions of Peru, yet it is mentioned only in passing by most academic research on Peruvian agriculture. Most research and development agencies would rather focus on the more compelling—and more importantly, fundable—topic of climate change than the eradication of an invasive grass. There is an urgent need for more research on how farmers can collectively respond to kikuyu as it is often a significant hindrance to other agricultural projects. During conversations with several development agencies, frustration with kikuyu was palpable, and all of their future plans involved some form of kikuyu management. Several development agencies that were focused on helping farmers to adapt to climate changes found that farmers struggle with climate changes, but that kikuyu is a larger agricultural threat. Without a strong kikuyu management strategy embedded within climate change adaptation plans, there will be little impact.

New research states that kikuyu may be an indicator of climate change. Kikuyu is a C4 photosynthetic plant, which are better adapted to lower elevations that are drier and hotter, while C3 plants are found at higher elevations. The presence of kikuyu at higher elevations (up to 4,000 m.a.s.l.) suggests that this altitudinal expansion of more C4 species, like kikuyu, may be an indicator of climate change (Giraldo-Cañas, 2010;

Hernández et al., 2012). However, the temperature changes in the upper RIWS to date have been minimal, suggesting that while the spread of kikuyu may be amplified by climate change, it would likely be occurring in its absence. The kikuyu-climate change connection does imply that climate change will likely worsen the effects of kikuyu in the upper RIWS. Therefore, climate change adaptation programs must include effective kikuyu management programs.

Removing kikuyu is a difficult task and its eradication is considerably limited by a farmer's lack of resource access. In many areas of the upper RIWS, kikuyu is such a problem—particularly when it compounds existing stressors—that many farmers leave their fields and migrate to the city. Many of the most effective kikuyu removal options (tillers, herbicides, dense multi-cropping, modern livestock management) require major changes in farmer practices that older farmers are unwilling to make. Farmers that do not have the capital to purchase herbicides to kill kikuyu often migrate to the city because they find that their agricultural fields are now useless.

Livestock management is a primary source of income for farmers in this area. Many of the development agencies are encouraging farmers to maintain traditional agricultural strategies, but kikuyu requires modern agricultural instruments to eradicate. The use of chemical fertilizers and other types of modernization can still be seen as "indigenous." This modernization when integrated traditional techniques still supports the overall objective to increase food sovereignty by sustaining the local populations and thus helping to prevent migration, a more serious threat to indigenous identity than the implementation of a new technology (Bebbington, 1993).

Conclusion

British agricultural scientists introduced kikuyu with good intentions, to expand forage crops available to farmers. The effects, however, like many "benevolent" agricultural additions, had unintended negative consequences. Over the last 100 years, kikuyu spread throughout Peru and pushed out vital crops. Within the upper RIWS, it has steadily invaded alfalfa fields and severely limited agricultural production and can eventually reach a threshold that forces farmers to abandon their fields. During surveys, farmers listed kikuyu as the primary challenge to agriculture, above other impediments that include "lack of water", "agricultural pests", and a "lack of manual labor". The classification of three satellite images corroborated farmer observations and showed that kikuyu dominated agricultural fields.

Current kikuyu management strategies are ineffective. Manual removal strategies that rely on reciprocal work parties may have been efficacious during previous times of higher population density but are now hampered by a shrinking and aging population. More modern strategies involving herbicides and small machinery are effective, but they often require consistent capital inputs that are beyond the financial means of most smallholder farmers. They also necessitate that farmers drastically change their agricultural strategies. The few options left to smallholder farmers in the upper RIWS leave them in a precarious situation. When combined with other factors that include climate changes, market forces, and outmigration, the future of smallholder farming in the upper RIWS is in doubt. There is a paucity of academic literature on how kikuyu impacts agricultural strategies. More research is needed on the incorporation of kikuyu management into larger climate change adaptation plans in this region and in similarly affected areas throughout the Andes. Ironically, kikuyu has helped increase agricultural production though not in the upper RIWS. Outmigration provides a steady labor force for export agriculture in the Ica valley. Smallholder farmers who once controlled their own land and cultivated using long-standing agricultural strategies are now paid daily wages to pick exotic crops for foreign plates.

CHAPTER FIVE

Opportunities and Obstacles: Smallholder Agriculture and Development Programs in the Twenty-First Century

Abstract

Smallholder farmers in the upper Rio Ica watershed (RIWS) face a variety of challenges that limit agricultural production, forcing field abandonment and outmigration. In the upper RIWS, smallholder farmers are supported heavily by governmental and non-governmental organizations that work to increase farmer resiliency. However, conflicts and frustration often arise, as many of these programs have limited long-term success. This chapter details the types of development organizations that support farmers (international, national, regional, and local) and describes how their projects function. It also shares farmer perspectives on development and their specific aid requests. Results show that both neoliberal and poststructural ideas of development are inappropriate for the upper RIWS, and that hybridity approach is most effective. The future of smallholder agriculture in this region is not determined, but it must find new strategies to stem outmigration and field abandonment.

Introduction

When visiting the remote mountain communities within the upper RIWS, and throughout similarly isolated mountains across Peru, it is easy to envision an uncertain future for smallholder agriculture. Many homes are vacant because the number of farmers has decreased significantly over the past 30 years. The younger generation prefers opportunities available in the large coastal cities. Aging farmers are often the only ones who continue to work these remote plots. The enduring question is: what is the future of smallholder agriculture in these remote, mountainous communities? It would be easy to conclude that this way of life is finished and that nearly all Peruvians will soon live in coastal cities, but this is not a foregone conclusion. Coastal migrants still maintain significant connections to their ancestral hometowns that are more complex than a unidirectional outmigration. Livestock, dairy products, and crops from these smallholder communities continue to be brought to market in Ica, providing income for farmers remaining in the *sierra*. Migrants who leave for the coast often return to live in the upper RIWS part time. There are certain challenges to smallholder agriculture in the RIWS, but its future is complex and uncertain.

Farmers in the upper RIWS include smallholders who cultivate along the steep slopes of the Andes using intricate canal systems, and herders who move camelids in the *altiplano*; both have minimal resources and are politically and economically marginalized. Their needs for development vary by altitude, though they are both limited by a paucity of water. Substantial investment from governmental and non-governmental agencies is spent in the upper RIWS, but many development programs regularly face opposition from the community, and few have long-term success. Farmers in these communities face numerous challenges in addition to young people emigrating, including climate changes, fluctuating market prices, and invasive species.

It would be presumptuous to proclaim a specific solution to support smallholder agriculture, especially when such a large number of experienced and hard-working development agents have made it their life's work. The goal of this chapter, therefore, is to provide a case study on how development programs support agriculture within the upper RIWS and the decision-making process that communities undertake to improve their lives. It will focus on the specific conflicts and disagreements that arise between development agents, local community leaders, and farmers.

This chapter is also careful not to simply romanticize or encourage "traditional" smallholder practices. Instead, it elucidates myriad livelihood strategies that smallholder farmers use to continue cultivating their land. Many farmers still practice "traditional", intensive, permanent, and diversified agriculture primarily for subsistence purposes, but they are also applying new modern agricultural techniques that keep them cultivating, and they are participating in the regional market through the sale of agricultural goods or wage labor. Coastal migration, rapidly shifting market prices, and irrigation limitations from climatic variation create significant challenges, but they also create opportunities to lessen agricultural vulnerability and promote sustainable practices.

Study Area

The study area is focused on the upper RIWS, allowing for an understanding of how development projects function across a transect, not just in one particular area. Fieldwork was conducted between 1,760 and 4,392 meters above sea level (m.a.s.l.) (Figure 5.1). The RIWS transitions from the highly arid and warm coast to the moist and cool *altiplano,* moderated by the cold Humboldt Current, the steep relief of the Andes Mountains, and the South Pacific Anticyclone. Precipitation is highly seasonal and falls only between December and May. The mountainous environments within the RIWS have high climatic variability and uncertainty, and microclimates created by slope, aspect, elevation, and exposure can have differential effects on water resources, agrobiodiversity, and native ecosystems (Pepin and Lundquist, 2008; Buytaert et al., 2010; Veteto, 2014). This extreme topographical variation often supports high biodiversity, endemism, and microrefugia in both natural and agricultural systems (Zimmerer and Douches, 1991; Perrault-Archambault and Coomes, 2008; Dobrowski, 2011).

Smallholder farmers in this landscape grow primarily alfalfa (*Medicago sativa*), an introduced species of forage legume used as a feedstock for cows, sheep, and goats. These smallholders also cultivate potatoes, corn, wheat, barley, quinoa, and lima beans. They produce predominantly for household consumption but also for the local and regional market in Ica. Farmers rely on traditional Andean agricultural strategies that include pre-hispanic terraces and canal irrigation to cultivate in a semi-arid, mountainous landscape. Herders are found in the high Andean grasslands (above 4,000 m.a.s.l.) of the upper RIWS. They base their system of production exclusively on raising camelids (llamas and alpacas) and sheep, as cold nighttime temperatures prohibit cultivation. Both of these landscapes are largely indigenous, and some still speak Quechua as a first language, particularly members of older generations. Crop cultivation and livestock management, when combined with strict cultural norms of family and community relations and trade practices, offer families diverse means of food security, even in the extreme landscapes of the high Andes, and may still do so in the context of global change (Zimmerer, 2014).

The upper RIWS is an ideal environment to study how a conglomeration of development projects—conducted by both governmental and non-governmental organizations—work to increase adaptive capacity. The upper RIWS lies within the region of Huancavelica, which ranks highest in the country for levels of childhood malnutrition, access to resources (Human Development Index of 0.49), and poverty (average monthly income of US $49 and 86% of population in the department lives below the poverty line) (INEI, 2007; Hepworth et al., 2010). The population centers within this region are five to seven hours by *colectivo* from the populated coastal areas. This isolation leads to a heavier reliance on "traditional" agricultural strategies, and also creates a clear distinction between corporate agricultural methods in the Ica valley.

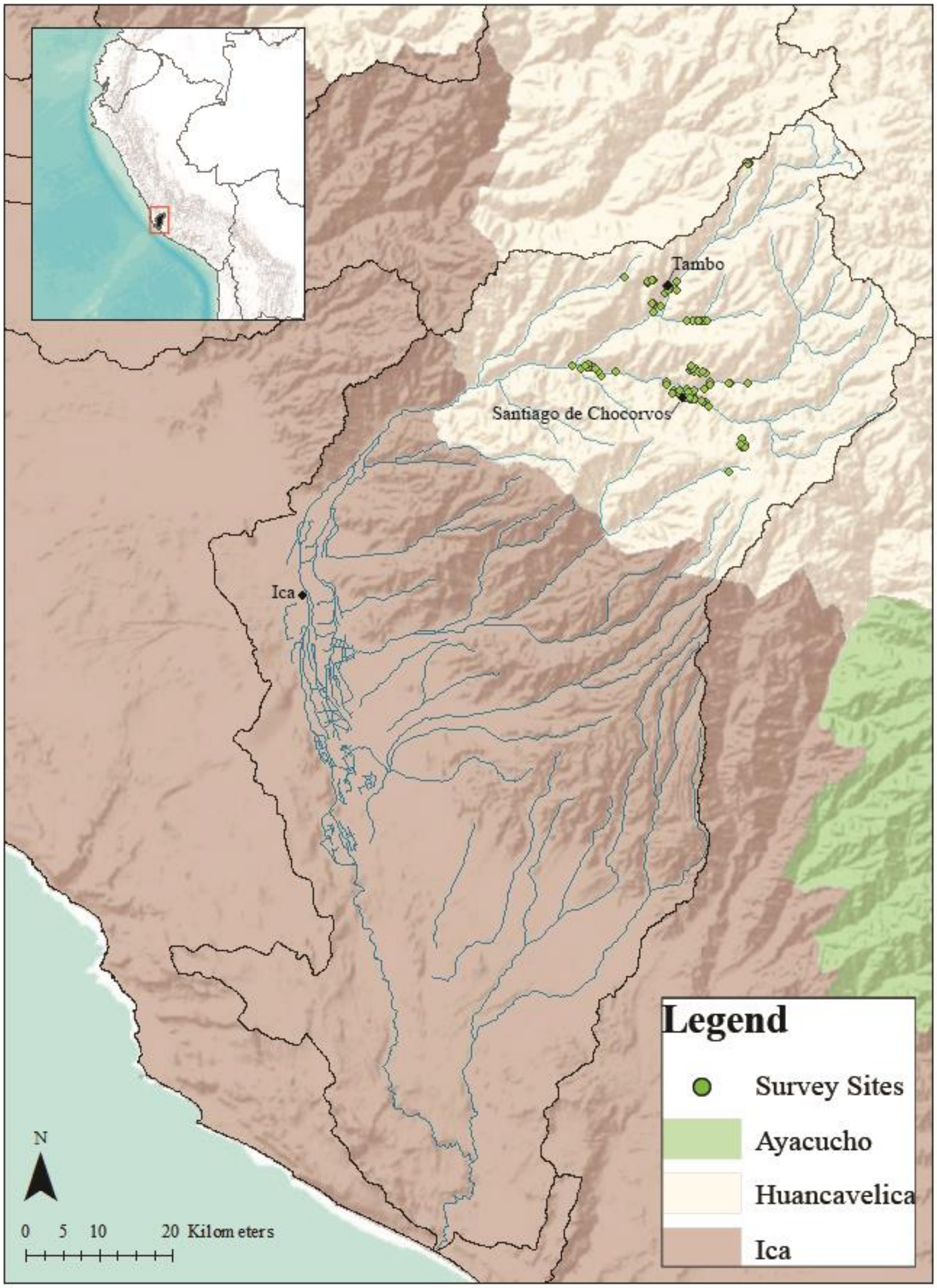

Figure 5.1: Map of the Rio Ica watershed with regions.

Methods

This study uses two primary types of data: semi-structured interviews and farmer surveys. Fifty-five semi-structured interviews were conducted with different actors in the RIWS, including four corporate farmers in the Ica valley, seven development agents not associated with the Peruvian government, 10 female leaders, 13 government officials, and 18 smallholder farmers. Because the focus of this chapter is on how development programs affect smallholder farmers, these interviews are its core. The impetus is to understand smallholder farmer realities and how they interact with development agencies, recognizing that this relationship can have both positive and negative effects on farmer livelihoods. Interviews with development agents (both non-governmental and governmental) allowed them to describe their program's goals and implementation.

This study also relies on data from 105 farmer surveys. The majority of farmers surveyed were male, and the average age was 56 years old with an age range of 23 to 86 years old. Whenever possible, surveys were conducted at the farmer's field to document their agricultural strategies and to mark each survey site with a GPS point. The primary focus of the farmer surveys is to analyze how modern climate affects farmers (Chapter Two) and what types of agricultural strategies farmers apply in response (Chapter Three). The farmer surveys also included questions on their concerns and forms of aid that they feel are the most beneficial.

Along with these formal interviews and surveys were hundreds of informal conversations with farmers and development agents during my 12 months of fieldwork. I lived in several small towns in the upper RIWS for months at a time and attended community meetings, participated in town festivals, and gave talks at the local schools. My intention was to develop relationships that extended past a 30 minute survey. As an international researcher, I was also granted access to meetings and interviews with development agents in the upper RIWS and in their headquarters in the cities of Lima and Ica. I heard both sides of the development narrative and maintain a neutral positionality.

Drivers of Smallholder Agricultural Change

Agriculture within this high altitude, arid environment of the upper RIWS has always been challenging. The steep mountain slopes leave little flat land and climatological patterns limit crop diversity. In response, farmers devised agricultural strategies and communal work practices that evolved to thrive within this distinctive socio-ecological system. More recently, challenges to agriculture in the upper RIWS have moved past typical climate variability, and farmers now face “double exposure” as global environmental change and globalization are fundamentally altering livelihoods (O’Brien and Leichenko, 2008).

The biophysical environment of the RIWS has continually presented difficulties, but now global environmental change, primarily through climate changes and the effects of an invasive grass species, is significantly limiting agricultural production, as time-tested agricultural strategies appear to be less effective. These environmental changes impact crop productivity, species diversity, and water availability. Smallholder farmers possess the necessary tools and techniques to combat these challenges. However, when combined with other external forces that weaken their adaptive capacity, many farmers abandon smallholder agriculture altogether.

Globalization is generally understood as a movement towards greater economic, political, and cultural integration across nations (Sklair, 2002; Dicken, 2007). Within the upper RIWS, globalization-related transformations include international trade and investment, increasing travel and migration, expansion of communication networks, the emergence of mass media, and the homogenization of a consumer culture. The upper RIWS has never been completely isolated, but recent changes have reduced the transportation and communication costs and time, effectively bringing their world into the global context (Harvey, 1990).

This chapter does not label globalization as benign or malignant. Instead, it illustrates that globalization can have significant impacts on agriculture, and that these impacts need to be recognized and understood in order to ensure sustainable development. Some farmers enjoy increased yields through the transfer of new technologies. However, globalization can also make their agricultural products less competitive on the regional market and floods the upper RIWS with cheap products. In addition, globalization creates a surfeit of employment opportunities within export agriculture in the Ica valley, a major driver of out-migration.

A human-environment discourse emphasizes the linkages between social (globalization) and physical (global environmental change) systems. Such a “coupled social-ecological" system is characterized by continual interactions between physical and social processes, and the notion of the natural environment as being inseparable from human activities (Berkhout et al., 2003; Easterling and Polsky, 2004; Clark et al., 2005). The activities of smallholder farmers in the upper RIWS and the environment in which they cultivate are inextricably linked to the larger social process occurring within and outside of the region.

Results

A number of organizations have programs that operate on international, national, regional, and local levels. A complete list of all of the organizations that have worked in the upper RIWS is not available, as many come and go. Findings of those surveyed do illustrate how development projects are completed, their hierarchical structure of support, and numerous common conflicts.

Within the upper RIWS, development programs do not simply provide funds or improve agricultural infrastructure, they stimulate the growth of local networks, and bring knowledge, ideas, and experiences from the outside. They also provide climate data that can be of value to farmers.

International Programs

International development agencies play an important role in Peru. They generally have abundant resources, and they represent the principal goals of their country of origin.

There are two active international development agencies in the upper RIWS: 1) The German Federal Enterprise for International Cooperation on Adaptation to Climate Change in Ica and Huancavelica (GIZ-ACCIH); and 2) Asociacion Instituto Integral de Desarrollo Comunal (INDESCO).

GIZ-ACCIH is the only development agency within the upper RIWS that has an explicit climate change focus. GIZ-ACCIH works to increase resiliency for farmers facing the effects of climate change, with an emphasis on the most vulnerable populations. GIZ-ACCIH was my primary fieldwork contact, and I was able to see firsthand how they directly interacted with farmers. Their work has four separate objectives: 1) to help construct safer and more secure homes, both against the elements and to improve in public health; 2) to foster dialogue between the various, and often conflicting, actors; 3) to strengthen cooperation with institutions having similar goals; and 4) to increase agricultural adaptations to climate change. Objectives one through three are beyond the scope of the study, and are only briefly mentioned in this study, while the fourth is clearly agriculture related.

The practices that they foster are concerned with the management and conservation of natural resources (soils, water, and forests) and the development of agricultural, livestock, and forests activities. GIZ-ACCIH has numerous projects that work toward the same goal. One focus of their agricultural line is the protection and conservation of water sources. GIZ-ACCIH works to increase the agricultural infrastructure by protecting high elevation sources of water and building infiltration ditches that increase percolation. They also assist farmers by providing materials, capital, and expertise in constructing water storage pools that capture precipitation during the rainy season, so that it can be used later. In addition, GIZ-ACCIH promotes water conservation using sprinkler irrigation so that farmers apply much less water than long-standing irrigation methods of periodic field flooding.

As a group with a climate change mandate, GIZ-ACCIH deliberated in staying within the strict guidelines of their mission statement in order to increase adaptive capacity to climate change. Many of the problems facing farmers they found are not directly tied to climate change. They realized that climate changes did have major impacts on farmers, but that there are a plethora of other factors that farmers face. Therefore, to support farmers in responses to climate change, investment in a variety of other strategies that are more acute challenges to agriculture is also vital. A changing climate is a major component of the decrease in crop production, along with migration to the coast. Even under ideal agricultural conditions, farmers may decide to leave the upper RIWS.

A common problem with many development projects is that they are introduced without a long-term implementation plan or discussion with the local community. Dr. Carlos Herz, a consultant for GIZ-ACCIH who has worked in development projects in Peru for nearly 20 years, summarized this problem:

> …Technologies that are forcefully introduced will work only while the project is working. When the project is over they collapse…more than 50%

of projects fail like this. They begin with the best intentions, but after the project funding runs out, the project does not work.

…Las tecnologías introducidas a la fuerza funcionan mientras tengas el proyecto funcionando. Cuando acabo el proyecto, esto colapsa...más que 50% de los proyectos fracasan así. Uno va con la mejor intención y después esto proyecto no funcionan más cuando se acabó el financiamiento.

Dr. Herz believes that one way to prevent such failure is to empower those who benefit from the project. However, this method of involving and working with the local population is slower and more complicated. Most projects are financed for one or two years, and therefore cannot move at a slower speed.

In response to such a problem, GIZ-ACCIH is working with new development strategies that empower the local population to prevent project collapse. This new program is facilitated by both the regional government and GIZ-ACCIH, and places an agricultural expert, known as a *kamayoc*, in remote villages to help with the implementation of new agricultural technologies. *Kamayoc* is a Quechua word that signifies, "He who knows (*El quien sabe*)", typically trained in Cuzco. They live amongst the community for one year and will help farmers with problems implementing new technologies. This may entail fixing a leaky sprinkler system or providing veterinary medicines for sick livestock. Their presence in the community is key to sustainable application of new technologies. While many other development agents may only be in the community for hours at a time, the *kamayoc* are a consistent presence in constant communication with farmers. A *kamayoc* also provides important information to development programs so that funds can be dispersed more quickly and projects can be continually monitored.

The second international organization working in the upper RIWS is INDESCO, a non-governmental organization with funding from *Bread for the World*. Its three goals are to improve public health, increase crop production, and foster market associations. INDESCO's programs are not explicitly linked to climate change, though their representatives detailed a reforestation campaign directed toward the reduction of atmospheric carbon dioxide.

A primary component of INDESCO's work in agriculture is to increase irrigation efficiency and to reduce soil erosion. INDESCO has invested heavily in irrigation for Sangayaico, a small town that is water-stressed. They have worked to increase water retention by building infiltration ditches at higher elevations. This aids in irrigation by raising the water table and increasing stream flow. Another component of INDESCO's work is building fences at higher elevations to close off native pasture, giving pastures more time to rejuvenate. Much of the current available pasture has been degraded through overgrazing. By isolating high pastures, INDESCO is nurturing native seeds and rejuvenating natural pastures (Figure 5.2).

Figure 5.2: Fence built by INDESCO to prevent grazing and allow natural pasture to rejuvenate. The left side is protected while the right has been overgrazed.

International development programs typically focus on projects that are beyond the financial and organizational resources of the local community, such as the improvement of irrigation networks. Their work is important and much needed for the long-term success of the community. Smallholder farmers in this region also benefit from the consistent presence of agricultural engineers. Both GIZ-ACCIH and INDESCO have numerous workers living in this region.

National Programs

In addition to foreign-funded programs, there are several nationally funded projects in the upper RIWS. Each of these programs has a different mandate and goals. Some focus on social service monies, others on the regulation of resources, education, medical support, and specific agricultural improvements. All of these programs use different strategies, but they all serve to increase the adaptive capacity of smallholder farmers.

Social Service Monies

"Pension 65" is a national program that gives social service monies for those over the age of 65 living in extreme poverty, according to census statistics. Participants receive 250 Peruvian soles (~ US $81) every two months, and the money is dispersed in the district capitals. This money can be difficult to obtain as elderly residents have to register for the program, and the travel to the district capitals can be long and arduous. For many older farmers, "Pension 65" is their primary safety net. These older farmers rely on their agricultural output as their means of sustenance, so in the event of a poor agricultural year, they may use this money to buy foodstuffs or to invest in new agricultural technologies.

"Juntos Crecer" is a second national program that provides social service monies. It supports families with school-aged children and develops human capital for the next generation. This program provides 200 Peruvian soles (~US $65) every two months to the parents of school-aged children if the children attend school and get regular health checkups. “Juntos Crecer” focuses on the poorest people and on districts with more than 40% of the population living below the poverty line, which is any household earning less than 1,500 Peruvian soles/year. Funds are intended to cover school supplies for families who might otherwise not be able to send their children to school. Children have historically played a major role in household labor, with their primary task being to help move livestock between pastures. Juntos Crecer was created to reduce child labor, as well as promote education and health care.

Both “Pension 65” and “Juntos Crecer” represent a significant investment of the national government in increasing the adaptive capacity of the population and infuse these communities with much needed capital.

Water Regulation

Other national programs exist in a regulatory capacity. “La Autoridad Nacional del Agua (ANA) del Peru” wants to formalize water rights throughout the RIWS using the 2009 Water Resource Law. This agenda is promoted at the national level, in part because local governments have difficulty dealing with broad-scale issues. ANA believes that water resources belong to the national government, and they enforce water regulation to increase conservation. ANA wants smallholder farmers in the upper RIWS to organize themselves into hierarchical groups and charge them approximately 10 Peruvian soles/month (~US $3), depending on the size of their irrigated land. Representatives from

ANA assured farmers that the price was reasonable and stated, “If they use less, then they will pay less (*Si menos usan, menos van a pagar*).” ANA claims that farmers will benefit from this formalization because these new organized associations can petition ANA to improve existing canal infrastructure and provide assistance in times of major drought. ANA discussed helping farmers in the construction of larger projects such as small dams at higher elevations to ensure that more water stays in the upper watershed. The formalization of water usage would also discourage the misuse of water because groups of farmers would have a greater ability to fine violators.

ANA representatives received some opposition at the local level during a town meeting. Some farmers disliked the outside management of a resource that they have never paid for and have always controlled. Others felt that this was yet another ploy to extract more water for corporate farmers in the Ica valley. Farmers in the upper watershed believe that they should have primary access to this resource, whereas export agricultural companies want as much water as possible to flow unexploited through the upper watershed to recharge the depleted Ica-Villacuri aquifer in the Ica valley. Corporate farmers in the Ica valley grow non-native crops that include asparagus, pomegranate, date palm, and red globe grapes, for export using modern irrigation technologies. A tension exists between the upper and lower RIWS, and throughout Peru, between coastal export farmers who make up the majority of the country’s agricultural production, and smallholder farmers on the western side of the Andes Mountains, the origin of coastal water. A representative from ANA conceded this point and said, “Ica without Santiago de Chocorvos [referring to the *sierra*] is nothing (*Ica sin Santiago de Chocorovos no es nada*).” The same representative countered by highlighting how much farmers in the upper RIWS rely on a strong economy in Ica, which they depend on for trade, goods, and labor. Several community leaders supported the measure because the canals are in need of repair, and every year there are fewer farmers to help with maintenance. Some farmers also conceded that the current lists of irrigators has not been updated and includes many farmers who have either died or migrated to the coast.

Water regulation by the national government can increase adaptive capacity by conserving water resources, though it must be conducted in coordination with and supported by smallholder farmers.

Agricultural Support

“Servicio Nacional de Sanidad Agraria (SENASA)” is another national program that operates within the upper RIWS. The primary function of SENASA is to maintain a national system of plant and livestock health that protects against pests and diseases that are not indigenous to Peru and pose an agricultural threat. SENASA works mainly with larger export producers on the coast to reduce the spread of pests that can damage crops and focuses on economically valuable crops. In the upper RIWS, the focus is on *mosca de la fruta* (*Ceratitis capitata*), a pest that attacks fruit trees. *Mosca de la fruta* lays its egg on fruit. As the larvae develop, they eat the fruit, thereby destroying it. When the fruit falls to the ground, the larvae emerge and burrow into the soil where they pupate.

The adults then emerge from the pupa, tunnel up through the soil, and reproduce. They can devastate orchards without proper pest management. In the upper RIWS, SENASA runs campaigns that publicize the problem and encourage inhabitants not to bring fruit from outside of the region, which is the primary means of introduction to new regions. SENASA also contracts with local farmers who spray trees with pesticides and encourage farmers to collect fruit that is already infected and bury it deep in the ground. Control of *mosca de la fruta* is another external issue that exposes farmers in the upper RIWS. *Mosca de la fruta* is originally from the western coast of Africa and was first detected in the Ica valley in 1958 (SENASA, 2011). However, it is unknown when it made it to higher elevations in the watershed. There do not appear to be any effective local eradication methods.

Educational Programs

The national government also provides access to free education for all communities in the upper RIWS. "El Ministerio de Educación del Peru" states its mission to, "Generate opportunities and educational results of the same quality for all…and complete a high quality of education that creates positive development and national competitiveness (*Generar oportunidades y resultados educativos de igual calidad para todos....y lograr una educación superior de calidad como factor favorable para el desarrollo y la competitividad nacional*)" (El Ministerio de Educacion del Peru, 2014). Even the most isolated villages had access to preschool, primary, and high school education staffed with university-trained teachers. Although, some students with homes far from schools may walk over an hour each way, showing great dedication and perseverance. According to survey respondents and many informal conversations, literacy rates have increased significantly in the region with greater access to education.

The schools in the upper RIWS teach a standard curriculum, but high schools also have an agricultural instructor dedicated to promoting modern and diversified agricultural techniques. Most high school campuses have a greenhouse and grow garden vegetables using sprinkler irrigation. Instructors also planted trees across campus as teaching demonstrations. The agricultural instructor exposes students to new crops and methods that they may not see on their family's field with the hopes that they will bring these new technologies home, or that they would use them when they begin their own field. Figures 5.3 and 5.4 show an exercise that many students in the upper RIWS were assigned. Students first draw a picture of their family's current agricultural landscape, which typically includes native Andean crops and grazing animals without more modern inputs (Figure 5.3). Next, students draw their agricultural vision of the future (Figure 5.4). Immediately, the major differences are noticeable between the two illustrations. The first illustration shows a typical home and agricultural field. There is a small number of livestock on the field, an unknown crop, and two fruit trees. The illustration does not show significant investment in the agricultural infrastructure. The second illustration has substantial agricultural investments. Eight fruit trees surround a new diversity of crops that are irrigated using sprinklers that pull from a pool that is also a trout aquaculture.

Livestock are kept in stables or a barn to lessen the risk of injury and better control their food supply. The agricultural landscape within the second illustration has greater diversification and investment that is purportedly less vulnerable to both climate changes and globalization, encompassing many of the techniques pushed by development agencies in the region. Agricultural instruction is directed at motivating the emerging generation to embrace a new paradigm of agricultural production. Unfortunately, much of this instruction may be futile with the younger generation deciding to migrate out.

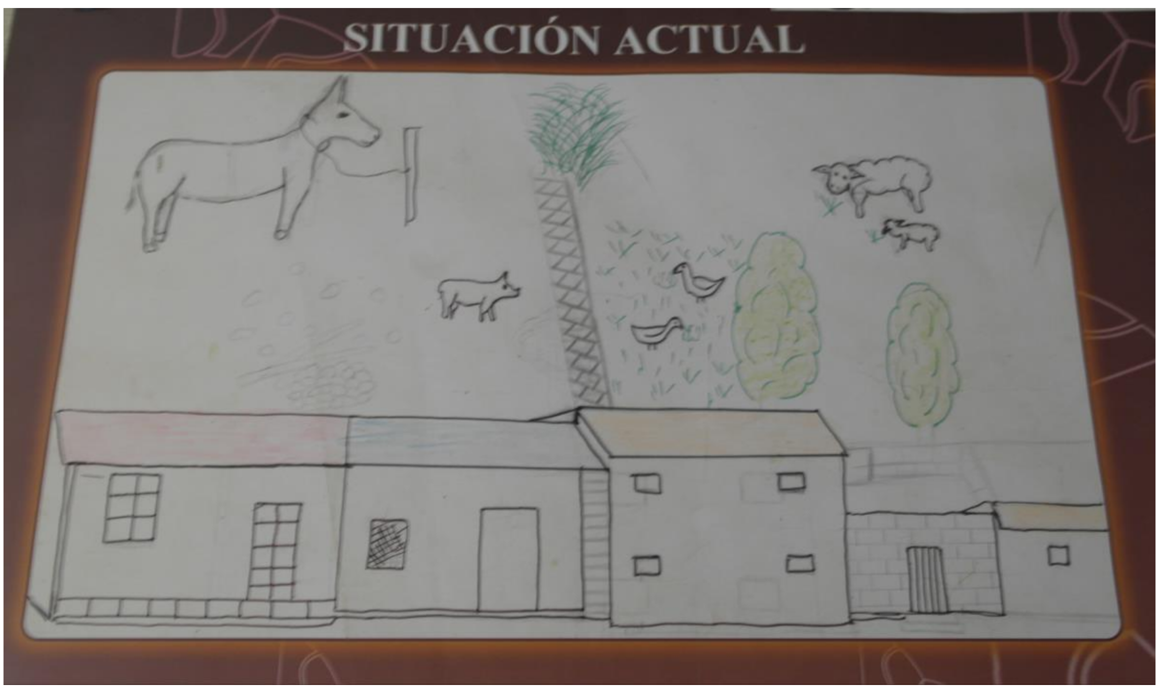

Figure 5.3: Drawing of the student's current agricultural situation.

Figure 5.4: Student's agricultural vision of the future. Note the increase in capital and technological investments.

Medical Aid

The Peruvian government also supports the upper RIWS through programs that do not pertain to agriculture but do increase adaptive capacity of the region's inhabitants. In Peru, all doctors, nurses, and dentists who study medicine must spend one year working in a community of need as a residency program. These residencies ensure that small, remote communities have access to medical services that would otherwise not be available. In every community I visited, there was a medical center with either one nurse or doctor or both. Most medical centers also have ambulances to reach patients in outlying areas and are capable transporting more serious cases to the city of Ica. Larger towns have more complete medical facilities that include birthing centers and a dentist office. Easy access to medical care is important in increasing adaptive capacity, especially for an aging population. Without the national programs, farmers there would have much less opportunity in the upper RIWS, leading to greater out-migration and field abandonment.

Regional Government

The greater regional government of Huancavelica has several programs operating within the upper RIWS. “SEDE Agraria” de Huancavelica is one of the primary government presences within the upper RIWS. They have an office in both the population center of Tambo and Santiago de Chocorvos and have agents that live in these regions full time. Their primary focus is to increase crop and livestock production and make products from the upper RIWS more competitive in the regional market. A source of income in this region is the sale of dairy products, most notably. Farmers have traditionally made these dairy products in their homes on a small scale and typically make around 9 Peruvian soles (~US $3) per kilo of cheese, while the market price for competing cheese in Ica is usually around 15 Peruvian soles. SEDE Agraria believes that dairy producers in the upper RIWS can increase the quality of dairy production, thus increasing their market price while not involving major structural changes in production. SEDE Agraria facilitates workshops and classes on dairy production to encourage a more consistent market product that can fetch a higher price. They have encouraged farmers to create value-added products that can compete with other dairy products sold within the city of Ica. This may also include the pasteurization of products, so that they have a longer shelf life and are more desirable in the regional market in Ica. Government agencies have made investments in dairy processing facilities to increase the scale of production and storage. SEDE Agraria also holds agricultural fairs with prizes for the best produce and dairy products (Figure 5.5). They want to encourage farmers to discuss their processing techniques and stimulate market associations.

Figure 5.5: Agricultural festival in Santiago de Chocorvos.

Another limitation to dairy production is that cattle in the region do not produce enough milk to compete in the regional market. Most cattle at higher elevations are a breed known as *corriente*, which are hearty in the cold conditions though not best for milk production. Lower in the upper watershed are more *chuzco* cattle that are typically mixed breeds of the local *corriente* cattle, along with genes from Holstein and Brown Swiss, two breeds known for high milk production.

Disagreements exist between SEDE Agraria and many farmers. One agricultural engineer in the town of Tambo discussed why many of the projects in this region fail. His frustration stemmed from the lack of farmer participation and community support:

> …There is support. So many non-governmental organizations, government organizations, etc. etc. But the community does not respond. Here many NGOs have come to support. But none work well because they do not receive support from the community. They are here for a short time and they leave.
>
> *…Apoyos hay. Tantos organizaciones, no gubermentales, como del estado, etc., etc. Pero la comunidad no responde. Aquí han venido varios ONGs apoyando. Pero ningunos funciono bien. Como no le daba apoyo de parte de la comunidad. Han estado poco tiempo. Se retiran.*

There is a palpable frustration on part of some regional development agents who want agriculture in this region to be rapidly modernized and believe the principal agricultural problem is inefficiency. The neoliberal interpretation of development would want agricultural in this region to increase capital inputs, improve genetics (livestock and crops), and become more involved within the regional market. However, most solutions that rely too heavily on modern implementations have been unsuccessful. Farmers often reject such proposals because they require them to drastically change their agricultural strategies.

Local Community Leaders

Local leaders also play a primary role in securing development projects within their region and work with other government officials (national and regional) and other development agents. They have an office in each region's capital, though most spend significant time traveling throughout their region. Many of these areas can cover significant elevation, so the representatives must be aware of the specific needs of each community.

During fieldwork, I interviewed two mayors, two regional governors, and one community president. The mayor is elected directly by the region, while the governor is appointed by the president's party and helps distribute funds. The community president is typically in charge of agriculture and resources. They are in a difficult position as they try to provide resources to their community and also work to stem out-migration. They are aware of global climate change but are often not preoccupied with it as there are other problems, chiefly their own reelection.

During interviews, community leaders spoke with candor about the problems facing their community, both criticisms of development organizations and internal conflicts. One younger (33 years old) mayor in the community of Capillas outlined three impediments to development: lack of water; kikuyu; and a mentality of many older farmers who do not want to change their techniques. As mayor, he attempted to implement a number of programs to modernize components of the community's agriculture. The following quote reveals one major conflict that local community leaders routinely face:

> …We know that we do not have water and the technology gives us the opportunity that we can utilize, for example, irrigation systems, sprinklers, drip lines, and others that exist. Then the traditional farmers says, 'but I am used accustomed to irrigating by flooding my field, my alfalfa, and my crops.' This part I cannot change. We have tried to convince some and they practice the system for a month or two and then get tired of it or they don't understand it and they return again to the irrigation by flooding. Only nine out of 300 farmers use sprinkler irrigation.
>
> …*Sabemos que no tenemos agua pero la tecnología nos da la oportunidad para poder utilizar, por ejemplo, sistemas de riego tecnificado, aspersión y goteo, y las demás que existe, y entonces este agricultor tradicional dice no, 'pero yo estoy acostumbrado a regar por inundación, mis chacras, mi alfalfa, mis cultivos.' Por ese parte yo no puedo cambiar. Hemos*

intentado convencer a unos cuantos y han estado practicando este sistema por un mes o dos meses y se canse o no lo entienden y nuevamente retornan a su actividad de riego por inundación. Solo nueve de 300 agricultores usan aspersores.

This mayor describes a frustration common among local community leaders. He believed strongly in the need to modernize certain aspects of agriculture within Capillas. He recognized that climate changes and other external forces had decreased agricultural production. However, he did not find most farmers willing to make major changes in their agricultural strategies. The mayor is part of a younger generation more eager to embrace new agricultural strategies. Many of the farmers within his community have applied time-tested agricultural strategies for decades with success and did not want to make major changes, even in the face of decreasing yields.

The district governor of Santiago de Chocorvos, a representative of president Ollanta and supervisor of national programs, believed that the lack of agricultural development should be blamed on development agencies. He complained that work of development agencies does not penetrate into the community and had not seen an improvement within agriculture. He also lamented the poor market connections, recounting when farmers were told by development agents to grow *kiwicha*, a pseudograin similar to quinoa. Like *quinoa*, the prices of *kiwicha* have increased rapidly and farmers can make a significant profit selling it in the regional market. Farmers produced an abundance of *kiwicha*, but they had difficulties finding buyers and lost a portion of the crop. He blamed this problem on development agencies.

The district governor also saw a lack of water and poor quality of the livestock as other major problems. He claimed that there is usually water for most of the year, but farmers may run out before the rainy season arrives. He also stated that the district's livestock are not improved genetically, which means that they produce minimal milk, stating, "95% of those who are raising cows are doing it to raise them and nothing else. They only produce four or five liters [per day]. It's not worth it. (*El 95% de crianderos de esta zona crían el ganado por criar, nada más. Las vacas que botan cuatro o cinco litros. No veo el trabajo*)." Farmers care for their livestock, but milk production rates are very low and far from their potential. Other similar regions in Peru have significantly higher production levels. The district governor believed that the solutions to these problems included more connection to the national government.

These two local community leaders are only two of many that work within the upper RIWS, but their experiences are representative of many others working to improve the lives of the farmers within their communities.

Farmer Perspectives

Farmers in the upper RIWS all operate in a context of resource vulnerability, unstable prices, unreliable and corruption-prone political and economic frameworks, weak institutions, rapid urbanization, land degradation, and shifting social organization.

To continue cultivating, they rely on a mosaic of livelihood strategies, several of which do not pertain to agriculture. Supporting these smallholder farmers is often difficult, as many do not want to fundamentally change their agricultural strategies or have a strong desire to leave agriculture altogether. These are daunting challenges. A survey of farmers asked participants: "If you could communicate your needs to the government or another organization, what would you ask them (*Si pudiera comunicarle sus necesidades al gobierno o otra organización, que le pediría*)?" Reponses varied, though the vast majority focused on agricultural necessities (Table 5.1).

Table 5.1: Farmer requests for the most essential development disbursement

Aid Requested	**Responses**
General agricultural support	39
Improved irrigation infrastructure	38
Kikuyu eradication	13
Loans	5
Work and organization	5
Agricultural pest management	4
Health	1

The most common response was a general need for agricultural support. Of the 105 farmers surveyed, 39 stated that their primary desire from the government and other development organizations was technical support for their agriculture. One farmer summarized this desire, "We need agricultural improvements and help with more technology in our agriculture. Nature varies and now is not like before. We need training to better our agriculture (*Mejoramiento de la agricultura y ayuda con la tecnificación de* *la agricultura. La naturaleza varia y ya no es como antes. Necesitan capacitaciones para mejorar la agricultura*).” Many farmers echoed this sentiment and felt that biophysical and cultural change made agriculture more difficult within the region. Farmers also expressed an aspiration to add new agricultural technologies to their long-standing agricultural strategies. Some farmers wanted new hybrid seed varieties, such as the *canchan* potato and improved alfalfa, that either had increased production, a shorter maturation process, or greater resistance to agricultural pests. Other farmers wanted to improve the genetics of their livestock, primarily cows, to increase dairy production. Most cattle in the region are ancestors of the *corriente* cattle that the Spanish brought in the fifteenth century, and that are well-adapted to the harsh environment but are poor milk producers. Many farmers improve cattle genetics using bull semen, a technology that must be supported by development agents.

The desire for improved irrigation resources was another common response that 38 (36.3%) of farmers requested. Farmers wanted four types of irrigation infrastructure: improved canals, storage reservoirs, sprinkler irrigation, and dams at higher elevations. Combined, this infrastructure would extend water availability and increase irrigation efficiency. Farmers saw their irrigation infrastructure as a major limitation to agriculture. One farmer captured this sentiment, “We need water, this is fundamental. How can you live without water? Cows without water do not make money. We need more canals and pipes for irrigation. (*Necesitan el agua, esto es fundamental. ¿Como si vives sin agua? Vacas sin agua no son rentables. Necesitan mas canalización y tubería*).” All of these irrigation projects require substantial investment from outside sources to function. The construction materials (cement, hoses, tubes, and heavy machinery) must be brought from the coast at significant cost.

Within agricultural needs, 13 (12.3%) smallholder farmers asked for specific agricultural help with kikuyu eradication. Many farmers view kikuyu as the primary limiting factor to agriculture. One farmer stated, "More than anything, we need help with the kikuyu. If this plant disappears, the economy can be good (*Mas que todo es sobre el kikuyu. Si este planta desparece la economía puede ser regular*)." Kikuyu has spread to so many fields that it is difficult to eradicate without using herbicides, large work parties, or small-engine tillers. Historically, these farmers relied on communal work parties to remove the plant. Out-migration now limits the success of this method, and now many farmers rely instead on herbicides or the use of mobile small-engine tillers.

Other farmers stated that the major limitation was available capital to improve their agriculture. Five (4.8%) respondents identified their primary need as access to capital. One farmer detailed this problem as, "We need capital from an agrarian bank. We want to buy genetically improved cattle, but the monthly interest [from many banks] can be difficult (*Necesitamos capital de un banco agraria. Queremos comprar vacas mejoradas, pero el interés mensual puede ser difícil*)." Many of the new challenges to smallholder farmers in the RIWS require investments that are beyond the means of most farmers.

Other responses focused on a general lack of communication and organization among smallholder farmers. Five of the farmers surveyed (4.8%) requested help in increasing organization among smallholder farmers. Due to migration, there are not enough farmers to complete many of the necessary tasks such as cleaning the canals or removing kikuyu. One popular solution to stem migration is to provide more opportunities in the upper RIWS. One farmer stated, "We need a technical education center to slow migration a little. (*Necesitamos un centro de estudios tecnológicas para que la migración frenar poco por falta de oportunidades*)." According to farmers in the town of Santiago de Chocorovos, there was previously a center devoted to agriculture, but it closed decades ago, leaving fewer options for the younger generation. Nevertheless, it is unclear whether the younger generation in the upper RIWS would stay, even under ideal agricultural conditions. In conversations with inhabitants between the ages of 13 and 18 in the upper RIWS, there was little desire to stay in these rural communities and maintain their family's agricultural field. Most expressed aspirations to leave and find jobs working with heavy machinery in the city of Ica. The booming export agriculture in Ica requires a large labor force, and there is a surplus of agricultural jobs available. Those who leave are almost always able to find work. Even within these isolated communities, they get a glimpse of the larger world. There are two television channels available, consistent cell phone reception in the larger towns, and intermittent access to Internet. Therefore, any program must recognize that it may be difficult to persuade the young farmers to stay and cultivate, as most seem to have already made up their minds.

Another response was agricultural pest management. Four (3.8%) of the farmers surveyed stated their primary requirement were resources to help manage agricultural pests. Farmers reported substantial increases in pests, primarily aphids, mites, and grasshoppers. Of all the farmers surveyed, 49 (47%) stated that they now rely on chemical fertilizers, herbicides, or insecticides. These chemicals are a recent agricultural addition and most farmers stated that they were added over the last three to 10 years. Many farmers feel that they now must rely on them to sustain crop production.

In conversations with farmers, there were numerous conflicts that arose both within their own community, and with a perceived lack of attention they received from both non-governmental and governmental agencies. Some more industrious farmers who embraced new technologies criticized their fellow farmers for a lack of ability to change their strategies. One exasperated farmer with an exceptionally productive field that relied on modern additions stated, “People in San Miguel de Curis are conformists (*Gente de San Miguel de Curis son confromistas*).” Some farmers felt that a chief reason for decreasing agricultural production was not only environmental changes, but also an inability for many farmers to change their long-standing agricultural methods, exacerbating many environmental problems (i.e. the spread of kikuyu and inefficient water usage).

Farmers also criticized development organizations and programs with many believing that they do not spend enough time in the upper RIWS. One farmer complained, “The engineers [development agents] do not work in the fields. They come visit for one day and then they leave (*Los ingenieros no trabajan en las chacras. Solo vienen por un dia y salen*)." This farmer felt frustration that development workers were more oriented towards the coast and did not spend enough time helping farmers in the upper RIWS. Another common expression of discontent during surveys and interviews was, "We are forgotten (*estamos olvidados*)", as farmers believe that the State had ignored them. Both of these conflicts can have major impacts on adaptive capacity. This lack of communication and perceived neglect erodes trust, making development programs less sustainable.

Farmers within the upper RIWS show substantial resiliency in the face of this "double exposure." Throughout all of these conversations, I witnessed farmers working diligently with limited resources. Agricultural production is decreasing, but these farmers have navigated difficult scenarios using a multitude of strategies.

Discussion

If one looks at a calculus of development purely in how the smallest amount of resources help the greatest number of people, it is expedient to direct resources to the greatest density of people, those living on Peru's arid coast. It is difficult and costly to support the smallholder farmers of the upper RIWS, who are isolated, even by Peruvian standards. There is an expectation among many in Peru that all of these farmers will soon leave the *sierra* to find work in the city. Whatever the future of smallholder agriculture in these regions, it will clearly look much different than "traditional" expectations in which “rural cultivators practicing intensive, permanent diversified agriculture” (Netting, 1993: 2). Farmers may still cultivate these areas, but agriculture will be less permanent with a greater percentage of crops going to the market. Connections to the coast will increase through better roads, improved cell phone coverage, and greater access to Internet connection. Many in the RIWS have built economically viable livelihood strategies that, while neither agricultural nor rural, allow people to stay connected with rural places (Bebbington, 2000). Farmers supplement their crops with work in construction or mining and gas concessions. Others spend months working as wage laborers in export agriculture in Ica. This hybridity is the most effective development, “constantly piecing the old and new, elements of modernity with longer-standing elements of local practice” (Escobar, 1995: 217-26). It will continue to rely on more long-standing or “traditional” practices thus making it more likely they will be sustainable and continually used. Farmers in Acora (1,937 m.a.s.l.), for example, started growing avocados roughly 20 years ago for consumption locally and for sale in Ica. Avocados are not an Andean cultivar and there is no long-standing tradition of their cultivation in the region. However, the cultivation has made farmers less vulnerable to changes as they now have a tree crop that provides sustenance and brings in capital. For this hybridity to succeed in the upper RIWS, continued cultivation is dependent on several factors that are now major limitations to agricultural development: the control of kikuyu, improved transportation and telecommunication between the coast and the upper RIWS, and enhanced irrigation management.

Kikuyu is found throughout the upper RIWS, and is the primary limitation of agriculture. This invasive grass chokes alfalfa, among other crops, limits the number of livestock a farmer can raise and decreases milk production. Eradicating kikuyu is difficult without technological aid from development agencies. Terraces prevent the use of large tractors to dig fields, and thus farmers use manual labor. The use of small-engine tillers that break up the soil with metal blades are slowly being implemented in some areas and may help slow the spread of kikuyu. Another method to destroy kikuyu is through the application of herbicides. The eradication of kikuyu is beyond the financial means of many smallholder farmers.

It is intuitive that improved transportation and telecommunication networks from the region of Huancavelica to the city of Ica would only increase migration, making it easier to leave and increases the visibility of mass media and consumer culture. However, greater transportation infrastructure supports smallholder agriculture by increasing the options available to those in the community that would help them to stay. A stronger connection to the coastal centers of Ica creates a superior access to agricultural resources (e.g. seeds, fertilizers, irrigation tools). There are current plans to build new roads that would decrease the four hour plus travel time, but the process is only in the exploratory stage. Transport and trade are difficult, which decreases the available options for farmers and spurs out-migration.

Within the upper RIWS, there is minimal cell phone coverage outside of the larger towns and intermittent Internet access. Increasing information access and strengthening telecommunication networks will help facilitate farmers' anticipatory and adaptive capacity (de Grenade et al., 2015). An increase in telecommunication infrastructure would improve market access and climate forecasts. Farmers often produce crops (e.g. *kiwicha*, *quinoa*, avocados, dairy, and livestock) for regional markets but have difficulty finding buyers because of their market isolation. If they had better access and greater understanding of market prices, they could fetch higher prices and cater crop cultivation. Seasonal climate forecasts and forecasts of the onset of the rainy season have the ability to improve farmer livelihoods. However, there is a faulty assumption that mass media, extension agents, and local governments are part of the communication that farmers use to make agricultural decisions. Scientific forecasts are rarely used by Andean producers (Gilles and Valdivia, 2009). Therefore, increased telecommunication access in the upper RIWS must also encourage collaboration between smallholder farmers and development agents in the next generation of better forecast communication.

Climate changes in the RIWS have limited the duration of the rainy season. For this hybridity to succeed, farmers must have consistent access to irrigation. Development projects in the region have largely been unsuccessful at increasing water conservation strategies on a larger scale, though some areas have built more efficient irrigation infrastructure (e.g. sprinklers, improved canals, storage pools) that allows farmers to irrigate less and save water during the dry season. These techniques can still be used along with other "traditional" agricultural techniques within the watershed.

Water scarcity is exacerbated in the upper RIWS due to conflicts with the agro-export industry in the lower watershed. The Ica valley is now one of the principal agro-exporting valleys in Peru, accounting for 30% of the country's exports of fruits and vegetables (Oré et al., 2013). To sustain this agricultural model in a hyperarid environment requires large irrigation resources. From 1950 to 2007, 50% of the water supply for agriculture in the Ica valley came from groundwater, 42% from the Rio Ica, and 8% from the Choclococha system (Schneir, 2011). The lack of control and monitoring has permitted the overexploitation of groundwater, putting the Ica-Villacuri aquifer in serious danger. Surface water from the Rio Ica is the primary source of conflict with smallholder farmers in the upper RIWS. The agro-export industry wants the majority of precipitation that falls in the upper watershed to flow unimpeded to the lower watershed. The new ANA regulations that seek to formalize water usage will serve this goal. Many of the farmers surveyed were aware of this connection and opposed new regulations on irrigation. The Choclococha system was built in 1959 and begins at the high altitude Laguna Choclococha (4,521 m.a.s.l.) within the Pampas watershed, which flows to the Atlantic Ocean and has a surplus of precipitation (Figure 5.6). A dam at Laguna Choclococha limits water flow until the end of the dry season, which is then carried by canal and then tunneled through into the Rio Tambo, a tributary of the Rio Ica. There are plans to expand the Choclococha system to increase the available irrigation to export farmers, but there is significant opposition, most notably from camelid herders in the Pampas watershed (Oré et al., 2013).

Figure 5.6: Laguna Choclococha transports irrigation water from the Pampas watershed to corporate agriculture in the lower RIWS.

Even without decreasing precipitation in the upper RIWS from climate change, agricultural strategies in the Ica valley are not sustainable. Large-scale irrigation has attained its objectives to let the desert bloom and increase agro-exports from Peru, although it does so at the cost of aquifer depletion. Rather than cultivating crops with a smaller water footprint or decreasing cultivation in a region with limited natural water resources, agro-export industries want to create larger infrastructure projects as an engineering solution. The agro-export industries apply modern irrigation technology, whose principal virtue is saving water, when in the context of promoting export agriculture and without proper governmental regulations can cause just the opposite: major depletion of the aquifer (Oré et al., 2013). Many of these similar agricultural strategies (e.g. modern irrigation, agricultural chemicals, and hybrid seeds) are promoted by development agents. This neoliberal model of agriculture may increase production, however, if applied in the upper RIWS without consideration of existing strategies, it will be unsuccessful.

Those who choose to leave the upper RIWS frequently send remittances to family and return with new agricultural technologies. This influx of capital is invested in new projects that increase production and allow smallholder farmers to buy foodstuffs during a year with decreased agricultural production. Migration can also be beneficial to those who stay behind. Water resources in this region are limited during the dry season. A decreased density of cultivators creates less competition over irrigation resources, keeping only the best agricultural lands in cultivation. Decreased population levels may allow for more sustainable agricultural production given the current available resources. Further, migration is not always permanent, as many farmers who leave for the coast to find short-term work then return with more money and knowledge that can be invested in their agricultural plots. This form of circular migration is common. Some farmers leave for a season to harvest in Ica, as there is almost consistent work available year-round. Others leave for decades, and return for their retirement with a pension. Agricultural knowledge of modern strategies is invaluable as these farmers retake leadership positions in the upper RIWS.

Years of distrust and unfulfilled promises which have fostered animosity between development agents and farmers came forth during interviews and surveys. A common narrative repeated by farmers is that they are forgotten, while many agricultural extensions agents are frustrated by the farmers' reluctance to apply many of their proposed strategies. This distrust and subsequent conflict limits successful development programs, which can increase farmer vulnerability. This is particularly damaging during a time when farmers face "double exposure" to the impacts of globalization and global environmental change (O'Brien and Leichenko, 2000).

Conclusion

Agriculture in the upper RIWS does not exist in isolation. Farmers are not responding to environmental and cultural changes in a vacuum using only "traditional" agricultural methods. Instead, there is a complicated relationship that has developed between the lower watershed in the Ica valley and the upper watershed in the department of Huancavelica. Ica has weakened Huancavelica's agricultural production, particularly through the introduction of invasive species and the loss of manual labor to migration. However, Ica also facilitates adaptation and reduces vulnerability. Doctors and agricultural extension agents move from the coast to the *sierra* to provide medical and agricultural support. There is a misconception that smallholder farmers are entirely self-reliant and that outside market influences pull them out of subsistence agriculture. Farmers in the RIWS rely heavily on support from the international organizations, the national government, and regional governments, and consistently participate in the regional market.

Critiques from both post-structural and neoliberal development theories tend to see different "failures" of development. Neoliberal critiques see "inefficient" patterns of resources and "nonviability" of large parts of Andean peasantry (Bebbington, 2000), and they would push modernization of agricultural strategies and increased involvement in the larger market such as programs in the upper RIWS that increase dairy production. Post-structural critiques instead view development as a process of cultural destruction and homogenization (Bebbington, 2000). This critique calls for a re-emphasis on traditional agricultural strategies and a focus on grassroots development movements. Both critiques see the State as the primary problem. Neither post-structural nor neoliberal interpretations of development capture the full extent of rural transformation in the RIWS. The RIWS provides examples of both, neither of which provide sustainable solutions to a volatile agricultural future. The neoliberal model in the Ica valley is productive and profitable, but its water usage is unsustainable. Traditional agriculture in the upper RIWS faces declining agricultural production, as new social and environmental forces lessen the utility of some traditional strategies. A hybrid model of both traditional and modern components is best suited for the upper RIWS. This may mean that farmers cultivate traditional crops along pre-Inca terraces, but using modern sprinklers and small amounts of pesticides and fertilizer. The hybrid model also requires kikuyu management, improved transportation and telecommunication, and enhanced irrigation management.

Agriculture in the upper RIWS is at a crossroads. The “status quo” of smallholder agricultural will not produce long-term, sustainable agricultural strategies. Nor will antiquated ideas of what is “traditional” or what must constitute smallholder agriculture. There must be a greater dialogue between farmers and development agents, as well as a renewed effort at engaging the younger generation in agriculture. More nuanced versions of development are necessary that allow for emphasize choice and human agency.

Appendix
Survey (Encuesta de la Adaptación Agrícola)

Cuestionario Numero	
Fecha	
Lugar (Pueblo y Región)	
Lon. y Lat. (DD)	
Altitud (Metros)	
Muestra de suelo (si o no)	
Fotografía (si o no)	
Persona entrevistada	
Edad	
Sexo	
Entrevistador	

COMPONENTE 1: Información Básica

1. ¿Desde hace cuanto tiempo han estado/vive en este lugar?

Numero de años:	
Lugar de Nacimiento:	

2. Hijos

Numero de hijos en total:	
Edades:	
Número en condición de dependencia:	
Número que migraron a otros lugares:	

Donde:	Remesas:	Cuanto:

2. Actividad Agrícola. Lista de los cultivos en numero de importancia.

Nombre y variedad	
1.	10.
2.	11.
3.	12.
4.	13.
5.	14.
6.	15.
7.	16.
8.	17.
9.	18.

3. ¿Hectáreas en total?

Numero de Hectáreas en todo:	

4. ¿Comida para vender o consumir?

Vender o consumir:	

5. ¿Rotación? ¿Con que frecuencia?

Rotación:	

6. Datos de sembrar y cosechar de las chacras.

Cultivos	Meses de Siembra	Meses de Cosecha

7. Notas sobre las niveles de producción en los últimos 40 años

Notas de producción:	

8. Otra(s) actividad(es) económica(s). Especifique:

Otras actividades:	

9. Dibujo de la chacra en otro papel

COMPONENTE 3: Manejo de recursos naturales

1. ¿Que es el fuente de agua (manantial o rio)? Tipo de riego (gravedad, aspersión, goteo, lluvia, nada)?

Fuente de agua:	

Tipo de riego:	

2. ¿Que tipo de abono o fertilizante usa con su(s) cultivas? ¿De donde viene?

Tipo:	
De donde viene:	

3. ¿Usa un arado? ¿Qué tipo de herramientas?

Tipos de herramientas:	

4. ¿Algún tipo del mejoramiento de la ganadería?

Explicación de mejoramiento:	

COMPONENTE 4: Cambio de Cultivas y Animales

Vamos hacer preguntas sobre la actualidad y los años 70, 80, y 90s. Lo que más nos interesa qué usted se acuerde son los cambios que ocurrieron desde entonces.

1. ¿Ha cambiado los cultivos o la ganadería? ¿Si o no?

Explicación de cambio:	

2. ¿Porque cambiaste los cultivos?

Porque ha cambiado:	

COMPONENTE 5: Plagas

Plaga 1:				Cultivo:				Remedio:			
70s			80s			90s			Actualidad		
N	P	M	N	P	M	N	P	M	N	P	M
Notas:											

Plaga 2:				Cultivo:				Remedio:			
70s			80s			90s			Actualidad		
N	P	M	N	P	M	N	P	M	N	P	M
Notas:											

Plaga 3:				Cultivo:				Remedio:			
70s			80s			90s			Actualidad		
N	P	M	N	P	M	N	P	M	N	P	M
Notas:											

Plaga 4:				Cultivo:				Remedio:			
70s			80s			90s			Actualidad		
N	P	M	N	P	M	N	P	M	N	P	M
Notas:											

Plaga 5:				Cultivo:				Remedio:			
70s			80s			90s			Actualidad		
N	P	M	N	P	M	N	P	M	N	P	M
Notas:											

Plaga 6:				Cultivo:				Remedio:			
70s			80s			90s			Actualidad		
N	P	M	N	P	M	N	P	M	N	P	M
Notas:											

COMPONENTE 6: Clima

1. ¿En la actualidad, en qué meses llueve? ¿En los años 70,80, 90 en que meses llovía?

	E	F	M	A	M	J	J	A	S	O	N	D	NR	Meses (para Excel)
Hoy														
70s														
80s														
90s														

¿Cambios mas específicos? ¿Años de lluvias fuertes o sequias?

Específicos:	
Años fuertes:	

2. ¿En la actualidad, cuáles son los meses de heladas?
¿En los años 70, 80, 90 cuáles fueron los meses de heladas?

	E	F	M	A	M	J	J	A	S	O	N	D	NR	Meses (para Excel)
Hoy														
70s														
80s														
90s														

3. ¿Otros cambios de la clima?

Otros cambios:	

4. ¿Técnicas agrícolas ha cambiado especialmente por la clima?

Cambio de técnicas:	

COMPONENTE 7: Percepciones

1. ¿En que orden son sus 5 preocupaciones mas grandes?

Preocupación #1	
Preocupación #2	
Preocupación #3	
Preocupación #4	
Preocupación #5	

2. ¿Que significa el cambio climático?

Significa el cambio climático:	

COMPONENTE 8: Apoyo

1. ¿En la actualidad recibe apoyo de algún programa, proyecto, institución, o miembro de la familia?

Tipos de apoyo:	

Ejemplos:

a.) Gobierno Regional
b.) Gobierno Local
c.) Familia
d.) GIZ
e.) Grupo de la iglesia
f.) Juntos Crecer
g.) Pensión 65

2. ¿Si pudiera comunicarle sus necesidades al gobierno o otra organización, que le pediría?

Necesidades:	

Glossary of Spanish and Quechua Terms

altiplano – high Andean plain

amarillo – variety of potato grown for its sandy texture

baretas – large crow bar

canchan – variety of potato grown by most farmers because of its high productivity

chakitaqlla – human-powered plow of Andean origin

cherimoya – a subtropical tree with sweet fruit that have a rich and creamy texture

chuzco – colloquial term for an animal of mixed genetics, specifically refers to cattle that have both *corriente* and European genetics

colectivo – local taxi

corriente – breed of cattle brought to Peru by the Spanish in the fifteenth century

costa – natural region of Peru on the western side from zero to 500 m.a.s.l.

faena – communal work party

huayro – variety of potato known for ability to withstand frosts

kamayoc – agricultural expert trained in Cuzco who lives in the community and helps with development projects

kiwicha – also known as amaranth, it is a pseudocereal noted for its dense nutritional content with smaller seeds than quinoa

lúcuma – subtropical tree with fruit with a dry texture

mashua – flowering plant known for its edible tubers

montsefu – traditional variety of alfalfa

mosca de la fruta – pest that attacks fruit trees

oca – root vegetable native to the central and southern Andes

olluco – root vegetable native to Peru

puna – natural region of Peru consisting of Andean grasslands between 4,000 and 4,500 m.a.s.l.

san pedrano – traditional variety of alfalfa

sierra – mountains

suni – natural region of Peru with a dry and cold climate located between 3,500 and 4,000 m.a.s.l

quechua – native language spoken in the Andes and natural region of Peru with big valleys divided by rivers located between 2,300 and 3,500 m.a.s.l.

quinoa – a pseudocereal known for its dense nutritional content

yunga – natural region of Peru characterized by a semi-arid climate with year-round sun and located from 1,700 to 2,300 m.a.s.l.

References

Adger, W. N., J. Barnett, K. Brown, N. Marshall, and K. O'Brien. 2013. "Cultural Dimensions of Climate Change Impacts and Adaptation." *Nature Climate Change* 3 (2): 112–17.

Adger, W. N., S. Huq, K. Brown, D. Conway, and M. Hulme. 2003. "Adaptation to Climate Change in the Developing World." *Progress in Development Studies* 3 (3): 179–95.

Adolf, V., S. Jacobsen, and S. Shabala. 2013. "Salt Tolerance Mechanisms in Quinoa (*Chenopodium Quinoa* Willd.)." *Environmental and Experimental Botany* 92: 43–54.

Agrawal, A. 1995. "Dismantling the Divide between Indigenous and Scientific Knowledge." *Development and Change* 26 (3): 413–39.\

Asseng, S., F. Ewert, C. Rosenzweig, J. W. Jones, J. L. Hatfield, A. C. Ruane, K. J. Boote, et al. 2013. "Uncertainty in Simulating Wheat Yields under Climate Change." *Nature Climate Change* 3 (9): 827–32.

Atkinson, R., and J. Flint. 2001. "Accessing Hidden and Hard-to-reach Populations: Snowball Research Strategies." *Social Research Update* 33 (1): 1–4.

Aubron, C., H. Cochet, G. Brunschwig, and C. Moulin. 2009. "Labor and Its Productivity in Andean Dairy Farming Systems: a Comparative Approach." *Human Ecology* 37 (4): 407–19.

Bassett, T.J. 1994. "Hired Herders and Herd Management in Fulani Pastoralism (Northern Côte d'Ivoire)." *Cahiers D'études Africaines* 34 (133): 147–73.

Bassett, T. J., and K.S. Zimmerer. 2003. "Cultural Ecology." In Gaile, G., Willmott C. eds., *Geography in America at the Dawn of the 21st Century*. Oxford: Oxford University Press: 99-112.

Batterbury, S. 1996. "Planners or Performers? Reflections on Indigenous Dryland Farming in Northern Burkina Faso." *Agriculture and Human Values* 13 (3): 12–22.

Bebbington, A. 1993. "Modernization from below: An Alternative Indigenous Development?" *Economic Geography* 69 (3): 274–92.

Bebbington, A. 2000. "Reencountering Development: Livelihood Transitions and Place Transformations in the Andes." *Annals of the Association of American Geographers* 90 (3): 495–520.

Berkhout, F. 2003. *Negotiating Environmental Change: New Perspectives from Social Science*. Cheltenham: Edward Elgar Publishing.

Black, R., S. Bennett, S.M. Thomas, and J.R. Beddington. 2011. "Climate Change: Migration as Adaptation." *Nature* 478 (7370): 447–49.

Boillat, S., and F. Berkes. 2013. "Perception and Interpretation of Climate Change among Quechua Farmers of Bolivia: Indigenous Knowledge as a Resource for Adaptive Capacity." *Ecology and Society* 18 (4): 232-44.

Bord, R., R. O'Connor, and A. Fisher. 2000. "In What Sense Does the Public Need to Understand Global Climate Change?" *Public Understanding of Science* 9 (3): 205–18.

Bradshaw, B., A. Dolan, and B. Smit. 2001. "Crop Diversification as an Adaptive Response to Climate and Other Risks in the Prairies." In *Presentation for the Annual Meeting of the Canadian Association of Geographers, Montreal, Quebec*.

Browman, D. 1983. "Andean Arid Land Pastoralism and Development." *Mountain Research and Development* 3 (3): 241–52.

Brklacich, M., D. McNabb, C. Bryant, J. Dumanski, B. Ilbery, Q. Chiotti, T. Rickard, and others. 1997. "Adaptability of Agricultural Systems to Global Climate Change: A Renfrew County, Ontario, Canada Pilot Study." In Illberry, B., Chiotti, Q., Rickard, T., eds., *Agricultural Restructuring and Sustainability: A Geographical Perspective.* Brighton: CAB International: 185–200.

Brooks, S.O. 1998. "Prehistoric Agricultural Terraces in the Rio Japo Basin, Colca Valley, Peru." (Ph.D. Dissertation, University of Wisconsin at Madison).

Brooks, N. 2003. "Vulnerability, Risk and Adaptation: A Conceptual Framework." *Tyndall Centre for Climate Change Research Working Paper* 38: 1–16.

Buytaert, W., M. Vuille, A. Dewulf, R. Urrutia, A. Karmalkar, and R. Celleri. 2010. "Uncertainties in Climate Change Projections and Regional Downscaling in the Tropical Andes: Implications for Water Resources Management." *Hydrology and Earth System Sciences* 14 (7): 1247–58.

Centro Internacional de la Papa (CIP) and Federación Departamental de Comunidades Campesinas (FEDECCH). 2006. *Catálogo de Variedades de Papa Nativa de Huancavelica-Perú.* Lima: Centro Internacional de la Papa.

Clark, W., P. Crutzen, and H. Schellnhuber. 2005. "Science for Global Sustainability: Toward a New Paradigm." KSG Working Paper No. RWP05-032.

Crosby, A.W. 2003. *The Columbian Exchange: Biological and Cultural Consequences of 1492*. West Port: Greenwood Publishing Group.

de Granade, R., J. Rudow, R. Taboada, M.E. Adauto, C. Scott, B. Willems, J. de la Rosa, and R. Varady. 2016. Anticipatory Capacity, Food Security and Global Change Across an Extreme Elevation Gradient in the Ica Basin, Peru. Regional Environmental Change. Submitted.

de la Cruz, L.A., D.D. Arias, and J.M. Kuroiwa. 2007. "Comparison of Erosion Control Methods in Steep Slopes." In *World Environmental and Water Resources Congress 2007: Restoring Our Natural Habitat*, 1–10. ASCE.

De Loë, R., R. Kreutzwiser, and L. Moraru. 2001. "Adaptation Options for the near Term: Climate Change and the Canadian Water Sector." *Global Environmental Change* 11 (3): 231–45.

Denevan, W.M. 2001. *Cultivated Landscapes of Native Amazonia and the Andes.* Oxford: Oxford University Press.

Dicken, P. 2007. *Global Shift: Mapping the Changing Contours of the World Economy*. Thousand Oaks: SAGE Publishing.

Dobrowski, S.Z. 2011. "A Climatic Basis for Microrefugia: The Influence of Terrain on Climate." *Global Change Biology* 17 (2): 1022–35.

Easterling, W.E., and C. Polsky. 2004. "Crossing the Divide: Linking Global and Local Scales in Human-environment Systems." In Sheppard, E., McMaster, R.M., eds. *Scale and Geographic Inquiry: Nature, Society, and Method.* Oxford: Blackwell Publishing Limited: 66-85

Escobar, A. 1995. *Encountering Development: The Making and Unmaking of the Third World*. Princeton: Princeton University Press.

Erickson, C.L. 1988. "Raised Field Agriculture in the Lake Titicaca Basin." *Expedition* 30 (3): 8-16.

Etkin, D., and E. Ho. 2007. "Climate Change: Perceptions and Discourses of Risk." *Journal of Risk Research* 10 (5): 623–41.

Etter, A., C. McAlpine, K. Wilson, S. Phinn, and H. Possingham. 2006. "Regional Patterns of Agricultural Land Use and Deforestation in Colombia." *Agriculture, Ecosystems & Environment* 114 (2): 369–86.

Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, and others. 2014. "IPCC Climate Change 2014: Impacts, Adaptation, and Vulnerability." In *Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Rep*, 1132. Cambridge and New York: Cambridge University Press.

Füssel, H., and R. Klein. 2006. "Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking." *Climatic Change* 75 (3): 301–29.

Gardener, C.J., J.G. McIvor, and A. Jansen. 1993. "Survival of Seeds of Tropical Grassland Species Subjected to Bovine Digestion." *Journal of Applied Ecology* 30 (1): 75–85.

Gilles, J., and C. Valdivia. 2009. "Local Forecast Communication in the Altiplano." *Bulletin of the American Meteorological Society* 90 (1): 85–91.

Giraldo-Cañas, D., 2012. "Distribución e invasión de gramíneas C3 y C4 (poaceae) en un gradiente altitudinal de los andes de Colombia." *Caldasia* 32 (1): 2357-3759.

Glaser, B., L. Haumaier, G. Guggenberger, and W. Zech. 2001. "The 'Terra Preta' phenomenon: A Model for Sustainable Agriculture in the Humid Tropics." *Naturwissenschaften* 88 (1): 37–41.

Gonzalez, F. 2009. "Socio-environmental Dynamics of Biological Invasions: The Case of Kikuyu Grass (*Pennisetum clandestinum*) in the Cotahuasi Valley, Southern Peru." (Ph.D. Dissertation, University of Wisconsin at Madison).

Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. "Global Patterns in the Vulnerability of Ecosystems to Vegetation Shifts Due to Climate Change." *Global Ecology and Biogeography* 19 (6): 755–68.

Gregory, P. J., and J. S. I. Ingram. 2000. "Global Change and Food and Forest Production: Future Scientific Challenges." *Agriculture, Ecosystems & Environment* 82 (1): 3–14.

Harden, C. 1993. "Land Use, Soil Erosion, and Reservoir Sedimentation in an Andean Drainage Basin in Ecuador." *Mountain Research and Development* 13 (2): 177–84.

Harvey, D. 1990. *The Condition of Postmodernity: An Enquiry into the Conditions of Cultural Change*. Hoboken: Wiley Blackwell

Harrison, E. 1947. Maiz, Papa, Calcio, Pastos, Grass "Kikuyu". Informaciones Technicas 20. Lima: Servicio Cooperativo Interamericano de Produccion de Alimentos.

Haylock, M. R., T. C. Peterson, L. M. Alves, T. Ambrizzi, Y. M. T. Anuncia\ccão, J. Baez, V. R. Barros, M. A. Berlato, M. Bidegain, and G. Coronel. 2006. "Trends in Total and Extreme South American Rainfall in 1960-2000 and Links with Sea Surface Temperature." *Journal of Climate* 19 (8): 1490–1512.

Head, L. 2009. "Cultural Ecology: Adaptation–retrofitting a Concept?" *Progress in Human Geography* 34: 234–42.

Hepworth, N.D., J.C. Postigo, B. Güemes Delgado, and P. Kjell. 2010. "Drop by Drop: Understanding the Impacts of the UK's Water Footprint through a Case Study of Peruvian Asparagus." Progresio, CEPES, and Water Witness International.

Hernández E., A, Mejía M.S., Durán C. 2012. "Respuesta Fotosintética del Pasto Kikuyo (*Pennisetum clandestinum*) en Pisos Térmicos Contrastantes." *Acta Agronómica* Numero Especial: 79-80.

Hoddinott, J., and Y. Yohannes. 2002. "Dietary Diversity as a Food Security Indicator." *Food Consumption and Nutrition Division Discussion Paper* 136: 2002.

Inbar, M., and C.A. Llerena. 2000. "Erosion Processes in High Mountain Agricultural Terraces in Peru." *Mountain Research and Development* 20 (1): 72–79.

Instituto Nacional Estadistica e Informatica (INEI). 2012. *Medición de la Pobreza*. Lima, Peru.

Kintz, D.B., K.R. Young, and K.A. Crews-Meyer. 2006. "Implications of Land Use/land Cover Change in the Buffer Zone of a National Park in the Tropical Andes." *Environmental Management* 38 (2): 238–52

Knapp, G. 1982. "Prehistoric Flood Management on the Peruvian Coast: Reinterpreting the' Sunken Fields' of Chilca." *American Antiquity* 47 (3): 144–54.

Knapp, G. 1991. *Andean Ecology: Adaptive Dynamics in Ecuador*. Boulder: Westview Press.

Kronik, J., and D. Verner. 2010. *Indigenous Peoples and Climate Change in Latin America and the Caribbean*. Washington D.C.: World Bank Publications.

Lane, K (Archaeologist). Personal Communication. July 20, 2014.

Lasco, R., R. Delfino, and M. Espaldon. 2014. “Agroforestry Systems: Helping Smallholders Adapt to Climate Risks While Mitigating Climate Change.” *Wiley Interdisciplinary Reviews: Climate Change* 5 (6): 825–33.

Liverman, D.M. 1990. “Drought Impacts in Mexico: Climate, Agriculture, Technology, and Land Tenure in Sonora and Puebla.” *Annals of the Association of American Geographers* 80 (1): 49–72.

Lobell, D., W. Schlenker, and J. Costa-Roberts. 2011. “Climate Trends and Global Crop Production since 1980.” *Science* 333 (6042): 616–20.

Malo, J., and F. Suárez. 1995. “Establishment of Pasture Species on Cattle Dung: The Role of Endozoochorous Seeds.” *Journal of Vegetation Science* 6 (2): 169–74.

Marais, J. 2001. “Factors Affecting the Nutritive Value of Kikuyu Grass (*Pennisetum clandestinum*)-a Review.” *Tropical Grasslands* 35 (2): 65–84.

Mark, B.G., J. Bury, J.M. McKenzie, A. French, and M. Baraer. 2010. “Climate Change and Tropical Andean Glacier Recession: Evaluating Hydrologic Changes and Livelihood Vulnerability in the Cordillera Blanca, Peru.” *Annals of the Association of American Geographers* 100 (4): 794–805.

Martínez, E., E. Veas, C. Jorquera, R. San Martín, and P. Jara. 2009. “Re-Introduction of Quínoa into Arid Chile: Cultivation of Two Lowland Races under Extremely Low Irrigation.” *Journal of Agronomy and Crop Science* 195 (1): 1–10.

McSweeney, C., G. Lizcano, M. New, and X. Lu. 2010. “The UNDP Climate Change Country Profiles: Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries.” *Bulletin of the American Meteorological Society* 91 (2): 157–66.

Meade, B. 2011. *Peru: An Emerging Exporter of Fruits and Vegetables*. Darby: Diane Publishing.

Mertz, O., C. Mbow, A. Reenberg, and A. Diouf. 2009. “Farmers’ Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel.” *Environmental Management* 43 (5): 804–16.

Milan, A., and R. Ho. 2014. “Livelihood and Migration Patterns at Different Altitudes in the Central Highlands of Peru.” *Climate and Development* 6 (1): 69–76.

Ministerio de Educación del Peru. 2015. Reglamento de Organización y Funciones del Ministerio de Educación. Lima, Peru.

Montgomery, M.R. 2008. "The Urban Transformation of the Developing World." *Science* 319 (5864): 761–64.

Morris, A. 1999. "The Agricultural Base of the Pre-Incan Andean Civilizations." *Geographical Journal* 10 (3): 286–95.

Murra, J.V. 1968. "An Aymara Kingdom in 1567." *Ethnohistory* 15 (2): 115–51.

O'Brien, K. and R. Leichenko. 2008. *Environmental Change and Globalization: Double Exposures*. Oxford: Oxford University Press.

Oré, M., D. Bayer, J. Chiong, and E. Rendon. 2014. "Water Emergency in Oasis of the Peruvian Coast. The Effects of the Agro-Export Boom in the Ica Valley." In *Colloque" Oasis Dans La Mondialisation: Ruptures et Continuités", Colloquium" Oases in Globalization: Ruptures and Continuities", Colloquio" Los Oasis En La Globalización: Rompimientos Y Continuidades,"* 167–76.

Oria, C.A., and G.J. Avalos. 2003. "Cambio Climático En Las Cuencas de Los Ríos Ica Y Pisco." Servicio Nacional de Meteorología e Hidrología del Perú.

Ortiz, R., K.D. Sayre, B. Govaerts, R. Gupta, G.V. Subbarao, T. Ban, D. Hodson, J.M. Dixon, J. Iván Ortiz-Monasterio, and M. Reynolds. 2008. "Climate Change: Can Wheat Beat the Heat?" *Agriculture, Ecosystems & Environment* 126 (1): 46–58.

Parsons, J. 1972. "Spread of African Pasture Grasses to the American Tropics." *Journal of Range Management* 25 (1): 12–17.

Parry, M.L. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Peet, R., P. Robbins, and M. Watts. 2011. "Global Nature." In Peet, R.; Robbins, P.; Watts, M., eds., *Global Political Ecology*. Abingdon: Routledge: 1-49.

Pepin, N.C., and J.D. Lundquist. 2008. "Temperature Trends at High Elevations: Patterns Across the Globe." *Geophysical Research Letters* 35: L14701.

Perrault-Archambault, M., and O. Coomes. 2008. “Distribution of Agrobiodiversity in Home Gardens along the Corrientes River, Peruvian Amazon.” *Economic Botany* 62 (2): 109–26.

Postigo, J. 2012. “Responses of Plants, Pastoralists, and Governments to Social Environmental Changes in the Peruvian Southern Andes.” (Ph.D. Dissertation, University of Texas at Austin).

Postigo, J. 2014. “Perception and Resilience of Andean Populations Facing Climate Change.” *Journal of Ethnobiology* 34 (3): 383–400.

Postigo, J.C., K.R. Young, and K.A. Crews. 2008. “Change and Continuity in a Pastoralist Community in the High Peruvian Andes.” *Human Ecology* 36 (4): 535–51.

Pulgar Vidal, J. 1987. *Geografía Del Perú: Las Ocho Regiones Naturales Del Perú*. Lima: Editorial Universo.

Quinlan, T.J., K.A. Shaw, and W.H.R. Edgley. 1975. “Kikuyu Grass (*Pennisetum clandestinum*) Grown in Queensland.” *Queensland Agricultural Journal* 101 (6): 737-49.

Richardson, K., W. Steffen, and D. Liverman. 2011. *Climate Change: Global Risks, Challenges and Decisions*. Cambridge: Cambridge University Press.

Ruiz, K., S. Biondi, R. Oses, I. Acuña-Rodríguez, F. Antognoni, E. Martinez-Mosqueira, A. Coulibaly, et al. 2014. “Quinoa Biodiversity and Sustainability for Food Security under Climate Change. A Review.” *Agronomy for Sustainable Development* 34 (2): 349–59.

Sandor, J.A., and N.S. Eash. 1995. “Ancient Agricultural Soils in the Andes of Southern Peru.” *Soil Science Society of America Journal* 59 (1): 170–79.

Sarmiento, F. 2002. “Anthropogenic Change In The Landscapes Of Highland Ecuador.” *Geographical Review* 92 (2): 213–34.

Schjellerup, I. 2000. “La Morada. A Case Study on the Impact of Human Pressure on the Environment in the Ceja de Selva, Northeastern Peru.” *AMBIO: A Journal of the Human Environment* 29 (7): 451–54.

Schwendenmann, L., E. Veldkamp, G. Moser, D. Hoelscher, M. Koehler, Y. Clough, I. Anas, et al. 2010. “Effects of an Experimental Drought on the Functioning of a Cacao Agroforestry System, Sulawesi, Indonesia.” *Global Change Biology* 16 (5): 1515–30.

Schneir, E. 2011. “Agri-food Exports and Environmental Impacts in the Peruvian Coast: Proposal of Sustainable Water Management in the Ica Valley.”

Seth, A., J. Thibeault, M. Garcia, and C. Valdivia. 2010. “Making Sense of Twenty-First-Century Climate Change in the Altiplano: Observed Trends and CMIP3 Projections.” *Annals of the Association of American Geographers* 100 (4): 835–47.

Smit, B., and M. Skinner. 2002. “Adaptation Options in Agriculture to Climate Change: A Typology.” *Mitigation and Adaptation Strategies for Global Change* 7 (1): 85–114.

Sklair, L. 2002. *Capitalism and Its Alternatives*. Oxford: Oxford University Press.

Smit, B., and J. Wandel. 2006. “Adaptation, Adaptive Capacity and Vulnerability.” *Global Environmental Change* 16 (3): 282–92.

Smithers, J., and B. Smit. 1997. “Human Adaptation to Climatic Variability and Change.” *Global Environmental Change* 7 (2): 129–46.

Taylor, M. 2014. *Political Ecology of Climate Change Adaptation*. Abingdon: Taylor and Francis.

Thomas, D., C. Twyman, H. Osbahr, and B. Hewitson. 2007. “Adaptation to Climate Change and Variability: Farmer Responses to Intra-Seasonal Precipitation Trends in South Africa.” *Climatic Change* 83 (3): 301–22.

Thibeault, J. M., A. Seth, and M. Garcia. 2010. “Changing Climate in the Bolivian Altiplano: CMIP3 Projections for Temperature and Precipitation Extremes.” *Journal of Geophysical Research: Atmospheres* 115 (D8): D08103.

Valdivia, C., A. Seth, J. Gilles, M. García, E. Jiménez, J. Cusicanqui, F. Navia, and E. Yucra. 2010. “Adapting to Climate Change in Andean Ecosystems: Landscapes, Capitals, and Perceptions Shaping Rural Livelihood Strategies and Linking Knowledge Systems.” *Annals of the Association of American Geographers* 100 (4): 818–34.

Van Meter, K.M. 1990. “Methodological and Design Issues: Techniques for Assessing the Representatives of Snowball Samples.” *NIDA Research Monograph* 98 (51.40): 31–43.

Veteto, J.R. 2014. “Seeds of Persistence: Agrobiodiversity, Culture, and Conservation in the American Mountain South.” *Journal of Culture and Agriculture* 36 (1): 17-27.

Vuille, M., R. Bradley, M. Werner, and F. Keimig. 2003. “20th Century Climate Change in the Tropical Andes: Observations and Model Results.” *Climatic Change* 59 (1): 75–99.

Walker, P.A. 2005. “Political Ecology: Where Is the Ecology.” *Progress in Human Geography* 29 (1): 73–82.

Walsh, S.J., R.E. Bilsborrow, S.J. McGregor, B. Frizzelle, J.P. Messina, W.K. Pan, K.A. Crews-Meyer, G.N. Taff, and F. Baquero. 2003. “Integration of Longitudinal Surveys, Remote Sensing Time Series, and Spatial Analyses.” In Fox, J.; Rindfuss, R.R., Walsh, S.J.; Mishra, V, eds., *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS.* Boston: Kluwer Academic Publishers: 91–130.

Weber, E. 2010. “What Shapes Perceptions of Climate Change?” *Wiley Interdisciplinary Reviews: Climate Change* 1 (3): 332–42.

Wiegers, E., R. Hijmans, D. Hervé, and L. Fresco. 1999. “Land Use Intensification and Disintensification in the Upper Canete Valley, Peru.” *Human Ecology* 27 (2): 319–39.

Whitmore, T.M., and B.L. Turner. 1992. “Landscapes of Cultivation in Mesoamerica on the Eve of the Conquest.” *Annals of the Association of American Geographers* 82 (3): 402–25.

Zimmerer, K.S. 1999. “Overlapping Patchworks of Mountain Agriculture in Peru and Bolivia: Toward a Regional-Global Landscape Model.” *Human Ecology* 27 (1): 135–65.

Zimmerer, K. 2014. “Conserving Agrobiodiversity amid Global Change, Migration, and Nontraditional Livelihood Networks: The Dynamic Uses of Cultural Landscape Knowledge.” *Ecology and Society* 19 (2): 1.

Zimmerer, K.S., and D.S. Douches. 1991. “Geographical Approaches to Crop Conservation: The Partitioning of Genetic Diversity in Andean Potatoes.” *Economic Botany* 45 (2): 176–89.

Vita

Joshua Rudow received a Bachelor of Arts in Geography from the University of North Carolina at Chapel Hill in 2006. He was a WorldTeach Volunteer in Portoviejo, Ecuador from 2007 to 2008. In May 2009, he received a Master's of Arts degree in Geography from the University of Texas at Austin. In 2011, he began the Ph.D. program in the Department of Geography and the Environment at the University of Texas at Austin.

Email: jorudow@gmail.com

This dissertation was typed by the author.